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Firms Left Behind: Emigration and Firm Productivity

Abstract

This paper establishes a causal link between the emigration of skilled workers and firm performance in source countries. Using firm-level panel data from ten Eastern European countries, we show that the emigration of skilled workers lowers firm total factor productivity. We exploit time, country, and industry differences in the opening of EU labor markets from 2004 to 2014 as a source of exogenous variation in the emigration rates from new EU member states. We argue that a potential channel behind this effect relates to the reduction in firm-specific human capital due to a higher worker turnover.

JEL-Codes: O150, D240, F220, J240.

Keywords: migration, firm productivity, human capital, EU enlargement.

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1 Introduction

The emigration of high-skilled workers poses a challenge for many countries, not only in the developing world. As workers leave their firms to follow better opportunities abroad, policy-makers and managers complain about skill shortages and emphasize the negative effects of brain drain. However, whether there is a causal link from skilled emigration to firm productivity is not clear. Scarcity of firm-level data from emigrants' countries of origin and the endogeneity of migration flows have so far inhibited from going beyond anecdotal evidence. The direction of causation could well go the other way with migrants leaving the least productive firms or a change in unobservable factors triggering both lower performance of domestic firms and higher emigration rates. Yet, identifying firm-level effects of emigration and thoroughly disentangling the mechanisms is indispensable for the design of appropriate policies in source countries.

Central and Eastern Europe is a region that has experienced particularly high emigration rates in recent years. Following the EU accession in 2004 and 2007, migration flows from new member states (NMS) to old EU member states have increased considerably. In 2003, the number of NMS emigrants residing in other EU countries amounted to 846,000 people. By 2014 this number had reached 3.95 million.[1] Despite important positive consequences of free labor mobility in terms of lower unemployment and a better skill match, there have been growing concerns that the emigration of skilled workers has created severe challenges for source countries (Kahanec 2012; OECD 2013; Zaiceva 2014).

This paper investigates the causal effects of skilled emigration on firm performance. As 'skilled', we denote individuals with either tertiary education or a professional qualification. We first develop a simple theoretical model that links emigration to firm total factor productivity (TFP) and illustrates one plausible mechanism. In our model, better emigration opportunities induce more skilled workers to quit their jobs. For firms, this realizes in higher worker turnover that lowers firms' incentives to invest in firm-specific training of new employees. As turnover increases and more new workers have to be trained, intensive training programs become more expensive. Consequently, the stock of firm-specific skills and knowledge decreases. The effect is captured by TFP, as this form of human capital is not fully accounted for in wages.

Using firm-level data from NMS, we confirm the model predictions. We show that firms in industries that were exposed to higher outflows of skilled workers experienced a drop in TFP. To empirically identify the effect of interest, we exploit changes in EU labor mobility

[1] Eurostat

legislation to construct a proxy for exposure to emigration. The transitional provisions applied by old EU member states during 2004-2014 created a quasi-experimental setting by allowing earlier or later free labor mobility for workers from NMS. While these transitional provisions were in place, emigration opportunities for NMS citizens varied, depending on their country of origin and the industry they were qualified to work in. Our estimations show that in the extreme case of a change from "no" to "full" labor mobility, firm TFP would drop on average by 20 percent. The estimates are qualitatively robust to various measures of TFP and firm profits.

Apart from analysing the reduced-form effects of legislation changes on firm productivity, we also perform 2SLS regressions to estimate the effect for firms which effectively experienced skill shortages due to higher emigration rates. Changes in EU labor mobility laws strongly predict skill shortages as reported by firms in NMS. This allows us to use the legislation changes as an instrument. The instrument is valid, as detailed sector- and country-specific legislation changes had not been anticipated and are uncorrelated with other integration-related events, such as the free movement of goods or capital. We find that a one percentage point increase in instrumented skill shortages leads to a 1.6 percent drop in firm TFP and a 3 percent increase in personnel costs. We further find evidence for higher turnover of workers in sectors that are strongest hit by emigration and document an increase in firms' overall personnel and training costs, which is in line with our model predictions.

Panel data allow us to account for firm heterogeneity and to explore the link between firms' characteristics and their sensitivity and adjustment to higher quitting rates of workers. We find that innovating and foreign-owned firms substantially increase their per-employee personnel costs. These firms are apparently able to (at least, partly) match wages offered abroad and to provide more training, and therefore prevent the loss of firm-specific human capital.

Our theoretical and empirical results fit well into the previous literature. Konings and Vanormelingen (2015) find that the productivity of workers increases by more than their wage after they have participated in training. Consequently, if trained workers are leaving, this is captured by the residual TFP. Jäger (2016) shows that longer-tenured workers are harder to replace with outsiders. For more studies on the relationship between job turnover, firm-specific human capital, and firm productivity we refer to Brown and Medoff (1978), Shaw (2011), Strober (1990), and Yanadori and Kato (2007).

This paper makes three key contributions to the literature. First, we analyze the effects of emigration at the firm level. So far, the studies on the economic effects of emigration

and brain drain have focused on the aggregate labor outcomes (Clemens 2013; Docquier and Rapoport 2012; Freeman 2006; Grossmann and Stadelmann 2011, 2013) or have investigated changes at the individual level (Borjas 1987; DaVanzo 1983; Mincer 1978). We expect that the emigration literature can gain richer insights into the consequences of migration by analyzing firm-level outcomes. Kerr et al. (2014), Kerr et al. (2013) and Kerr (2013), for instance, are encouraging the firm-level approach for the analysis of migration. Accounting for firm-level outcomes allows us to identify firm adjustment mechanisms and to address firm heterogeneity. Both are important for our understanding of how the observable aggregate effects of migration are being shaped.

While there is an emerging migration literature that focuses on the firm as the unit of analysis, until now it has investigated the effects of immigration. Peri (2012), Kerr and Kerr (2013), Kerr et al. (2014) study the effects of immigration on firm productivity in the US and Paserman (2013), Mitaritonna et al. (2014) and Ottaviano et al. (2015) in Israel, France and the UK respectively. They find that an increase in the supply of foreign-born workers positively affects firm productivity due to skill complementarities, a faster growth of capital and the specialization of natives in more complex tasks. Lewis (2013) furthermore finds that besides increased investment, firms also adapt new technology. Using firm-level German data, Dustmann and Glitz (2015) analyze how industries and firms respond to changes in the local labor supply due to immigration. They emphasize three adjustment mechanisms: a change in factor prices, a within-firm change in skill intensity, and an adjustment through the entry and exit of different producers. Focusing on the effects of emigration, our research is complementary to this literature. Some of the above mentioned mechanisms could be transfered to the case of emigration. Emigration could lead to a slower growth of capital and a downgrading of technology. If there are skill complementarities or externalities due to the interaction of high-skilled workers in a firm, emigration of some workers can negatively affect productivity of stayers. In this paper, we explore one additional mechanism that links emigration and firm productivity through changes in firm-specific human capital.

The second contribution is using exogenous variation to circumvent the endogeneity problem. To the best of our knowledge, this paper is the first to exploit industry-level variation in labor mobility laws to causally evaluate the consequences of emigration. Due to a lack of firm-level data for source countries and the endogeneity of migration, the causal analysis is not trivial. To address these issues, we create an extensive dataset that merges firm-level data to exogenous labor mobility legislation changes in the destination countries of NMS migrant. We are thus able to show that emigration imposes binding

skill shortages for firms and lowers TFP through a loss of firm-specific human capital.

Third, we add to the literature on the consequences of EU enlargement, which is relevant for policy makers in Brussels, in accession countries, and in candidate countries. In particular, we complement the research that investigates the consequences of the recent emigration wave from NMS. Mayr and Peri (2009) develop a model to study the consequences of European free labor mobility on human capital in the sending countries and differentiate between brain drain and brain gain due to return migration and increased incentives to invest in education. Dustmann et al. (2015) and Elsner (2013) estimate the effects of emigration on wages in Poland and Lithuania and find that wages increase for the stayers. Our contribution is to illustrate that, while firms, on average, experience a drop in TFP, more productive firms are affected to a lesser extent. Moreover, by providing evidence for a particular channel, we can suggest policies that could help in mitigating the negative effects.

The paper is organized as follows. The next section outlines a theoretical framework to motivate and structure our empirical analysis. Section 3 describes the data, followed by Section 4 that presents the empirical specification. Section 5 discusses the results including heterogeneous effects, while Section 6 provides robustness checks. Section 7 concludes.

2 Theoretical Framework

2.1 General Setting

Our theoretical framework illustrates the consequences of skilled emigration for a firm in the source country. Using a partial-equilibrium framework, we generate predictions about changes in firm TFP, training provision, and factor demand.[2]

We assume that job separations occur at an exogenous rate, and in order to fill vacant positions firms post costly vacancies. An easier legal access to foreign labor markets induces higher emigration and thus increases job separation rates for firms in the source country. Consequently, firms experience higher skill shortages. In this setting, skill shortages are not a disequilibrium phenomenon, but correspond to firm hiring and training expenses that arise when a firm has to replace a worker who emigrated.

We allow firm-specific human capital to explicitly enter the production function. A

[2]On a macro level, this problem was examined by Grossmann and Stadelmann (2011). In their overlapping generations model, the drop in TFP is attributed to less firm entry and, consequently, to the reduction in human capital externalities of skilled employees.

higher worker turnover destroys part of the firm-specific human capital. Since the latter is not fully captured by wages, this loss translates to a drop in TFP. In this way, we characterize one possible micro channel, through which skilled emigration directly affects firm productivity.

The economy consists of a representative firm that produces output according to the production function:

$$Y = Af(K, L_s, L_u) \tag{1}$$

$Af()$ is a general production function, where K is the capital input and L_s and L_u are the skilled and unskilled labor inputs. $f()$ increases in the production factors K, L_s, L_u; exhibits diminishing marginal returns to K, L_s, L_u and is twice-differentiable. Each period L_s and L_u workers are involved in the production process. At the end of the period, a share δ_s (δ_u) of skilled (unskilled) jobs are separated. To fill the positions with new workers, a firm posts vacancies V. For simplicity, we assume that vacancies are matched with probability one. In equilibrium, the number of job separations must equal the number of matched vacancies:

$$V_i = \delta_i L_i, i = s, u. \tag{2}$$

Posting vacancies creates a search cost of c_s (c_u) per period and per vacancy.

We represent TFP as $A = t^\gamma$. In our setting, the firm TFP consists entirely of firm-specific knowledge t. This tacit knowledge makes all the input factors more productive. It could be, for instance, a collection of the firm's best practices, a code of conduct, or tricks of an internal IT system. In order to employ this knowledge in the production, the firm has to train all skilled workers in using it. We assume that there is no training needed for unskilled workers. If a skilled worker leaves and the firm hires a new worker as a replacement, it has to pay the training costs for the new worker, which are proportional to the amount of firm-specific knowledge to learn. Given a turnover rate δ_s, the total training costs per period would amount to $\delta_s L_s c_t t$, where $\delta_s L_s$ is the number of newly hired skilled workers. c_t denotes the teaching costs of training, which we set equal to 1. The total training costs can also be interpreted as the loss of firm-specific human capital due to worker turnover. We treat the amount of training per worker t as adjustable when the firm hires new skilled workers. For instance, if it becomes too expensive to teach a particular firm practice to all the new hires, the firm can drop this practice, thus reducing its knowledge t. If there is no turnover, $\delta_s = 0$, the firm-specific knowledge is equal $\bar{t} \geq t$, which could be interpreted as the maximum attainable knowledge for a firm.

