Firm Heterogeneity and the Impact of Immigration: Evidence from German Establishments*

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Abstract

We use a detailed establishment-level dataset from Germany to document a new dimension of firm heterogeneity: large firms spend a higher share of their wage bill on immigrants than small firms. We show analytically that ignoring this heterogeneity in the immigrant share leads to biased estimates of the welfare gains from immigration. To do so, we set up and estimate a model where heterogeneous firms choose their immigrant share and then use it to quantify the welfare effects of an increase in the number of immigrants in Germany. Two new adjustment mechanisms arise under firm heterogeneity. First, native workers reallocate across firms, which mitigates the competition effect between immigrants and natives in the labor market. Second, the gains are largely concentrated among the largest and most productive employers, which induces an additional aggregate productivity gain. If we ignore the heterogeneity in the immigrant share across firms, we would underestimate the welfare gains of native workers by 11%.

JEL: F16, F22, J24, J61
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1 Introduction

During the past two decades, the number of immigrants living in developed countries increased by more than 80%, which has fueled the academic and public debate regarding the impact of immigration on native workers. To study this question, most of the literature has assumed, implicitly or explicitly, that a representative firm exists. However, firms are heterogeneous along many dimensions such as size, productivity, export behavior, and demand for labor. In this paper, we ask whether such heterogeneity across firms matters as we aim to understand the effect of immigration on the welfare of native workers.

We start by using a detailed establishment-level dataset from Germany to document a new dimension of heterogeneity: large employers are more immigrant-intensive than small employers. We then show analytically and quantitatively that ignoring this heterogeneity leads to biased welfare gains from immigration. First, when firms are homogeneous, the elasticity of substitution between immigrants and natives in the labor market coincides with the within-firm elasticity. However, when firms are heterogeneous, the aggregate immigrant-native substitution elasticity depends on the within-firm elasticity and the elasticity of substitution across firms or goods. Thus, having different immigrant-intensities across firms allows for natives and immigrants to specialize in working for different employers, which makes them less substitutable in the aggregate labor market. Second, when firms are heterogeneous, the gains are largely concentrated among the largest and most productive employers, which induces an additional aggregate productivity gain. We find that if we ignore this heterogeneity, the welfare gains from an increase in immigration would be underestimated by 11%.

To characterize the relationship between employer size and immigrant intensity, we use a comprehensive employer-employee matched dataset of social security records in Germany between 2003 and 2011. We show that the median establishment in the top wage bill decile spends 5.6% of their wage bill on immigrants, while the median establishment in the fifth decile spends almost half of that (2.9%), and the median establishment in the bottom decile spends even less (0.4%). This relationship is stronger in the tradable sector, where the immigrant share of the top decile is 8%, while the immigrant share at the bottom decile is zero. We explore the mechanisms behind this relationship and provide evidence suggesting that firms may incur fixed hiring costs to start recruiting immigrants. We also rule out confounders such as differences in worker skills, production technologies, and local labor markets.

Next, we set up a model with heterogeneous firms to quantify the general equilibrium adjustment and welfare implications of an influx of immigrants. The model incorporates a tradable and non-tradable sector, the decision to export (Melitz, 2003), and crucially, the decision to hire immigrant labor. Consumers have preferences over a set of goods in each sector, which are aggregated in a CES fashion. Each good is produced by a single firm that can use immigrant and native labor as inputs, which we consider imperfect substitutes in production (Peri and

Sparber, 2009, 2011).

We model the immigrant hiring decision following the input-sourcing literature (Antràs et al., 2017; Blaum, 2019; Blaum et al., 2018; Halpern et al., 2015). Firms can choose to hire immigrant labor, but to do so they must incur two types of fixed costs: an initial fixed cost to start hiring immigrants, and an additional fixed cost for any new country they source immigrants from. Such fixed cost structure has two implications supported by the data. First, larger and more productive firms will be more likely than small firms to hire immigrants in equilibrium. Second, larger firms will also find it profitable to recruit immigrants from more countries and spend a larger share of their wage bill on immigrants. To fully capture the rich relationships between size and immigrant intensities across firms observed in the data, the model allows for two sources of firm heterogeneity: innate productivity and the cost of hiring immigrants, which are both drawn from a joint distribution.

We use a simplified version of this model to analytically show that the welfare predictions of a model that ignores the relationship between firm size and immigrant share are biased. To this end, we compare the welfare gains between our model with full heterogeneity and a model without heterogeneity in immigrant intensities. The sign of the bias depends on whether the elasticity of substitution between immigrants and natives is larger or smaller than the elasticity of demand, which regulates the change in the scale of production. When the substitution effect is stronger than the scale effect, immigrants crowd-out natives at immigrant-intensive firms who are reallocated toward native-intensive firms. By specializing in producing different goods than immigrants, natives become less substitutable in the labor market, and the downward pressure on wages induced by competition with immigrants is weaker than when natives do not reallocate across firms. Such reallocation across firms implies that the aggregate elasticity of substitution in the model with full heterogeneity is lower than in the model without heterogeneity, which makes the welfare gains from immigration larger.

The ***magnitude of the bias*** depends on the elasticity of demand, the elasticity of substitution between immigrants and natives, and the joint distribution between firm-level productivity and firm-level immigrant-hiring costs. Following Oberfield and Raval (2014), we estimate the elasticity of demand from the average firms' markups (i.e., the ratio of revenue to total costs). The substitution between immigrants and natives is structurally estimated using the firm's first-order condition with respect to immigrant and native labor. We regress the firm-level relative wage between immigrants and natives on relative employment, following an IV approach as in Ottaviano and Peri (2012). Since the quantities in our model are in effective units of labor, we provide a model-based method to back out the effective units from data on labor quantities and wages.

Given the estimates of these two elasticities, we estimate the joint distribution of productivities and costs to match the observed dispersion and correlation between firm-level revenues and immigrant-intensities in the data. These parameters are jointly estimated with the remaining parameters of the model through a Simulated Method of Moments (SMM) approach to match key targeted micro- and macro-level moments in Germany between 2003 and 2011. We show that the estimated model is capable of replicating the cross-sectional distribution of immigrant intensities across firms, even for important untargeted moments in the distribution.

We validate the model by comparing our model-predicted treatment effects of an increase in immigration across firm sizes with the observed treatment effects estimated independently from the model. Specifically, we regress firm revenues and the relative wage bill between immigrants and natives on the share of immigrants in the local labor market and its interaction with firm size. To identify the causal effect, we follow Ottaviano and Peri (2012) and instrument the share of immigrants in a labor market with a shift-share instrument that exploits country-of-origin variation in the initial network of immigrants across local labor markets. For establishments in the tradable sector, we find that a 1% increase in the share of immigrants in the local labor market increases revenues for firms in the top decile by 2.16%, while it decreases revenues in the bottom decile by 0.42%. We also show that large establishments in the tradable sector become more immigrant-intensive than small establishments. For establishments in the non-tradable sector, we find weak heterogeneous effects in their response to immigration. The model does a good job in replicating the observed relative responses to immigration across firms in both sectors.

We use the estimated model to measure the welfare effects of a 20% increase in the total number of immigrants, which is what happened in Germany between 2011 to 2017 after the country unified its labor market with other EU countries. We find that native workers in both sectors benefit from immigration since wages are higher due to larger domestic and international demand, and prices are lower due to lower production costs. Revenues and profits increase for both sectors, but more so in the tradable sector, where firms are more intensive in immigrant labor. Natives reallocate within sector toward less immigrant-intensive firms and across sectors toward the non-tradable sector. In monetary terms, welfare gains from immigration amount to $4 billion for native workers and $15 billion for firm owners.

Finally, our welfare results, we quantify the significance of accounting for the heterogeneity in the immigrant share. To do so, we keep the same estimates of the elasticity of substitution and the elasticity of demand, and re-estimate the remaining parameters of our model for the case where all firms spend the same share of their wage bills on immigrants. Such model is equivalent to a quantitative model estimated without firm-level data on immigrant labor, a data limitation commonly faced by the literature. Overall, the model without heterogeneity understates the change in welfare of natives by 11%, which is driven by an underestimation of both the drop in the price level and the increase in wages caused by immigration. The bias can be explained by two main components. First, the aggregate elasticity of substitution between immigrants and natives in the heterogeneous model is lower than when ignoring heterogeneity in the immigrant share. Second, even when using the same aggregate elasticity in both models, there is a complementarity induced by heterogeneity that increases aggregate welfare, as the largest and most productive firms benefit the most from the endogenous productivity gains generated by immigrants.