2.2 The Firm's Optimization Problem

The firm chooses inputs K, L_s, L_u to maximize profits Π. In addition, when hiring skilled workers, the firm decides on t - the amount of firm-specific knowledge to teach. The exogenous variables are the output price (P), wages (w_s, w_u), the interest rate (r), the job separation rate (δ_s, δ_u), and the vacancy costs (c_s, c_u).

$$\Pi = PY - \sum_{i=s,u} (w_i L_i + c_i V_i) - rK - V_s t \tag{3}$$

s.t.

$$V_i = \delta_i L_i, i = s, u;$$

$$Y = t^{\gamma_\tau} f(K, L_s, L_u)$$

Using the constraint to substitute for V_i yields the total personnel costs of skilled workers: $L_s(w_s + c_s\delta_s + t\delta_s)$. These costs comprise wages, search costs, and training expenses. Similarly, the total personnel costs of unskilled workers are equal to $L_u(w_u + c_u\delta_u)$.

The emigration of skilled workers raises δ_s and results in a higher turnover. The marginal hiring costs of a skilled worker ($\delta_s(c_s + t)$) increase.[3] Thus, emigration augments the marginal personnel costs of a skilled worker ($w_s + \delta_s(c_s + t)$) and affects the relative input demand of the firm. Further, the incentives for training change. The higher turnover rate makes training more expensive, which consequently reduces the optimal level of the firm-specific knowledge t. This result follows from the fact that the firm has to teach all its specific knowledge t to all newly hired skilled workers.[4] Therefore, when δ_s increases, it becomes more expensive for a firm to sustain its knowledge level due to higher training costs. We provide a proof of the comparative statics results for a general production function in the Appendix.

2.3 Comparative Statics

We are interested in the effect of emigration on firm productivity. If workers obtain the possibility to emigrate to a country with higher wages, this results in a higher quitting

[3]The model is generalisable to the situation in which both skilled and unskilled workers emigrate. In this case turnover would increase for both groups but firm-specific human capital would only be lost for skilled workers.

[4]For instance, unless all of the firm's sales managers know how to use a Customer Relationship Management (CRM) system, there will be very poor coordination among them. This may lead to both the sales managers and the CRM system being unproductive.

probability. This can be triggered by exogenous political events such as the EU accession. In the model, the introduction of free labor mobility that resulted in higher emigration rates can thus be represented by higher job separation rates δ_s and δ_u. In the comparative statics, we focus on the effect of raising δ_s, because it has direct implications for firm TFP.

Proposition: *An increase in the job separation rate δ_s reduces the firm's TFP through the reduction in firm-specific knowledge t.*

1. *An increase in δ_s raises the marginal hiring costs of a skilled worker. This corresponds to an increase in the personnel costs $w_s + \delta_s(c_s + t)$. Depending on the elasticity of substitution between the inputs, firms might find it optimal to substitute high-skilled workers with low-skilled workers or with capital. The ratio $\frac{L_s}{L}$ decreases and/or the ratio $\frac{K}{L}$ increases.*
2. *An increase in δ_s leads to a lower provision of intensive training (t) per hired skilled worker because higher turnover rates increase costs per unit of provided training. This results in a negative effect on the firm's TFP. However, the total training $\delta_s L_s t$ might increase as, on the extensive margin, due to a higher δ_s, the firm has to train more workers.*

In our simple framework, we assume that wages are exogenously given, which is a realistic assumption if we consider an average small or medium-sized firm. Emigration lowers the available supply of skilled labor and should lead to a general increase of w_s. This will increase personnel costs $w_s + \delta_s(c_s + t)$ and thus lower the relative demand for skilled workers. Provided δ_s is now kept constant, the effect on the training provision t will be of a second order. Hence, if emigration leads only to the adjustment of wages, we would not observe a strong negative effect on firm TFP.

3 Data Description

3.1 Migration data

Disaggregated emigration data by country and industry is not available. The Eurostat Labour Force Survey provides information on the industry, education, and occupation of immigrants, but aggregates the country-of-origin information. While observing immigrants in EU15, Iceland, Lichtenstein, Norway and Switzerland we can only see if they

come from NMS8 (2004 entry) or NMS2 (2007 entry). [5]

3.2 Data on labor mobility law changes in the EU

This subsection shows how the gradual opening of the EU labor markets created time, country, and industry-level variation in the emigration rates of NMS citizens.

In 2004, ten Eastern and Southern European Countries joined the EU: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia. While free mobility of goods and capital was introduced either prior to or at the point of accession by all countries, free labor mobility was initially restricted. Some EU15 countries[6] feared an inflow of cheaper labor. The EU Commission thus allowed the old member states to unilaterally restrict their labor markets by national laws for a period of up to seven years. These transitional arrangements were applied to all new members in the same way, except Malta and Cyprus. We thus denote the remaining eight countries as NMS8. In 2007, Bulgaria and Romania (NMS2) joined the European Union, also facing the transitional agreement rules.

The option to unilaterally restrict labor markets generated different rules within the EU. While Ireland, Sweden, and the UK decided to open their labor markets immediately in 2004 without any restrictions, other countries delayed the access or applied special job schemes in certain industries. Denmark, Greece, Spain, and Portugal, for instance, removed restrictions only in 2009. France, Belgium, Netherlands, and Austria opened their labor markets gradually, allowing only workers in certain industries and introducing quotas. Germany kept the labor market almost completely closed until the expiration of the transitional agreements (2011 for NMS8; 2014 for NMS2). Furthermore, non-EU member states: Iceland, Liechtenstein, Norway, and Switzerland, also applied transitional provisions and we thus include them in our analysis (EU15+4 denote all countries that applied transitional provisions). Table 1 provides an overview of the precise opening dates and industry details per country.

This sequential opening by country, year and industry had a significant effect on migration rates. Constant (2011) and Kahanec (2012) provide descriptive evidence of EU migration flows following the enlargement. Using country-level data, they show that the transitional agreements influenced the movement of migrants. The UK and Ireland, for

[5] Even if the detailed origin information were available, though, it would likely be noisy and the labor force sample would have small numbers in the specific country-industry-year cell.

[6] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom (EU15).

Table 1: **Overview of the Gradual Opening of the EU15+4 Labour Markets**

Country	NMS8 (2004 entry)	NMS2 (2007 entry)	Sectoral Exceptions
Austria	2011	2014	NMS8 (2007-2010), NMS2 (2007-2013): Construction, Manufacturing of Electronics and Metals, Food and beverage services (restaurant business), other sectors with labour shortages
Belgium	2009	2014	-
Denmark	2009	2009	-
Finland	2006	2007	-
France	2008	2014	NMS8 (2005-2007), NMS2 (2007-2013): Agriculture, Construction, Accommodation and food services (tourism and catering), other sectors with labour shortages
Germany	2011	2014	NMS8 (2004-2010), NMS2 (2007-2013): sectors with labour shortages
Greece	2006	2009	-
Iceland	2006	2012	-
Ireland	2004	2012	-
Italy	2006	2012	NMS8 (2004-2005): sectors with labour shortages; NMS2 (2007-2011): Agriculture, Construction, Engineering, Accommodation and food services (tourism and catering), Domestic work and care services, other sectors with labour shortages; Occupations: Managerial and professional occupations
Lichtenstein	2011	2016	-
Luxembourg	2008	2014	NMS2 (2007 - 2013): Agriculture, Viticulture, Accommodation and food services (tourism and catering)
Netherlands	2007	2014	NMS8 (2004-2006), NMS2 (2007-2013): International transport, Inland shipping, Health, Slaugther-house/meet-packaging, other sectors with labour shortages
Norway	2009	2012	NMS8 (2004-2008), NMS2 (2007-2011): sectors with labour shortages
Portugal	2006	2009	-
Spain	2006	2009	Reintroduction of restrictions for Romanians: 11/08/2011 - 31/12/2013
Sweden	2004	2007	-
Switzerland	2011	2014	-
United Kingdom	2004	2014	NMS2 (2007-2013): Agriculture, Food manufacturing

Notes: Column 2 shows the year of the labor market opening of the respective country for NMS8 countries, column 3 shows the year of the labor market opening of the respective country for the NMS2 countries. Column 4 shows, which sectors were exempt from restrictions.
Source: European Commission.

example, have become the main EU destination country for Polish, Slovakian and Latvian workers. Kahanec et al. (2014) apply a difference-in-differences analysis and confirm that outward migration from the NMS increased with the EU entry, but its full potential was hampered by the presence of transitional arrangements.

One might argue that the restriction of a country's labor market is endogenous and related to local labor market conditions. Germany, for instance, experienced high unemployment rates during the mid-2000s and this was one of the reasons for its labor market restrictions. However, while the transitional arrangements are endogenous to labor market conditions and firm productivity in the *receiving* country, they are exogenous to firm outcomes in the *source* countries.

We thus can use this data on labor market openings to construct a proxy for an industry's exposure to emigration and thus circumvent the endogeneity problem. We source the legal information from the Labor Reforms database (section on labor mobility) of the EU Commission and complement it with information from the national legislation of the EU15+4 countries.

3.3 Firm-level data

We obtain firm-level data from Bureau Van Dijk's AMADEUS database that provides standardized annual balance-sheet and profit information for European public and private companies. We work with an unbalanced panel of about 110,000 firms located in NMS. The period covered ranges from 2000 to 2013, and there are five annual observations for each firm on average. The sample includes companies in manufacturing, construction, retail trade and services. Apart from financial reports, the dataset provides information on firms' patenting activities, ownership structures, export markets, and exit status (such as bankruptcy or liquidation).

We include firms with at least two years of available financial data to calculate the TFP index. As a note of caution, we might not capture companies at the lower tail of the productivity distribution if they are less likely to be included in the sample. Based on observables, though, firms in the regression samples are not statistically different from the full sample (see table 9). We used the largest possible number of firms with non-missing observations. The number of firms across regression results slightly varies due to differences in the availability of variables.

To obtain data on the training of employees, we complement this data with firm-level information from the Business Environment and Enterprise Performance Surveys (BEEPS) administered by the European Bank for Reconstruction and Development (EBRD)

in all NMS. The survey was conducted in 2002, 2005, 2009 and 2012 and contains an extensive questionnaire on firms' self-reported financial performance, workforce composition, management practices, innovation, and perceptions of the business environment (including the availability and quality of human capital). The survey data provides a representative sample of manufacturing, construction, service, and retail trade firms. In total, there are 13,972 firm-year observations, of which 2,556 (with 1,293 unique firms) make up an unbalanced panel.