Our paper contributes to the literature in three main ways. First, while some notable papers use general equilibrium models to study the impact of immigration (Burstein et al., 2020; Caliendo et al., 2021; Desmet et al., 2018; di Giovanni et al., 2015; Khanna and Morales, 2018; Morales, 2019), they tend to follow a neoclassical approach, where firms are assumed to be homogeneous in their immigrant hiring decisions. Relative to the existing quantitative models, we add the novel feature of firms endogenously choosing their immigrant intensities by following the literature on intermediate input sourcing (Antràs et al., 2017; Blaum, 2019; Blaum et al., 2018; Halpern et al., 2015). This approach allows us to consider the firm as a fundamental channel where aggregate production and labor adjust to immigration. We document a large heterogeneity in the immigrant share across firms and, in light of this heterogeneity, we find that it matters for quantifying the aggregate impact of immigration.

Second, we also speak to an emerging literature that uses firm-level data to provide reduced-form evidence on the effect of immigration on firms (Arellano-Bover and San, 2020; Card et al., 2020; Dustmann and Glitz, 2015; Kerr et al., 2015; Mahajan, 2020; Mitaritonna et al., 2017; Orefice and Peri, 2020). We contribute to this literature by documenting new facts regarding the relationship between firm size and immigration and by assessing the aggregate consequences of immigration with a general equilibrium model. In Section 8, we further discuss how our results compare to the findings of this literature and how the institutional context of Germany matters for our conclusions.

Third, we contribute to the literature that studies the importance of firm heterogeneity for aggregate outcomes. In the context of international trade, Arkolakis et al. (2012) show that, conditional on having the same trade elasticity, the welfare gains from trade are the same for a class of heterogeneous and homogeneous firm models. As opposed to that class of heterogeneous firm models, we allow firms to be heterogeneous in their input shares and, building on Oberfield and Raval (2021), we show how this heterogeneity affects the ***aggregate*** elasticity of substitution between immigrants and natives.[1] Our new insight is that if firms are heterogeneous in their immigrant share, immigration induces a reallocation of ***natives*** across firms. Such reallocation affects the aggregate substitution between natives and immigrants and, in turn, the welfare gains from immigration.

[1]Oberfield and Raval (2021) show that the aggregate elasticity between two inputs of production, labor and capital, depends on the elasticity of substitution within a firm and the reallocation of *market shares* across firms that employ capital and labor differently.

2 Data

We use a detailed, employer-employee matched dataset from Germany provided by the Research Data Center (FDZ) of the Federal Employment Agency in the Institute for Employment Research (IAB). The main data source is the Longitudinal Establishment Panel (LIAB), which includes records for a large sample of establishments over the period 2003-2011.[2] The dataset contains full employment trajectories for each employee who worked at least one day for one of the establishments in the sample during the period. It also includes employee information on citizenship, occupation, education, and daily wage. Regarding citizenship, countries are grouped into ten regions: 1) Germany, 2) France, United Kingdom, Netherlands, Belgium, Austria, Switzerland, Finland, and Sweden, 3) Italy, Spain, Greece, and Portugal, 4) countries that joined the EU after 2004, 5) countries of former Yugoslavia not in the EU, 6) Turkey, 7) all other European countries including Russia, 8) Asia-Pacific, 9) Africa and Middle East, and 10) the Americas. On the establishment side, the dataset contains information on industry, location, and establishment-level financials such as revenues, investment, and material use, among others. More information on LIAB can be found in Heining et al. (2016).

A key variable needed for our analysis is workers' immigration status at a given establishment, but the German social security data records citizenship as opposed to country of birth. Since we are interested in country of birth, we redefine this key variable to make sure we count immigrants properly. The most common recoding is when observing individuals with a foreign citizenship become Germans the next period. If a worker is recorded as a foreigner for at least two periods, we classify them as an immigrant from the initial citizenship country.[3]

It is important to note that the German administrative data is at the establishment level, and it is not possible to link multiple establishments to a single firm. Throughout the paper, we will use establishment and firm interchangeably. Also, while LIAB is not directly a representative sample of the population, we apply survey weights to get representative aggregates whenever necessary. For establishment location within Germany, our data includes an administrative subdivision of German states into districts called "Kreis." For part of our analysis, we also group districts into local labor market areas following the analysis of Kropp and Schwengler (2011), who use commuting flows to delineate functional labor markets. We complement the German administrative data with publicly available datasets from the World Bank to deflate wages and compute exchange rates, the World Input-Output tables for data on trade and international GDP, and the OECD for aggregate migration data.