3.4 Additional data

As additional covariates, we use aggregated (two- and four-digit NACE) industry level data, which is available for all EU member states and is harmonized by Eurostat. The structural business statistics database contains annual information on industries' performance, including output, investment, employment, and personnel costs. Macroeconomic controls (GDP, FDI, unemployment, interest rates) come from the Worldbank statistical database.

4 Econometric Specification

The aim of the empirical analysis is to estimate the effect of emigration on firm productivity and to test the predictions of our model regarding the specific channel of the effect. We thus want to establish how the exogenous increase in emigration rates influences TFP, personnel costs, training, and the capital/labor ratio of firms. If we estimate simple OLS regressions of firm outcomes on emigration rates, we will run into several estimation and endogeneity problems. Therefore, we present OLS regression results and their shortcomings in the Appendix 8.2. Our baseline estimations represent reduced-form regressions of firm outcomes on legislation changes, which proxy exposure to emigration. To summarize this legal information on a country-industry-year level, we construct a 'Free Movement' variable, which we describe in Section 4.3 below. The reduced-form regressions illustrate an 'intention to treat' (ITT) effect. To estimate treatment effects (LATE) in industries where emigration created *binding* constraints, we further employ a 2SLS strategy. For that end, we use the Free Movement variable as an instrument for skill shortages as reported by firms.

4.1 Reduced Form

The reduced-form empirical specification is described below:

$$Y_{fict} = \beta_1 FM_{ict-l} + \beta_2 X_{fict} + \beta_3 I_{ict} + \beta_4 J_{it} + \beta_5 C_{ct} + \tau_t + \nu_f + \epsilon_{fict} \tag{4}$$

where Y_{fict} are different performance measures of a firm (f) in industry (i), country (c) and year (t). FM_{ict-l} indicates the Free Movement variable. We include it in equation (4) with a lag of length l. β_1 is the reduced-form effect of the legislation change on a firm-level outcome. X_{fict} is a set of time-varying firm controls, such as age and capacity utilization. I_{ict} includes country-specific industry controls such as total investment, average mark-up (ratio of revenues to costs), and inward FDI. These variables account for variation due to other shifters of labor demand within an industry of a particular country, namely, technical change or higher competition. J_{it} are industry-specific controls, such as total sales and skill shortages that are measured at the aggregate EU level. C_{ct} is a vector of macroeconomic covariates, accounting for country-wide changes: the GDP growth rate and FDI inflows. All monetary variables are in natural logarithms. τ_t are time dummies. ν_f represent firm fixed effects, and ϵ_{fict} is the error term. In the baseline empirical model, we consider only within-firm variation. Such a specification allows us to take care of firm unobserved time-invariant heterogeneity (as initial management ability or quality of business ideas) and other constant characteristics of a firm's location or industry-specific production technologies.

The focus of this project is to estimate the effect of emigration on firm total factor productivity. We compute firm productivity in several ways: using a TFP-index and a semi-parametric approach as in Levinsohn and Petrin (2003). The latter method allows us to overcome the simultaneity bias between firms' inputs and unobserved productivity shocks. For details regarding the TFP calculation, we refer to the Appendix 8.4. As alternative measures of productivity, we consider firm profits: $\frac{EBIT}{Assets}$ calculated as the ratio of earnings before interest and tax over assets. Using a number of different productivity measures ensures that the effects we find are not driven by measurement issues.

To understand if our additional model predictions for firms' adjustment hold, we look at several other outcome variables and use the same regression equation. In particular, we are interested in the effects on the capital/labor ratio, the personnel costs, and training.

4.2 Two Stage Least Squares Model with Skill Shortages

Due to a lack of disaggregated migration data, we cannot directly test the relevance of the Free Movement variable for actual emigration rates from NMS. Instead we can go one step further in the causality chain and check if the EU15+4 labor mobility laws explain the increase in skill shortages as reported by NMS firms. The first-stage regression takes the following form:

$$SH_{ict} = \gamma_1 FM_{ict-l} + \gamma_2 I_{ict} + \gamma_3 J_{it} + \gamma_4 C_{ct} + \tau_t + \kappa_{ic} + u_{ict} \tag{5}$$

SH_{ict} is the industry-country-year measure of skill shortages. γ_1 is the coefficient of interest and reflects the marginal contribution of the Free Movement variable, given industry- and country-specific time-varying covariates $(I_{ict}, J_{it}, C_{ct})$, and time dummies (τ_t). By including industry-country fixed effects κ_{ic}, we identify the Free Movement effect only from within-industry variation in the propensity to emigrate.

We run a second-stage regression, similar to (4), but instead of the Free Movement variable, use the instrumented measure of skill shortages. The coefficient $\hat{\beta}_1$ thus captures the productivity effect of skill shortages caused by the transitional provisions. It is identified only for industries where the legislation changes created binding skill constraints for firms.

4.3 Construction of the Free Movement Variable

In our model, we analyze an exogenous increase in the job separation rate due to emigration. For firms in the new member states, higher emigration was triggered by the opening of the EU15+4 labor markets. As argued above, the legislation changes in the destinations were orthogonal to economic conditions in the source countries. We capture the changes in the EU labor mobility laws by constructing the Free Movement (FM) variable. We use it as the main explanatory variable in our baseline empirical specification and as the instrument for skill shortages in the 2SLS regression.

A country-industry-year cell makes up one observation. Industries are represented at the NACE two-digit level. The main period under consideration is from 2000 to 2014 (from the accession of NMS8 countries to the termination of all transitional provisions applied to NMS2). First, for each observation we construct a set of 15 dummies D_{cc_jit}, with each dummy corresponding to one of the EU15+4 countries, c_j. A dummy takes the value of 1 if according to the legislation of an old EU member, its corresponding industry i is open to labor migrants from a given new member state c. For example, the

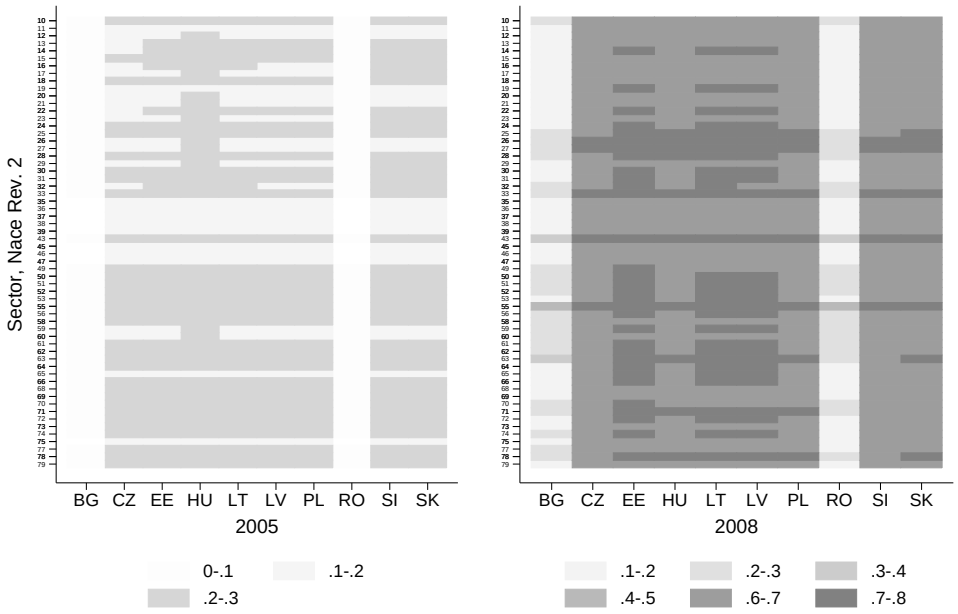
UK completely opened up its labor market for the NMS8 group in 2004. Therefore UK dummies for all industries for all NMS8 countries equal 1 starting from 2004. In contrast, France held the transitional provisions for the 2004-entrants until 2008. Prior to 2008, the French government applied a special job scheme, which allowed for free labor market access only in construction, tourism, and catering. France dummies for NMS8 industries take a value of 0 until 2008, except for the three mentioned sectors. Figure 3 in the Appendix shows how the legislation dummies enter our dataset.

One of the limitations of the legislation dummies is low industry-level variation. Austria, Germany, France, Italy, and the Netherlands, for instance, did not explicitly specify which industries are open to labor migrants from new member states, but rather allowed for special job schemes in sectors that experienced skill shortages. The dummies also do not capture different capacities of EU15+4 markets to absorb migrants. To account for this, we multiply the legislation dummies D_{cc_jit} by a measure of skill shortages in a given industry of a j_{th} EU15+4 country. For this, we use the share of firms (in destination industries) reporting to be constrained by the labor factor. These data are available from the EU Commission Business Survey. This modification controls for implicit legislation changes and for differences in labor market conditions across and within industries in old EU members.[7] Easiness to find a job, which increases in sectors experiencing skill shortages, can be another important criteria for worker mobility. A possible concern with such a modification is that skill shortages in the old EU member states might not be fully exogenous to firm productivity in NMS countries, due, for example, to common technology shocks. We can control for this by including industry-specific time dummies or an average measure of skill shortages in a given industry for all EU members. Another concern is that labor demand could increase in EU15+4 industries, which after the EU enlargement had become more competitive relative to their rivals from new member states. In this case, however, one would expect to see negative tendencies in NMS firm performance already prior to the outflow of workers. We can also control for higher product-market competition by including a mark-up measure.

To summarize the set of 19 dummies in a single measure, we apply special weights that reflect how strongly the opening of a particular EU15+4 labor market affects the citizens of a given new member state. It is reasonable to assume that labor migrants, for example, from Estonia were more sensitive to the opening of the Finnish labor market than the

[7]This allows to capture, for example, a decrease in demand for foreign labor force during and after the economic crisis in 2008-2009. At this time, many labor markets were already open for NMS citizens, but effective job possibilities were limited. De-jure, only Spain reacted to the worsening of economic conditions by reintroducing restrictions for Romanian citizens in 2011.

Figure 1: **Variation in the Free Movement Variable**



Notes: This graph shows the variation in the instrument. We compare different industries (y-Axis) in different countries (x-Axis) in 2005 and 2008. The darker the shading, the stronger these industries in these countries have been exposed to emigration.

Portuguese one. One approach is to use bilateral distances between the two largest cities of each source and destination country as a measure of proximity: the shorter the distance, the larger is the weight for a corresponding EU15+4 labor market.

The legislation information is summarized in one variable:

$$FM_{cit} = \sum_{j=1}^{19} w_{c,c_j} \cdot D_{cc_jit} \tag{6}$$

FM_{cit} is the value for one observation (source country-industry-year). D_{cc_jit} denotes the legislation dummy for openness of the labor market in a j_{th} old EU member's corresponding industry for the citizens of a given source country in a given year and w_{c,c_j} denote the weights. To ensure the comparability of different versions of Free Movement variables, we standardize them to be in the range [0;1]. Figure 1 illustrates the variation in the Free Movement variable across industries of NMS.

To investigate the plausibility of our identifying assumption, we check if firms' outcomes prior to 2004 predict changes in the legislation over 2004-2014. We also run several placebo tests. We report the results in Section 6.

5 Empirical Results

This section presents and discusses the empirical results and compares them with the model's predictions. All regressions include firm fixed effects and thus capture within-firm variation in performance as a response to changes in an industry's exposure to emigration.

5.1 Reduced Form Regressions

Table 2 presents the reduced form estimations: we regress firm outcomes directly on the Free Movement (FM) variable. We use a one-period lag for the Free Movement variable to account for some inertia between the legislation change and the migration decisions. All dependent variables are in natural logarithms, and the Free Movement variable is in the range from 0 to 1. The coefficients may be interpreted as the log point ($\simeq$ percent) change in dependent variables when the FM increases from 0 (no free labor mobility within EU for workers qualified to work in a particular industry) to 1 (maximum exposure to free labor mobility in our sample).

For the main sample of firms, the effect of free movement on productivity is negative, which confirms the prediction of our model. The maximum annual increase in the value of the FM variable in our sample is equal to 0.52 (for certain industries in Romania in 2007), while on average NMS industries experienced a maximum annual increase of 0.25. We can use this information to give a quantitative interpretation of our result. One year following the maximum increase in labor mobility, a firm's TFP drops by $0.25 \cdot 0.234 = 0.059$ or 5.9 log points. Given an average TFP of 29,500 EUR (estimated with the Levinsohn and Petrin (2003) method), this translates to annual losses of about 1,700 EUR per firm.

We can also see that firms adjust to emigration by increasing personnel costs. In our dataset, personnel costs include wages and other employee-related costs. We are thus not able to compare this aggregate data directly with our model predictions. However, the observed increase in personnel costs is consistent with more hiring and training expenses due to a higher job separation rate. The annual increase in the Free Movement value of 0.25 would lead to $0.25 \cdot 0.27 = 0.0675$ or 6.75 log point increase in personnel costs per employee. With average annual employee costs of 7,840 EUR, this leads to additional 550 EUR per worker. The change in the capital/labor ratio is positive, but imprecisely estimated.

These results are robust to different measures of productivity, to the exclusion of outliers (firms with sales below the 1st and above the 99th percentiles), and to the exclusion of firms that entered the market after 2002.

Table 2: **The Effect of Free Movement on Firm Performance (Reduced Form, Amadeus Data)**

	(1) TFP index	(2) TFP LP	(3) ROA	(4) Pers. costs	(5) K/L
FM_{ict-1}	-0.273***	-0.234***	-0.0344**	0.270***	0.172
	(0.0696)	(0.0619)	(0.0141)	(0.0628)	(0.106)
$Mark-up_{ict}$	0.212***	0.186***	0.0906***	-0.133***	-0.0824**
	(0.0526)	(0.0350)	(0.0165)	(0.0279)	(0.0404)
$log\_investment_{ict-1}$	0.00178	-0.00707	-0.00556***	0.00521	0.0243**
	(0.00680)	(0.00500)	(0.00203)	(0.00792)	(0.0106)
$log\_FDI\_inward_{ict-1}$	-0.00125	2.82e-05	-0.000435	0.00242	0.00502**
	(0.00143)	(0.00114)	(0.000509)	(0.00148)	(0.00219)
$log\_total\_sales_{it}$	0.00350	-0.00910	0.000439	0.0516***	0.00880
	(0.0100)	(0.00913)	(0.00262)	(0.00851)	(0.0126)
$Mean\ skill\ sh._{it}$	0.0763	0.160	0.175***	0.0702	-0.0866
	(0.158)	(0.117)	(0.0384)	(0.115)	(0.169)
log_FDI_{ct-1}	0.0123***	0.0108***	0.00231***	0.00819***	0.0113***
	(0.00248)	(0.00226)	(0.000617)	(0.00175)	(0.00229)
log_GDP_{ct-1}	1.520***	1.301***	0.179***	0.397***	0.130
	(0.163)	(0.142)	(0.0443)	(0.0996)	(0.135)
Observations	546,661	322,938	542,500	529,567	529,567
Number of firms	108,413	71,652	107,585	105,572	105,572
R^2	0.074	0.040	0.053	0.105	0.122
Dummies	firm (f) and year(y)	f y	f y	f y	f y
Clusters	2660	2521	2630	2618	2618

Notes: The table presents reduced-form estimates of the free movement variable on different firm outcomes. All specifications are estimated with firm fixed effects and time dummies. Dependent variables: TFP index, TFP LP - TFP estimated with the Levinsohn and Petrin (2003) procedure, ROA - return on assets, Pers. costs - personnel costs per employee, K/L - capital-labor ratio. FM - Free Movement variable (distance-weighted, interacted with skill shortages in destination industries), 1 year lag. Standard errors (in parentheses) are clustered on country-industry (NACE 4-digit) level.
*** p<0.01, ** p<0.05, * p<0.1

Table 3: **The Effect of Free Movement on Firm Performance (Reduced Form, BEEPS Data)**

	(1) TFP index	(2) Wage	(3) Train	(4) New product
FM_{ict-1}	-0.541***	0.772	1.706***	-3.589
	(0.083)	(0.620)	(0.577)	(2.772)
log_l_{fict-1}	-0.0501	-0.211***	0.0630***	0.0201
	(0.118)	(0.0347)	(0.0170)	(0.0159)
log_sales_{fict-1}	0.215**	0.225***	0.0218**	-0.0144*
	(0.107)	(0.0221)	(0.00945)	(0.00831)
$\%\ foreign_{fict}$	-0.187	0.462***	0.179***	0.115
	(0.207)	(0.118)	(0.0637)	(0.0717)
$export\_share_{fict}$	-0.0135	0.0620	-0.105*	-0.0681
	(0.198)	(0.100)	(0.0589)	(0.0707)
Observations	1,344	5,432	5,078	2,179
R^2	0.971	0.227	0.243	0.247
Dummies	c·y, c·i, i·y	c·y, c·i, i·y	c·y, c·i, i·y	c·y, c·i, i·y
Robust	yes	yes	yes	yes
Clusters	296	591	574	290

Notes: The table presents reduced-form estimates of free movement on firm performance using BEEPS data. All specifications are estimated with country·year (c·y), country·industry(c·i), and industry·year(i·y) fixed effects. The variable $Train$ represents the share of trained workers in the total workforce. Additional firm-level covariates include lagged sales, capital, quadratic terms for firm age and number of employees, share of foreign capital, share of export in sales. FM_{ict-1} represents the sum of legislation dummies, weighted by distance to a given old EU member-country and interacted with skill shortages in destination industries. Standard errors (in parentheses) are clustered on country-industry level.
*** p<0.01, ** p<0.05, * p<0.1

Next, we perform the same regression using firm-level data from the BEEPS survey to confirm our results and to analyze additional variables. Table 3 presents the reduced form estimates. BEEPS contains only a limited number of firms with available panel data. Therefore, in the reported specification we pooled firm observations together, adding firm-level covariates: lagged sales, capital, quadratic terms for firm age and lagged number of employees, share of foreign capital, share of export in sales. All regressions are estimated with country·year (c·y), country·industry(c·i), and industry·year(i·y) fixed effects. The remaining variation in dependent variables should come from country-industry-year changes in the value of the Free Movement variable. As with the Amadeus data, we find a negative effect of the EU labor market opening on firm TFP. Furthermore, we report significant increases in the share of trained employees by firms in industries, which have potentially experienced higher labor emigration. This is in line with our model, predicting that firms train more people as they increase their hiring due to a higher job separation rate.

One assumption we are making to bring the model to the data is that the Free Move-

Table 4: **The Effect of Free Movement on Tenure (Reduced Form, Eurostat Data)**

	(1) Mean tenure	(2) Mean tenure	(3) Mean tenure
$F.FM_{ict}$			-0.268
			(0.320)
FM_{ict-1}	-0.858***	-1.052***	-1.842***
	(0.144)	(0.219)	(0.272)
$log\_investment_{ict-1}$	-0.110***	-0.0899**	-0.107**
	(0.0389)	(0.0390)	(0.0422)
$log\_total\_sales_{ict}$	0.0261	0.00509	-0.00460
	(0.0907)	(0.0883)	(0.0943)
log_FDI_{ct-1}	-0.172***	-0.148***	-0.166***
	(0.0336)	(0.0320)	(0.0394)
log_GDP_{ct-1}	-1.200	-0.141	-3.564**
	(0.904)	(0.870)	(1.424)
Observations	1,873	1,873	1,564
Number of idc	314	314	312
R^2	0.142	0.136	0.208
Dummies	i·c, y	i·c, y	i·c, y
Clusters	314	314	312

Notes: The table presents reduced-form estimates of free movement on average tenure. All specifications are estimated with industry·country fixed effects and time dummies. FM - Free Movement variable, 1 year lag. In specification 1, we use only distance-weighted FM dummies. In specifications 2 and 3, FM dummies are interacted with skill shortages in destination industries. In specification 3, we add a forward lag of the FM variable to check for the absence of pre-trends. Standard errors (in parentheses) are clustered on country-industry level.
*** p<0.01, ** p<0.05, * p<0.1

ment variable affected average job separation rate in NMS industries. Table 4 shows reduced form regression results of the FM variable on tenure, which is inversely related to job separation rate.[8] The coefficient estimates confirm our hypothesis: industries exposed to higher labor mobility experience a decrease in average tenure (which corresponds to a higher job separation rate). The estimates are robust to the inclusion of country-specific time trends. To check for the presence of pre-trends, we add a one-period forward of the Free Movement variable (column 3), which turns out to be insignificant, as expected.

5.2 Heterogeneity

In the main specification, we analyze the effect of free movement for the full sample of firms. To check for heterogeneous effects, we estimate the baseline reduced form (specification 4) for different sub-samples of firms.

[8]Tenure can be expressed as $1/\delta$, where δ denotes job separation rate.

Tables 5 and 6 show the results for foreign-owned and innovating firms. The estimated effect of free movement on firm TFP is smaller compared to the full sample and loses its statistical significance. At the same time, the estimated coefficients for personnel costs and capital/labor ratios suggest that these firms adjust much stronger to the increased emigration opportunities of their workforce. Foreign-owned firms increase their personnel costs significantly more. They might be able to offer wage increases to retain workers and training to newcomers to teach firm-specific human capital. Patenting firms seem to adapt in particular through increasing the capital/labor ratio. These firms might also be able to provide an interesting work environment and have retention initiatives to keep their essential research staff. There is also evidence that innovating firms benefit from reverse knowledge flows and increased research networks through their former employees (Braunerhjelm et al. 2015; Kaiser et al. 2015; Kerr 2008).