[2]The data basis of this paper is the Longitudinal Model (version 1993–2014) of the Linked Employer-Employee Data from the IAB. The data were accessed on-site at the Research Data Centre of the Federal Employment Agency at the Institute for Employment Research (FDZ) and/or via remote data access at the FDZ.

[3]A second challenge is that some workers might join the labor market with a foreign citizenship, but they may have grown up in Germany to foreign parents. Our results are robust to recoding workers as natives if they have foreign citizenship and either join the labor force at age 20 or younger without a college degree, or join the labor force at age 25 or younger with a college degree.

3 Firms Are Heterogeneous in Their Immigrant Share

We present a series of facts that provide insight on how employers have different intensities on immigrants and use these facts to ground our model.[4] As a first step, we document that larger employers are more intensive in immigrant labor. We rank the establishments in our sample into wage bill deciles, where decile 1 includes the smallest establishments, and decile 10 includes the largest.[5] For each decile, we plot the median share of immigrant labor in the establishment wage bill to capture the firm-level intensity on immigrants. As shown in the solid blue line in Figure 1, there is a monotonic and increasing relationship between employer size and immigrant intensity. The median establishment in decile 10 spends 5.6% of their wage bill on immigrants, while the median establishment in decile 5 spends only 2.9%, and the median establishment in the lowest decile spends even less, 0.4%.

Figure 1: Immigrant share of the wage bill across establishments

Note. We divide all establishments with more than 10 employees into total wage bill deciles, with 1 being the smallest establishments and 10 the largest. For each decile, we plot the median immigrant share of the total establishment wage bill. We calculate the 95% confidence interval using 200 bootstrap repetitions.

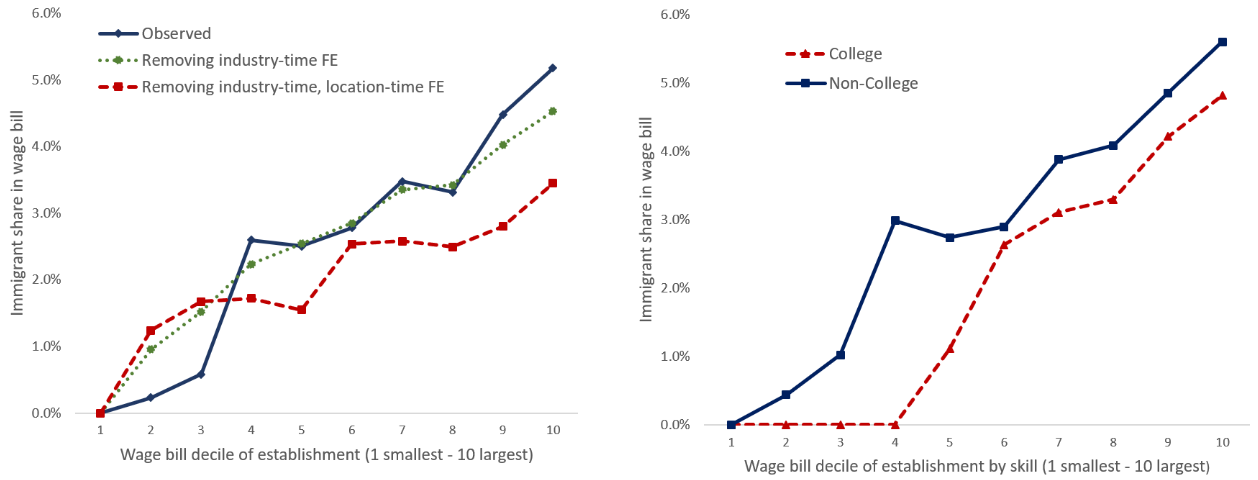
The relationship between employer size and immigrant intensity is not driven by specific confounders such as industry or labor markets. Large employers could be concentrated in industries that are more intensive in skills provided by immigrants. At the same time, immigrants might also concentrate in large cities where immigrant networks are larger, which also happens to be where large employers are located. However, none of these channels seem to explain the observed heterogeneity in immigrant intensities. As shown in the dashed lines in Figure 2a, the pattern remains strong after controlling for three-digit industry fixed effects and local labor market fixed effects, indicating that differences in production technologies or geographic

[4]In Appendix A, we present summary statistics on the sample of establishments, and the distribution of immigrants across sectors and origin regions.