Table 5: **Free Movement Effect on Firm Performance (Reduced Form, Foreign-Owned Companies)**

	(1) TFP index	(2) TFP LP	(3) ROA	(4) Pers. costs	(5) C/L
$L.FM_{ict}$	-0.0571	-0.124	0.0191	0.396***	0.395***
	(0.0796)	(0.0805)	(0.0269)	(0.0642)	(0.110)
$Mark-up_{ict}$	0.105***	0.143***	0.0480***	-0.0509	-0.0546
	(0.0339)	(0.0357)	(0.0136)	(0.0399)	(0.0446)
$L.log\_investment_{ict}$	0.0127*	-0.0108	-0.00692*	-0.0115	-0.0274**
	(0.00768)	(0.00798)	(0.00375)	(0.0110)	(0.0140)
$L.log\_FDI\_inward_{ict}$	4.88e-06	0.000242	-0.000519	0.00119	0.00414
	(0.00170)	(0.00182)	(0.000606)	(0.00139)	(0.00260)
$Log\_total\_sales_{it}$	-0.0114	-0.0245*	-0.00649	0.0509***	0.0302*
	(0.0119)	(0.0130)	(0.00538)	(0.0121)	(0.0171)
$Mean\ skill\ sh._{it}$	-0.103	0.178	0.0425	0.0712	0.0603
	(0.139)	(0.154)	(0.0647)	(0.149)	(0.204)
$L.log\_FDI_{ct}$	0.00938***	0.00639*	0.000382	-0.00195	-0.00690*
	(0.00292)	(0.00347)	(0.00165)	(0.00301)	(0.00394)
$D.log\_GDP_{ct}$	0.809***	0.791***	0.0941	0.196	0.200
	(0.145)	(0.172)	(0.0650)	(0.134)	(0.175)
Observations	56,960	34,354	56,580	55,730	55,730
Number of firms	10,415	6,846	10,361	10,308	10,308
R^2	0.021	0.019	0.016	0.088	0.044
Dummies	f y	f y	f y	f y	f y
Clusters	1683	1489	1668	1670	1670

Notes: The table presents reduced-form estimates of the free movement effect on firm performance. The sample is restricted to firms with foreign capital. All specifications are estimated with firm fixed effects and time dummies. Dependent variables: TFP index, TFP LP - tfp estimated with Levinsohn-Petrin procedure, ROA - return on assets, Pers. costs - personnel costs per employee, C/L - capital-labor ratio. L.FM - Free Movement variable (distance-weighted, interacted with skill shortages in destination industries), 1 year lag. Standard errors (in parentheses) are clustered on country-industry (NACE 4-digit) level.
*** p<0.01, ** p<0.05, * p<0.1

Table 6: **Free Movement Effect on Firm Performance (Reduced Form, Firms with Patents)**

	(1) TFP index	(2) TFP LP	(3) ROA	(4) Pers. costs	(5) C/L
FM	-0.0702	-0.0883	-0.104***	0.256*	0.604***
	(0.127)	(0.109)	(0.0363)	(0.144)	(0.132)
$Mark-up_{ict}$	0.0460	0.125***	0.0103	-0.0768	-0.0220
	(0.0380)	(0.0385)	(0.0126)	(0.0563)	(0.0638)
$L.log\_investment_{ict}$	-0.0156	-0.0245*	-0.00272	0.0251**	0.0440**
	(0.0121)	(0.0139)	(0.00479)	(0.0117)	(0.0184)
$L.log\_FDI\_inward_{ict}$	-0.000839	-0.00584***	-0.000692	0.000865	-0.000384
	(0.00184)	(0.00203)	(0.000740)	(0.00213)	(0.00277)
$Log\_total\_sales_{it}$	-0.0147	-0.0304	0.00435	0.00534	0.00906
	(0.0180)	(0.0189)	(0.00715)	(0.0162)	(0.0252)
$Mean\ skill\ sh._{it}$	0.0703	0.284	0.0201	0.239	-0.110
	(0.154)	(0.193)	(0.0644)	(0.166)	(0.226)
$L.log\_FDI_{ct}$	0.00130	0.00194	0.00176	0.0128***	0.0151***
	(0.00351)	(0.00450)	(0.00167)	(0.00292)	(0.00398)
$D.log\_GDP_{ct}$	0.383	0.263	0.0656	-0.00291	-0.474*
	(0.253)	(0.252)	(0.0700)	(0.250)	(0.274)
Observations	20,526	13,276	20,507	19,694	19,694
Number of firms	2,812	2,165	2,812	2,769	2,769
R^2	0.113	0.037	0.120	0.128	0.266
Dummies	f y	f y	f y	f y	f y
Clusters	843	729	843	832	832

Notes: The table presents reduced-form estimates of the free movement effect on firm performance. The sample is restricted to firms with patents. All specifications are estimated with firm fixed effects and time dummies. Dependent variables: TFP index, TFP LP - tfp estimated with Levinsohn-Petrin procedure, ROA - return on assets, Pers. costs - personnel costs per employee, C/L - capital-labor ratio. L.FM - Free Movement variable (distance-weighted, interacted with skill shortages in destination industries), 1 year lag. Standard errors (in parentheses) are clustered on country-industry (NACE 4-digit) level.
*** p<0.01, ** p<0.05, * p<0.1

5.3 Skill Shortages Due to Emigration: 2SLS Regressions

The reduced form regressions represent the "intention-to-treat" effect. Furthermore, it is of interest to estimate the effects for those firms that were effectively constrained by the outflow of skilled workers. We consider skill shortages as an indicator for this problem. If changes in EU15+4 labor mobility legislation indeed induce higher emigration rates of the qualified workforce, we will observe increasing skill shortages as reported by firms in NMS.

The measure of skill shortages is taken from the EU Commission Business Survey, which is conducted quarterly in all EU member countries by the Directorate General for Economic and Financial Affairs (DG ECFIN). The survey addresses representatives of the manufacturing, service, retail trade, and construction sectors and asks for firms' assessment and expectations of the business development. Among other questions, the survey's participants are asked to evaluate factors limiting their production (such as labor, access to finance, demand, and equipment). The EU commission publishes information on a two-digit NACE industry level, thus the obtained measure is equal to the share of firms in a given industry reporting to be constrained by labor. To match the data to other datasets, we aggregated quarterly indicators to annual levels.

Table 7 shows the OLS results of different firm outcomes regressed on skill shortages. We find that only one measure of TFP is significantly negative, while for other measures the relationship appears to be zero or even positive. We believe that these OLS results are upward biased due to reverse causality and omitted variable bias. For instance, those firms that experience a positive shock are likely to be more productive and thus need more labor. They are consequently more likely to report skill shortages. In the following, we perform a 2SLS analysis, which confirms the upward bias of the OLS regression.

Table 8 presents 2SLS estimates with the Free Movement variable serving as an instrument for skill shortages. Comparable to the reduced form estimations, we estimate the reported models using the distance-weighted instrument. The first-stage details (FM coefficient with the standard error) are presented below the main regression results.[9]

The measure of skill shortages (share of firms in an industry, reporting to be constrained by labor) ranges from 0 to 1. The coefficient of interest thus represents the log point change in the dependent variables when skill shortages increase by 1 unit (or 100%). A one percentage point increase in skill shortages caused by the EU15+4 labor market opening thus leads to a 1.6-3.1% drop in firm TFP (depending on the measure) and a

[9]The reported first-stage coefficients might differ slightly from those reported in Table 10, since some industry-year observations were dropped due to missing firm-level data.

Table 7: **Skill Shortages and Firm Performance (OLS Regressions)**

	(1) TFP index	(2) TFP LP	(3) ROA	(4) Pers. costs	(5) C/L
$L.skill\ sh.$	-0.0183	-0.0751***	0.0287***	0.0964***	-0.181***
	(0.0300)	(0.0258)	(0.00856)	(0.0323)	(0.0482)
$Mark-up_{ict}$	0.336***	0.302***	0.120***	-0.0254	0.0132
	(0.0817)	(0.0537)	(0.0205)	(0.0297)	(0.0474)
$L.log\_investment_{ict}$	0.00636	-0.00531	-0.00668***	0.00391	0.0238**
	(0.00698)	(0.00573)	(0.00198)	(0.00704)	(0.00955)
$L.log\_FDI)ct$	-0.00158	-0.000693	-0.000471	0.000983	0.00242
	(0.00153)	(0.00119)	(0.000351)	(0.00128)	(0.00200)
$Log\_total\_sales_{it}$	-0.00339	-0.0161	-1.11e-06	0.0504***	0.00719
	(0.0109)	(0.0107)	(0.00232)	(0.00819)	(0.0123)
$Mean\ skill\ sh._{it}$	-0.0205	0.106	0.158***	0.128	0.0451
	(0.160)	(0.124)	(0.0365)	(0.110)	(0.167)
$L.log\_FDI_{ct}$	0.0141***	0.0130***	0.00213***	0.00772***	0.0117***
	(0.00269)	(0.00245)	(0.000669)	(0.00199)	(0.00246)
$D.log\_GDP_{ct}$	1.549***	1.294***	0.239***	-0.0605	-0.285*
	(0.171)	(0.148)	(0.0370)	(0.0940)	(0.163)
Observations	501,277	291,346	497,393	486,190	486,190
Number of firms	88,370	54,965	87,651	86,960	86,960
Dummies	y f	y f	y f	y f	y f
Robust	yes	yes	yes	yes	yes
Clusters	2377	2210	2345	2361	2361

Notes: The table presents estimations of the skill shortages effect on firm productivity. All specifications are estimated with firm fixed effects and time dummies. Dependent variables: TFP index, TFP LP - tfp estimated with Levinsohn-Petrin procedure, ROA - return on assets, Pers. costs - personnel costs per employee, C/L - capital-labor ratio. Standard errors (in parentheses) are clustered on country-industry (NACE 4-digit) level.
*** p<0.01, ** p<0.05, * p<0.1

Table 8: **Skill Shortages as the Consequence of the Free Movement (2SLS Regressions)**

	(1) TFP index	(2) TFP LP	(3) ROA	(4) Pers. costs	(5) C/L
L.skill sh.	-3.071*	-1.635***	-0.281	3.042**	2.127
	(1.631)	(0.595)	(0.187)	(1.315)	(1.872)
$Mark-up_{ict}$	0.330***	0.308***	0.119***	-0.0106	0.0247
	(0.106)	(0.0647)	(0.0230)	(0.0594)	(0.0670)
$L.log\_investment_{ict}$	0.0298	0.00582	-0.00426	-0.0161	0.00814
	(0.0216)	(0.0101)	(0.00263)	(0.0179)	(0.0224)
$L.log\_FDI\_inward_{ict}$	-0.00338	-0.00171	-0.000652	0.00275	0.00381
	(0.00331)	(0.00193)	(0.000475)	(0.00271)	(0.00362)
$Log\_total\_sales_{it}$	0.0102	-0.00712	0.00135	0.0361*	-0.00400
	(0.0226)	(0.0140)	(0.00370)	(0.0211)	(0.0200)
$Mean\ skill\ sh._{it}$	0.977*	0.654***	0.260***	-0.826**	-0.702
	(0.562)	(0.231)	(0.0665)	(0.403)	(0.706)
$L.log\_FDI_{ct}$	0.0311**	0.0238***	0.00384**	-0.0100	-0.00219
	(0.0136)	(0.00705)	(0.00150)	(0.0116)	(0.0147)
$D.log\_GDP_{ct}$	1.375***	1.236***	0.221***	0.211	-0.0718
	(0.237)	(0.162)	(0.0510)	(0.249)	(0.240)
Observations	501,277	291,346	497,393	486,190	486,190
Number of firms	88,370	54,965	87,651	86,960	86,960
Dummies	y f	y f	y f	y f	y f
Robust	yes	yes	yes	yes	yes
Clusters	2377	2210	2345	2361	2361
fs_coef	0.0988	0.147	0.0981	0.0985	0.0985
fs_se	0.0423	0.0463	0.0424	0.0435	0.0435

Notes: The table presents estimations of the skill shortages effect on firm productivity. All specifications are estimated with firm fixed effects and time dummies. Dependent variables: TFP index, TFP LP - tfp estimated with Levinsohn-Petrin procedure, ROA - return on assets, Pers. costs - personnel costs per employee, C/L - capital-labor ratio. L.FM - Free Movement variable (distance-weighted, interacted with skill shortages in destination industries), 1 year lag. Standard errors (in parentheses) are clustered on country-industry (NACE 4-digit) level. $Firststage\_coef$ is the first-stage coefficient of the instrument and $Firststage\_se$ is the standard error.
*** p<0.01, ** p<0.05, * p<0.1

3.0% increase in personnel costs. Comparable to the reduced-form estimates, innovating and foreign-owned companies do not experience significant decreases in TFP, but raise their personnel costs and increase their capital intensity.

We include a number of covariates to switch off demand-driven changes in the reported measure of skill shortages. Country GDP growth rates and FDI inflows (GDP_{ct}, FDI_{ct}) control for general country-specific shocks. Lagged investment ($investment_{ict}$) accounts for country-industry specific increases in skill shortages due to the expansion of existing companies or new entries. The measure of average skill shortages in a given industry in EU15 countries ($Mean\ skill\ sh_{it}$) controls for industry-specific labor demand shocks, which are common across all EU members.

For all the specifications, we report the coefficients from the first-stage regressions (where we regress skill shortages on the Free Movement variable). A complete opening (from FM=0 to FM=1) of one industry in all EU15+4 labor markets results in a 10% increase in skill shortages for firms in the corresponding industry in the NMS. The free movement coefficient is statistically significant, and the F-test rejects the null hypothesis of insignificance.

6 Robustness

6.1 Exogeneity Assumption

The identification of the skill shortages effect builds on the exogeneity assumption of the constructed instrumental variable. Variation in the Free Movement variable comes from changes in legislation, bilateral distances, and skill shortages in destinations. All three components are determined on the industry level for *old* EU member states and hence should be exogenous to country-industry-year productivity shocks or changes in other unobservables in *new* EU member countries. As a robustness check for the validity of our IV approach, we ran the first-stage regression (5) on another variable, which also varies at the country-industry-year level, but, in contrast to skill shortages, should not systematically react to changes in EU labor mobility legislation. In the EU Business Survey, apart from skill shortages, firms also report on financial constraints. Table 11 presents first-stage regression results with financial constraints as a dependent variable. While for skill shortages all four IV modifications returned statistically significant coefficients, only one of them is weakly correlated with reported financial constraints. This, however, is not the modification we use in our regressions. This result reassures that the constructed

IV captures labor supply shrinking due to emigration instead of other contemporaneous shocks.

6.2 Using Different Lags of the Instrument

In our main specification, we have looked at the effects of emigration on firm performance one year after the respective labor market opening. We have chosen a one-year lag because we expect the effects appear with a certain delay, for instance due to the decision making process to migrate, the migration preparation process and the notice period. In the following, we are looking at simultaneous effects as well as the effects up to three years before and after the sector opening.

Figure 2 shows firm TFP that is regressed on lagged (1, 2 and 3 year lag), simultaneous and forwarded (1, 2 and three year forward) FM values. One can see that the forwarded values are always insignificantly different from zero. This is reassuring for us, as we do not want the future sector openings to affect current firm outcomes (for instance due to anticipation). The Free Movement variable gains significance during the year of the opening but is only borderline significant. The effect becomes stronger and more significant after one year and then remains at this lower level during the following two years.

Figure 4 in the appendix shows other firm outcomes that are regressed on lagged (1, 2 and 3 year lag), simultaneous and forwarded (1, 2 and three year forward) FM values.

Figure 2: **Annual Treatment Effects of Free Movement on Firm TFP**

Notes: Dependent variable - firm TFP, estimated with Levinsohn-Petrin procedure. The displayed coefficients correspond to the number of years before and after the largest increase in the Free Movement variable for a given industry. Year, industry, and country-fixed effects are included. Errors are clustered at the country-industry level.

7 Conclusion

This paper uses firm- and industry-level panel data to evaluate the effect of skilled emigration on firm productivity. To overcome the endogeneity problem, we exploit the natural experiment of the EU enlargements in 2004 and 2007. We argue that the gradual and industry-specific opening of the EU and EFTA labor markets to citizens from new member states throughout 2004-2014 has created exogenous variation in the emigration rates experienced by NMS. We show that an emigration-driven reduction in labor supply resulted in lower total factor productivity for firms in NMS. We also document an increase in personnel costs and share of trained personnel. This confirms the predictions of our model. Furthermore, we find that innovating and foreign-owned firms increased their personnel costs by more and experienced smaller drops in productivity. These firms have been more successful in circumventing the loss in TFP.

Our results are important both for firms and policy-makers. Being aware of the problem helps firms to react timely and in an adequate way. Firms can benefit from active human resource strategies, focusing, for instance, on providing training and retention measures. For policy makers, the effects of migration 'are not a matter of fate, [but] to a large extent, they depend on the public policies adopted in the receiving and sending countries'[10]. The prevalence of skill shortages justifies the need to invest in the skills of the local labor force and to mitigate search frictions. A skill upgrading of the local labor force can in the short term be addressed by providing specific training courses, which the state could subsidize to alleviate the burden for firms. In the long term the education system should be better adjusted to labor market needs. Knowing that those skilled people are required can justify the investment. An increase in local human capital might also happen in the long term due to increased incentives to invest in education, which rise with the prospect to emigrate (Beine et al. (2001)).

While the outflow of skilled workers leads to deteriorating firm performance in the short term, emigration can also create opportunities and countries can experience brain gain if they put the right policies in place. One possibility for brain gain is return migration. If companies and politicians in the new EU member states succeed in bringing back their skilled workers after some time abroad, then firms could benefit from even more experienced workers. These workers can create knowledge spillovers and bring their firms closer to the technological frontier. Another opportunity is to attract workers from other EU member states. An efficient labor agency, and especially harmonized EU-wide labor

[10]Docquier and Rapoport (2012).

agencies, should inform workers within the EU of all EU-wide job vacancies. A first step in this direction has been done with the European Commission's EURES job portal. This encourages unemployed workers in other EU states to search for a job in countries and industries that experience shortages. By attracting workers from other EU countries and incentivising return migration, firms in new member states could also reap the benefits of labor migration in an enlarged Europe.

This paper does not take general equilibrium effects. More intense competition on the labor market is likely to make the weakest firms leave and, thus, due to selection, industry-level productivity in NMS would increase in the medium- and long-run. Our results for foreign-owned and innovating firms indicate the plausibility of such developments. We also ignore aggregate effects at the European level. Free labor mobility and, consequently, the better allocation of workers and jobs should increase efficiency and welfare at the European level. We leave investigation of these effects for further research.

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8 Appendix

8.1 Additional Tables and Graphs

Figure 3: **Example of Legislation Dummies**

iso316612	nace2	year	DEU	ESP	GBR	FRA
PL	10	2004	0	0	.6666667	0
RO	10	2004	0	0	0	0
PL	43	2004	0	0	.6666667	0
RO	43	2004	0	0	0	0
PL	10	2009	0	1	1	1
RO	10	2009	0	1	1	0
PL	43	2009	0	1	1	1
RO	43	2009	0	1	0	0
PL	10	2012	1	1	1	1
RO	10	2012	0	0	1	0
PL	43	2012	1	1	1	1
RO	43	2012	0	0	0	0

Notes: The figure shows a print-screen from Stata to illustrate the construction of the Free Movement variable. 0 denotes that a given market is closed, 1 denotes that it is open for labour migrants from the new member states. If a country did not open from the beginning of a calendar year (for example, Great Britain opened in May 2004), the legislation dummy is weighted accordingly.

Table 9: **Summary of Variables**

	(1) Full	(2) Main_sample	(3) Incumbent	(4) Foreign	(5) Hightech	(6) Innovator
Firm-level data:						
number of employees	40.5	65.5	80.0	195	87.1	238
	[305]	[296]	[344]	[554]	[367]	[727]
sales, 000 EUR	3,908	5,554	6,686	26,972	9,954	34,662
	[162,210]	[61,742]	[70,814]	[172,423]	[109,758]	[267,709]
assets, 000 EUR	3,251	4,854	5,735	21,440	7,629	28,953
	[60,287]	[61,480]	[65,025]	[145,629]	[90,648]	[226,421]
firm age	9.16	10.7	13.6	10.8	10.8	14.6
	[8.03]	[7.78]	[7.71]	[8.66]	[7.78]	[9.63]
labour productivity ($\frac{Y}{L}$)	3.47	3.67	3.69	4.28	3.85	4.22
	[1.35]	[1.10]	[1.09]	[1.16]	[1.07]	[0.90]
labour productivity ($\frac{Y}{WL}$)	2.08	1.97	1.94	1.91	1.71	1.80
	[1.08]	[0.89]	[0.85]	[0.92]	[0.89]	[0.71]
TFP index	-0.012	-0.046	-0.050	-0.059	-0.10	-0.15
	[0.89]	[0.67]	[0.68]	[0.63]	[0.63]	[0.55]
Industry-level data, 2 digits:						
FM	0.083	0.13	0.13	0.14	0.19	0.15
	[0.11]	[0.14]	[0.14]	[0.14]	[0.18]	[0.15]
human capital constraints	0.090	0.092	0.10	0.088	0.096	0.12
	[0.11]	[0.11]	[0.12]	[0.11]	[0.12]	[0.13]
financial constraints	0.25	0.18	0.17	0.15	0.13	0.12
	[0.17]	[0.14]	[0.14]	[0.13]	[0.12]	[0.12]
number of employees	11.6	15.4	16.6	22.2	21.7	22.3
	[20.9]	[25.0]	[25.9]	[38.7]	[38.8]	[34.8]
sales, 000 EUR	948	1,033	1,136	2,076	1,911	2,468
	[5,403]	[7,006]	[8,135]	[7,331]	[5,174]	[11,083]
labour productivity ($\frac{Y}{L}$)	4.03	3.79	3.78	4.03	4.05	4.23
	[0.84]	[0.70]	[0.73]	[0.71]	[0.67]	[0.56]
labour productivity ($\frac{Y}{WL}$)	2.21	1.91	1.92	1.91	1.78	1.91
	[0.62]	[0.40]	[0.40]	[0.46]	[0.50]	[0.41]
Observations	3.25e+06	532760	334693	55979	116540	19143
No. of firms	555072	108256	58245	10628	26224	2758