[5]We use wage bill as our main measure to rank establishments, but results are robust to using employment or revenues. We focus on establishments with more than 10 employees, but the relationship between size and immigrant intensity is still positive and strong when including smaller establishments.

Figure 2: Immigrant share across industries, labor markets, and skill groups

(a) All establishments (b) By education group



Note. We divide all establishments with more than 10 employees into total wage bill deciles, with 1 being the smallest establishments and 10 the largest. For each decile, we plot the median immigrant share of the total establishment wage bill. Decile 1 is normalized to 0. Left panel: we plot the observed median immigrant share, the residual median share after removing industry-time fixed effects, and the residual median share after we remove industry-time and location-time fixed effects. Right panel: we divide all establishments with more than 10 college and non-college employee, respectively, into total wage bill deciles. For firms in each decile, we plot the median immigrant share of total wage bill spent in each education group.

destinations of immigrants alone cannot explain the observed relationship between size and immigrant-intensity.

Our relationship of interest is also not driven by immigrant skills. Large firms tend to be more intensive in high-skill labor (Burstein and Vogel, 2017), and if immigration policy in Germany would be skewed toward workers with a specific education, this could drive the relationship between size and immigrant intensity. As shown in Figure 2b, the relationship between size and immigration holds for workers with and without a college education. Additionally, we corroborate that the observed patterns are not driven by the establishment being foreign-owned, or being part of a multi-unit firm.

The evidence presented thus far is consistent with the existence of fixed costs to hire immigrants, which act as a barrier for small firms to hire their optimal immigrant labor shares. The immigration literature has well documented that immigrants and natives are imperfect substitutes as they perform different tasks in production (Peri and Sparber, 2009, 2011). Hence, all firms would optimally choose to hire immigrants in the absence of hiring costs. In the real world, however, many firms do not hire immigrants, and immigrant intensities across firms are very different even when controlling for industry, labor market, and skill differences.

For the most part, costs to recruit immigrants take the form of fixed costs since they do not depend on the number of immigrants to hire. These costs include training legal and human resources staff to comply with immigration law and learning how to screen foreign workers.

For example, employers may not be familiar with foreign institutions where the immigrant accumulated work experience or the foreign universities that granted their educational degrees. Firms may need to pay a one-time cost to learn about individual countries and their educational and business institutions. In Germany, particularly before the EU labor market integration in 2011, most immigrants needed a guaranteed employment offer in order to migrate there. Given this context and our data window between 2003 and 2011, it makes sense to focus on the decision of firms to explicitly decide to pay these costs and recruit immigrants.[6]

Based on this anecdotal evidence, in Appendix B, we show evidence consistent with the presence of fixed costs to hire immigrants. Importantly, we find that there is a significant mass of small firms that do not hire immigrants, and there is lumpiness in the hiring process. We also find that large firms recruit immigrants from more countries, which is consistent with the learning costs to understand immigrant backgrounds.[7]

Finally, we argue it is important to explicitly separate establishments in the tradable and non-tradable sectors throughout the analysis. As shown by Burstein et al. (2020), the tradability of the output produced by immigrants is a key feature to account for, as immigrants are absorbed differently in the labor market when working in tradable versus non-tradable occupations. Tradable sectors face a more elastic demand and can expand output more than non-tradable sectors in response to an influx of immigrants. Figure 3 shows that establishments in the tradable sector are more intensive in immigrants than similar sized establishments in the non-tradable sector. The tradable sector presents a stronger positive relationship between size and immigrant intensity than the non-tradable sector.[8]