Notes: The table reports means and standard deviations (in brackets) of variables used in the regressions. 'Full' denotes the sample of all available observations. Further sub-samples do not include observations with missing variables. 'Main sample' is a sub-sample of firms used in the main regression. 'Incumbent' is a sub-sample of firms that existed prior to 2002. 'Innovator' denotes a sub-sample of firms with patents. 'High-tech' denotes a sub-sample of firms operating in high-tech industries according to the Statistical classification of economic activities in the European Community (NACE) at 2-digit level. 'Foreign' denotes a sub-sample of firms with foreign capital.
Productivity measures are reported in natural logarithms.
Constraints are measured as the shares of firms in a given industry-country-year reporting to be constrained.
FM is our preferred instrument: the sum of legislation dummies, weighted by proximity measures to a given old EU member-country.
Sources: Amadeus, EU Commission Business Survey, Eurostat Structural Business Statistics

Table 10: **First Stage Regression. Effect of Free Movement on Skill Shortages**

	(1) FM, dist	(2) FM*skill sh., dist	(3) FM, migr	(4) FM*skill sh., migr
FM_{ict}	0.0522*	0.125***	0.0767***	0.112***
	(0.0298)	(0.0461)	(0.0144)	(0.0376)
$L.log\_investment_{ict}$	0.00644	0.00650	0.00400	0.00604
	(0.00451)	(0.00455)	(0.00447)	(0.00446)
$Log\_total\_sales_{it}$	0.0105	0.00993	0.0109	0.00912
	(0.00929)	(0.00914)	(0.00916)	(0.00885)
$Mean\ skill\ sh._{it}$	0.200**	0.165*	0.206**	0.148*
	(0.0905)	(0.0875)	(0.0891)	(0.0879)
$L.log\_FDI_{ct}$	0.00145***	0.00148***	0.00134***	0.00148***
	(0.000484)	(0.000483)	(0.000480)	(0.000482)
$D.log\_GDP_{ct}$	0.368***	0.372***	0.387***	0.377***
	(0.0807)	(0.0794)	(0.0812)	(0.0802)
Observations	2,069	2,069	2,069	2,069
Number of pp	428	428	428	428
R^2	0.349	0.352	0.357	0.355
Dummies	ci y	ci y	ci y	ci y
Clusters	428	428	428	428
Fstat	3.081	7.332	28.40	8.859
pval	0.0799	0.00704	1.60e-07	0.00308

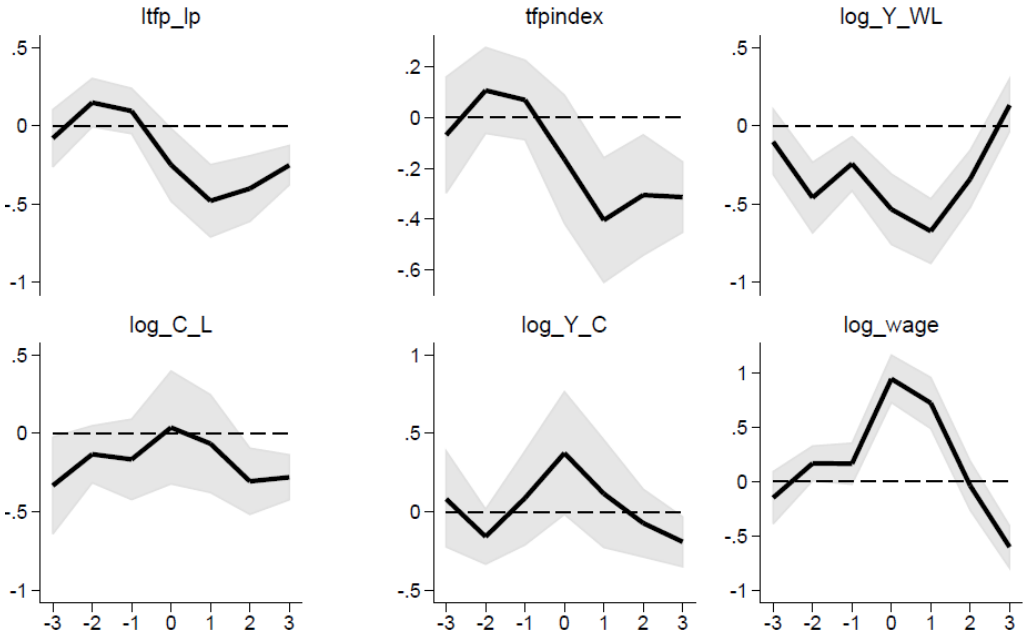
Notes: The table presents reduced-form estimates of free movement on skill shortages. All specifications are estimated with industry·country fixed effects and time dummies. Dependent variable: % of firms reporting skill shortages. FM denotes the Free Movement variable. In specifications 1 and 2, we use distance-weighted FM dummies, in 3 and 4 - weights with migration stocks. In specifications 2 and 4, FM dummies are in addition interacted with skill shortages in destination industries. Standard errors (in parentheses) are clustered on the country-industry level.
*** p<0.01, ** p<0.05, * p<0.1

Table 11: **First Stage Regression (Robustness). Effect of Free Movement on Financial Shortages**

	(1) FM, dist	(2) FM*skill sh., dist	(3) FM, migr	(4) FM*skill sh., migr
FM_{ict}	0.0791	-0.0414	-0.00399	-0.0800**
	(0.0535)	(0.0553)	(0.0274)	(0.0364)
$L.log\_investment_{ict}$	0.00126	0.00115	0.00131	0.00141
	(0.00638)	(0.00643)	(0.00654)	(0.00637)
$Log\_total\_sales_{it}$	0.00508	0.00522	0.00502	0.00601
	(0.0114)	(0.0115)	(0.0115)	(0.0113)
$Mean\ skill\ sh._{it}$	-0.0551	-0.0342	-0.0476	-0.00650
	(0.0970)	(0.0999)	(0.0967)	(0.102)
$L.log\_FDI_{ct}$	-0.000566	-0.000595	-0.000579	-0.000608
	(0.000508)	(0.000506)	(0.000512)	(0.000507)
$D.log\_GDP_{ct}$	-0.381***	-0.393***	-0.391***	-0.400***
	(0.0747)	(0.0730)	(0.0769)	(0.0734)
Observations	2,070	2,070	2,070	2,070
Number of pp	428	428	428	428
R^2	0.075	0.074	0.073	0.076
Dummies	ci y	ci y	ci y	ci y
Clusters	428	428	428	428
Fstat	2.184	0.561	0.0213	4.832
pval	0.140	0.454	0.884	0.0285

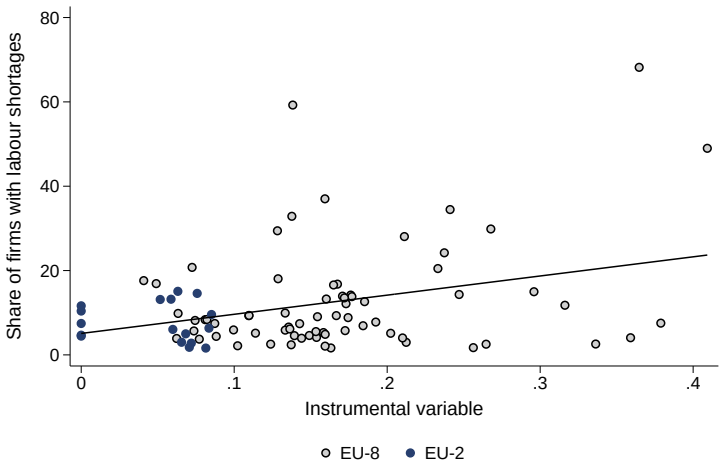
Notes: The table presents reduced-form estimates of free movement on skill shortages. All specifications are estimated with industry·country fixed effects and time dummies. Dependent variable: % of firms reporting skill shortages. FM denotes the Free Movement variable. In specifications 1 and 2, we use distance-weighted FM dummies, in 3 and 4 - weights with migration stocks. In specifications 2 and 4, FM dummies are in addition interacted with skill shortages in destination industries. Standard errors (in parentheses) are clustered on the country-industry level.
*** p<0.01, ** p<0.05, * p<0.1

Figure 4: **Dynamic effects (lagging and forwarding the instrument)**



Notes: This graph shows the coefficients of the L&P TFP measure, the TFP index, wage-adjusted labour productivity, the capital labour ration, capital productivity and personnel costs when the instrument is lagged, simultaneous or forwarded by up to three years. The 0 value on the x-axis indicates the year of the labour market opening and the values 1,2,3 are the years following the opening, while the values -3,-2 and -1 are the years preceding the sector openings.

Figure 5: **First stage illustration**



Notes: Skill shortages and FM (instrumental) variable are aggregated on a country-level proportionally to the number of firms in each industry. Source: EU Commission Business Survey, own calculations.

8.2 OLS regression and its shortcomings

Table 12 shows the OLS regression results of different firm outcomes on emigration numbers. We do not see a negative effect of emigration on firm productivity in these results for two main reasons. First, the migration date is measured very inaccurately and this measurement error biases our estimates towards zero. For example, all migration data to Germany is missing. Second, reverse causality is likely to affect the OLS regressions. If lower productivity levels lead to frustrated workers and thus more emigration, then we observe a negative relationship between the two variables that goes in the other direction. As a consequence, the OLS estimator is biased towards zero and we fail to find an effect in the OLS regressions.

Table 12: **OLS regressions**

VARIABLES	(1) tfpindex	(2) ltfp_lp	(3) log_ROA	(4) log_wage	(5) log_C_L
l_migr	-0.000305	0.0139	0.00344	-0.00440	0.00322
	(0.0110)	(0.0298)	(0.00681)	(0.0177)	(0.0406)
(mean) mean_Mup	0.218*	0.248	0.109*	-0.220**	-0.373**
	(0.119)	(0.215)	(0.0547)	(0.106)	(0.172)
L.log_inv_2d	0.00415	-0.0406	0.000814	-0.0178	-0.00769
	(0.0108)	(0.0336)	(0.00774)	(0.0273)	(0.0322)
(mean) log_total_sales	0.00345	0.136	-0.00511	0.0598	0.106
	(0.0421)	(0.0895)	(0.0229)	(0.0655)	(0.0839)
(mean) log_fdi_inward	-0.00511	0.00519	-0.00237	0.0163**	0.0136**
	(0.00409)	(0.0104)	(0.00170)	(0.00612)	(0.00604)
(firstnm) meanls	-0.560**	0.121	-0.268**	0.0963	0.877***
	(0.217)	(0.336)	(0.111)	(0.276)	(0.295)
L.log_FDI	-0.0789***	0.0849**	-0.0465***	0.0773***	0.181***
	(0.0148)	(0.0341)	(0.00933)	(0.0169)	(0.0291)
D.log_GDP	0.992***	3.414***	-0.250**	0.211	0.352
	(0.274)	(0.637)	(0.117)	(0.371)	(0.566)
Observations	439	439	439	439	439
Number of idc	46	46	46	46	46
R^2	0.902	0.389	0.922	0.856	0.962
Dummies	f y	f y	f y	f y	f y
Clusters	46	46	46	46	46

Notes: The table presents ols regression estimates of emigration numbers on firm outcomes. All specifications are estimated with firm and year fixed effects and time dummies. Standard errors (in parentheses) are clustered on the xx level.
*** p<0.01, ** p<0.05, * p<0.1

8.3 Proof of the Comparative Statics and the Simulation of the Model

In this sub-section, we first present the proof of the comparative statics results using a general production function and then provide a numerical solution to the model using a Cobb-Douglas production function.

8.3.1 Comparative Statics

We assume a general production function with three variable inputs: skilled and unskilled labour (L_s, L_u) and training t. Capital is fixed in the short-term. The firm faces the output price P, wages w_s and w_u, and job separation rate of skilled labour δ_s. V_s denotes the number of posted vacancies, c_s denotes the cost of a skilled vacancy, and $c_t = 1$ denotes the costs per hour of training t. For simplicity search and training costs for unskilled labour are set to zero. The firm solves the following maximization problem:

$$\Pi = Pf(t, L_s, L_u) - L_s w_s - c_s V_s - tV_s - L_u w_u$$

s.t.

$$\frac{V_s}{L_s} = \delta_s.$$

$f(t, L_s, L_u)$ is increasing and strictly concave in t, L_s, L_u. We denote the first-order partial derivatives of f by f_i where $i = t, L_s, L_u$. $f_i > 0$. f_{ij} are the second-order derivatives. $f_{ii} < 0$. We assume that the cross-derivatives $f_{ij}, i \neq j$ are positive.

Firms maximise profits, by choosing the number of workers and the initial amount of training (which then affects the level of firm-specific knowledge t). The first order conditions give the implicit solution of the model.

FOC1: $$\frac{\partial \Pi}{\partial L_s} = Pf_s - w_s - \delta_s c_s - \delta_s t = 0$$

FOC2: $$\frac{\partial \Pi}{\partial L_u} = Pf_u - w_u = 0$$

FOC3: $$\frac{\partial \Pi}{\partial t} = Pf_t - \delta_s L_s = 0$$

We apply the implicit function theorem to determine the signs of $\frac{\partial L_s^*}{\partial \delta_s}$ - the effect of δ_s on the firm's demand for skilled labour and $\frac{\partial t^*}{\partial \delta_s}$ - the effect on the initial training

and consequently the firm's TFP. We assume that the above system of equations has the unique internal solution L_s^*, L_u^*, t^*, which maximises the profit function.

$$\frac{\partial L_s^*}{\partial \delta_s} = \frac{|\tilde{D_{s\delta_s}}|}{|D|}$$

where $|D|$ is the determinant of the Hessian matrix:

$$D = \begin{bmatrix} Pf_{ss} & Pf_{su} & Pf_{st} - \delta_s \\ Pf_{su} & Pf_{uu} & Pf_{ut} \\ Pf_{st} - \delta_s & Pf_{ut} & Pf_{tt} \end{bmatrix}$$

To fulfil the second-order conditions, D has to be negative-definite, therefore, $|D| < 0$. $\tilde{D_{s\delta_s}}|$ is the determinant of the following matrix:

$$\tilde{D_{s\delta_s}}| = \begin{bmatrix} c_s + t & Pf_{su} & Pf_{st} - \delta_s \\ 0 & Pf_{uu} & Pf_{ut} \\ L_s & Pf_{ut} & Pf_{tt} \end{bmatrix}$$

The sign of $\frac{\partial L_s^*}{\partial \delta_s}$ depends on the term $(P^2 f_{uu} f_{tt} - P^2 f_{ut}^2)(c_s + t) + P^2 L_s f_{ut} f_{su} - PL_s f_{uu}(Pf_{st} - \delta_s)$. Under the assumption that the above profit maximization problem has a solution, this term will be positive.[11] Since $|D| < 0$, $\frac{\partial L_s^*}{\partial \delta_s} < 0$.

Similarly, the sign of $\frac{\partial t^*}{\partial \delta_s}$ depends on the term $(P^2 f_{uu} f_{ss} - P^2 f_{su}^2)(L_s) + P^2(c_s + t) f_{ut} f_{su} - P(c_s + t) f_{uu}(Pf_{st} - \delta_s)$, which is also positive. Therefore, $\frac{\partial t^*}{\partial \delta_s} < 0$.

8.3.2 Simulation

We further illustrate the effect of an increasing job separation rate δ_s on the firm's factor demand and TFP. For this exercise, we assume a Cobb-Douglas production function and simulate the model in Matlab.

$$\Pi = Pt^{\gamma} L_s^{\alpha} L_u^{\beta} - L_s w_s - c_s V_s - tV_s - L_u w_u$$

s.t.

$$\frac{V_s}{L_s} = \delta_s.$$

[11] $(P^2 f_{uu} f_{tt} - P^2 f_{ut}^2)(c_s + t) > 0$, $P^2 L_s f_{ut} f_{su} > 0$. $PL_s f_{uu}(Pf_{st} - \delta_s) > 0$, but should be smaller than the sum of the two first summands, otherwise the stationary point will be a saddle point.

The first-order conditions define the implicit solution of the problem.

FOC1: $\dfrac{\partial \Pi}{\partial L_s} = \alpha P t^{\gamma} L_s^{\alpha-1} L_u^{\beta} - w_s - \delta_s c_s - \delta_s t = 0$

FOC2: $\dfrac{\partial \Pi}{\partial L_u} = \beta P t^{\gamma} L_s^{\alpha} L_u^{\beta-1} - w_u = 0$

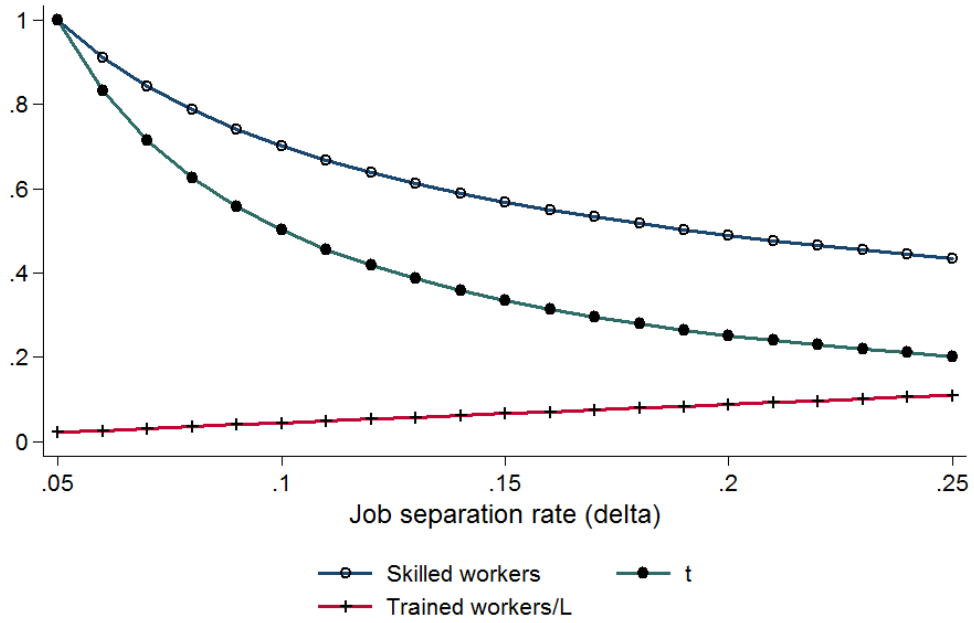
FOC3: $\dfrac{\partial \Pi}{\partial t} = \gamma P t^{\gamma-1} L_s^{\alpha} L_u^{\beta} - \delta_s L_s = 0$

Again, we assume that the solution to the above maximization problem exists: $\gamma + \alpha + \beta < 1$ and the second-order conditions are satisfied.

To simulate the model, we used the following parameter values: $\gamma = 0.1$, $\alpha = 0.5$, $\beta = 0.3$, $w_s = 1$, $w_u = 0.6$, $c_s = 0.05$.

Figure 6 presents the simulation results. We investigate the effect of δ_s on the firm's demand for skilled workers L_s, on the firm-specific knowledge t, and on the share of trained workers $\dfrac{\delta_s L_s}{L}$. The graph illustrates that if δ_s increases, the firm's demand for skilled labour decreases and so does the amount of training t that the firm decides to provide for the new hires. The latter eventually lowers the firm-specific knowledge and hence TFP. The share of trained workers to the total workforce, however, increases since more workers have to be trained.

Figure 6: **The Effect of the Job Separation Rate δ_s, Simulation Results**



Note: This graph shows the simulation results of our theoretical framework for different values of delta (the job separation rate). "Skilled workers" - the amount of optimal skilled labour, "t" - the amount of of the optimal training (the firm-specific knowledge). Both "Skilled workers" and "t" are normalised to their optimal values at $\delta_s = 0.05$. "Trained workers/L" - the share of trained workers to the firm's total workforce.

8.4 TFP Index Calculation

We calculate the TFP index, following Gorodnichenko and Schnitzer (2013), according to the formula below:

$$TFP_{fict} = \hat{y}_{fict} - s_{ic}^{L}\hat{l}_{fict} - s_{ic}^{K}\hat{k}_{fict} - s_{ic}^{M}\hat{m}_{fict} \tag{7}$$

where $\hat{y}_{fict}, \hat{l}_{fict}, \hat{k}_{fict}, \hat{m}_{fict}$ are log deviations of a firm's output, labour, capital, and materials from industry's averages. The latter are calculated on a four-digit industry level (for each country), by taking geometric means across all firm-year observations.

By using deviations instead of levels, we exclude time-invariant country-industry fixed effects and make the index more comparable across different industries and countries.

$s_{ic}^{L}, s_{ic}^{M}, s_{ic}^{K}$ are cost shares of labour, materials, and capital, which are computed for each firm-year and then also aggregated on a four-digit industry level for each country.

As a proxy of output we use firms' sales, labour (wages and salaries), capital (fixed assets), and material (material costs). We should note that the obtained TFP index contains not only firms' unobserved technology and management ability, but also firms' market power, and differences in their workforce composition.