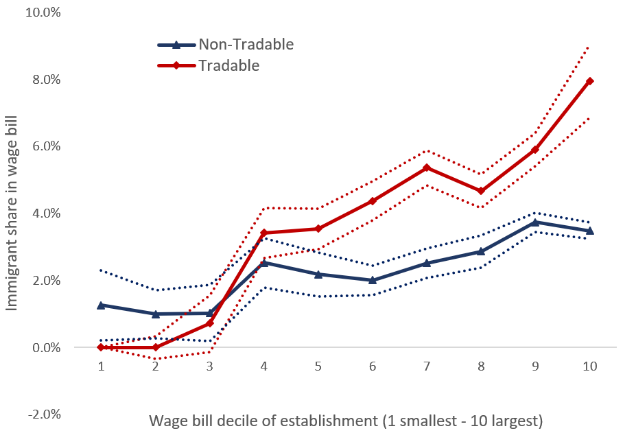
The differences in the immigrant share across firm sizes documented in this section imply that firms can benefit differently from immigration: immigrant-intensive firms are likely to experience a larger drop in cost of production than native firms. Given that firms make production decisions that determine employment and wages of natives, the documented heterogeneity can potentially affect our current understanding of the effects of immigration on natives' welfare. To quantify the welfare gains of immigration under the observed differences in firm immigrant shares and characterize the bias introduced by ignoring this heterogeneity, we set up a quantitative model presented in the following section.

[6]Our framework is well suited to study cases where firms have an active role in finding and sponsoring immigrants. The US H-1B program where firms sponsor workers' visas, and Canada's point system that gives high weights to guaranteed employment offers, are good examples of cases similar to Germany prior to 2011.

[7]The relationship between immigrant share and firm size could also be explained by recent theories on the internal organization of firms, as in Caliendo et al. (2015). If larger firms with more layers of management can supervise and hire more immigrants than smaller firms, it could also rationalize the patterns in Figure 1. Alternatively, large firms could have a technology that is biased toward immigrants, which would also rationalize these patterns. However, these theories would not rationalize that larger firms also hire workers from more countries, as shown in Appendix B.

[8]Our definition for the tradable sector considers manufacturing, professional services, and wholesale trade. While immigrants do concentrate in some small establishments in the non-tradable sector (e.g., restaurants), the representative establishment captured by the median tends to have a low immigrant intensity.

Figure 3: Tradable and non-tradable sector.



Note. We divide all establishments with more than 10 employees into total wage bill deciles, with 1 being the smallest establishments and 10 the largest. For each decile, we plot the median immigrant share of the total establishment wage bill. We separate establishments in each decile on whether they belong to the tradable or non-tradable sectors. We calculate the 95% confidence interval using 200 bootstrap repetitions.

4 The Model

Our quantitative model has two main components: the labor demand and the labor supply. On the labor demand side, heterogeneous firms choose their optimal immigrant share, following the setup proposed by the literature on importing intermediate inputs (Antràs et al., 2017; Blaum, 2019; Blaum et al., 2018; Halpern et al., 2015). Firms also choose whether to export their goods by paying a fixed cost as in Melitz (2003). The labor supply side of the model is based on the combination of Eaton and Kortum (2002) model of comparative advantage with Roy (1951), commonly referred to as EK-Roy models.[9] We focus on the main components of the model and relegate some derivations to Appendix C.

Consumption:

Domestic workers (indexed by i), supply L_d effective units of labor inelastically and have Cobb-Douglas preferences for goods from two sectors indexed by k as shown in equation 1:

$$U_i = (Y_i^T)\ (Y_i^{NT})^{1} \tag{1}$$

where Y^T stands for a tradable sector and Y^{NT} for the non-tradable sector. Each sector k is composed by a CES aggregate of varieties indexed by z as in equation 2:

$$Y_i^k = \int_{J_z} (y(z)_i^k)^{\frac{\ 1}{}} dz^{\ \frac{}{1}} \tag{2}$$

[9]The so-called EK-Roy models have been used to model individual choices across sectors (Lagakos and Waugh, 2013; Lee, 2020) and across countries to migrate (Morales, 2019), among many other applications.

where J_z represents the set of varieties available in the country, and > 1 is the elasticity of demand.

Production:

In each industry k, there is a mass of N firms indexed by j that produce a specific variety. Firms employ only labor inputs, which can be native "domestic" workers or immigrants. There is a long tradition in immigration literature to think about immigrants and natives as imperfect substitutes in production, as they have different comparative advantages across tasks and specialize in different occupations (Peri and Sparber, 2009, 2011). We assume that firms combine domestic and foreign effective units of labor (d_j and x_j, respectively) in a CES manner as shown in equation 3. For simplicity, we omit the subscript k from the equations below, but all parameters except for the elasticities are industry-specific:

$$y_j = \ _j \ d_j^{\frac{1}{}} + (1 \ ) x_j^{\frac{1}{}} \ ^{\frac{}{1}} \tag{3}$$

where is a sector-specific distributional parameter that captures the average intensity in immigrant labor, is common across sectors and captures the degree of substitution between native and immigrant workers within the firm, and $_j$ is an firm-specific productivity draw. Using CES properties, the unit cost for firm j can be written as in equation 4:

$$u_j = \ w_d^{1} \ + (1 \ ) \ W_{x;j}^{1} \ ^{\frac{1}{1}} \tag{4}$$

where w_d and and $W_{x;j}$ are the wage per effective unit of native and immigrant labor, respectively. Following CES properties for the expenditure share in a given input, we can write the domestic share as in equation 5:

$$s_{d;j} = \frac{w_d^{1}}{w_d^{1} \ + (1 \ ) \ W_{x;j}^{1}} = \frac{w_d^{1}}{u_j^{1}} \tag{5}$$

If the wage per effective unit of immigrant labor, $W_{x;j}$, was the same across firms, the unit cost of production would also be the same. In that case, all firms, regardless of their productivity or size, would have the same immigrant and domestic shares. However, as shown in Section 3, the data suggests that the immigrant share is not constant across firms, and large firms have a larger intensity in immigrants than small firms. To incorporate this into the model, we need a theory on why firms hire different shares of immigrants and face different immigrant costs $W_{x;j}$.

As discussed in Appendix B, we find multiple features in the data that suggest that firms face fixed costs of hiring immigrants, and part of it seems to be dependent on the origin region of the immigrants hired. Larger firms are not only more intensive on immigrants than small firms, but also hire immigrants from more countries. Additionally, there is lumpiness in the observed hiring patterns when firms start hiring immigrants from a given region. Finally, the immigrant share of the firm has a strong correlation with the number of regions that the firm recruits from, even after controlling for the total number of immigrants hired. These features of the data are consistent with the idea that firms must invest resources into learning how to recruit immigrants from additional origin regions.

Environment to Recruit Immigrants:

To theorize on the firm choice of its immigrant share that accommodates those facts and remains tractable in a general equilibrium framework, we follow Blaum et al. (2018) and Blaum (2019), who develop a theory of how firms choose their intermediate input share. We assume that the immigrant input of labor, x_j, is a composite of labor from different origin countries (indexed by o) as in equation 6:

$$x_j = \left(\int_{\Sigma_j} \beta_o x_{j,o}^{\frac{\sigma-1}{\sigma}} d_o \right)^{\frac{\sigma}{\sigma-1}} \tag{6}$$

σ is the elasticity of substitution between origin countries, such that every additional origin country the firm hires from will have a positive impact on productivity and lower the effective immigrant unit cost $W_{x,j}$ faced by firm j. The hiring strategy of the firm, denoted by Σ_j, represents those countries where the firm hires immigrants from, out of a total of O origins.

Firms must pay a fixed cost f_{imm} to begin hiring immigrants from abroad and a firm-specific fixed cost f_j for each additional origin country it wants to hire from. For example, if the firm hires immigrants from two origins, it spends $w_d \times (f_{imm} + 2 \times f_j)$ in hiring costs. One interpretation is that the fixed cost f_{imm} captures the costs of setting up a legal department or training HR staff on the immigration hiring process in order to start hiring immigrants. The cost f_j captures the learning cost that is country-specific, such as understanding foreign education credentials and labor experience necessary to screen workers.

We assume that hiring costs f_j are jointly drawn with the firm-specific productivities φ_j, from a multivariate sector-specific log normal distribution with mean $[\mu_\varphi, \mu_f]$, dispersion $[\sigma_\varphi, \sigma_f]$, and covariance between firm productivity draws and hiring costs of $\sigma_{\varphi,f}$.

Choosing Σ_j becomes computationally challenging because it requires computing profits for 2^O possible combinations of countries. To overcome this difficulty, we make a series of simplifications. First, we assume that foreign countries are perfectly ranked in terms of productivity β_o, such that firms will first source from the foreign country with the largest β_o and move down the ladder as they source from more countries. This assumption simplifies the sourcing problem as it now boils down to choosing the mass of countries, $n \in [0, 1)$, to hire from. Second, we assume $_o$ is a random variable distributed Pareto with shape parameter and scale parameter $^-$. This assumption allows us to get a closed form expression for the wage index of immigrants as in equation 7:[10]

$$W_{x;j} = w_x \underbrace{\frac{1}{-\frac{}{1}} \quad \frac{}{}}_{z} \quad ^{\frac{1}{1}} n_j^{\overbrace{\frac{1}{}\ \frac{}{1}}} \tag{7}$$

where > 0 can be interpreted as the elasticity of the immigrant unit cost to expanding the mass of countries the firm hires from. Intuitively, imperfect substitution of immigrants generates productivity gains from hiring immigrants from additional origins. This reduces the wage index of immigrants and the unit cost of production.

Pricing Decision:

For a given domestic share (and unit cost of production), firms choose the price that maximizes variable profits. Given that consumers have CES preferences, the optimal price is a constant markup over the marginal cost:

$$p_j = \frac{}{1} u_j \tag{8}$$

where p_j is the price charged in the domestic market.

Optimal Domestic Share:

An advantage of this setup is that we can write the unit cost u_j, price p_j, and the optimal mass of countries n_j as a function of the key object $s_{d;j}$, as in equations 9 and 10:

$$p_j = \frac{}{1} \underbrace{w_d^1 \, s_{d;j}^{\ 1}}_{u_j} \tag{9}$$

$$s_{d;j} = \frac{w_d^1}{w_d^1 + (1 \quad) \, w_x^1 \quad (\bar{z})^1 \quad n_j^{(\quad 1)}} \quad ! \quad n(s_{d;j}) = {}^- \quad \frac{1}{s_{d;j}} \quad 1^{\frac{1}{(\quad 1)}} \tag{10}$$

where $^-$ is a combination of parameters and wages w_d, w_x. Equation 9 follows from equation 4 and the consumer's optimization problem. Equation 10 follows from equations 4, 5, and 7.

Firms maximize their profits by choosing the optimal native share $s_{d;j}$, as shown in equation 11:

[10] The specific implementation of these assumptions can be found in Appendix C.

$$\max_{s_{dj}} \Pi_j = \underbrace{(p_j(s_{d;j}) - u_j(s_{d;j}))\,y_j}_{\text{profits}} - \underbrace{n_j(s_{d;j})\,f_j w_d - w_d f_{imm}\,\mathbb{I}(n_j(s_{d;j}) > 0)}_{\text{Sourcing cost}} \tag{11}$$

The main takeaways of the model are as follows: firms benefit from an immigration inflow because the wage of immigrants drops and so does the unit cost of production. The size of the drop in the unit cost of production is firm-specific, and it depends on the firm's domestic share. In other words, the domestic share acts as a firm-exposure to a common immigration shock and becomes the key empirical object to learn about how much each firm (and the economy as a whole) benefits from immigration. The native share $s_{d;j}$ can be directly observed in our firm-level data and is the fundamental link between the model and the data.

How do firms choose their optimal domestic share? They face a trade-off between the drop in the marginal cost of production induced by complementarity of hiring from an additional country and the fixed cost to source from that additional country. Given their scale of production, larger firms earn higher profits and can afford paying f_j more times than small firms. Thus, larger firms hire immigrants from more countries than small firms, and they become more immigrant-intensive.

Export Decision and the Rest of the World (RoW):

Consumers in the RoW are assumed to have identical preferences over local and German varieties as in equation 2 with elasticity of demand σ_x.

German firms in the tradable sector can decide to export their goods by paying a fixed cost f_x, as in Melitz (2003). Therefore, a firm will choose to export if the variable profits from export sales are larger than f_x. The exporters choose the price to charge abroad to maximize export profits. The optimal price in that market is again a constant markup over total marginal cost, which now includes an iceberg cost $\tau > 1$ that represents a fraction of the good that gets "lost" in transit as in equation 12:

$$p_j^x = \frac{\sigma_x}{\sigma_x - 1} \tau u_j \tag{12}$$

Finally, conditional on its export decision, the firm chooses $s_{d;j}$ by solving a problem analogous to 11.[11]

Since our focus is the German economy, we make several simplifications to the modeling of the RoW. We assume it has a single tradable sector, foreign firms are equally productive, and use only domestic labor to produce with a constant return to scale production function $y_j^x = \bar{\varphi}^x d_j^x$.

[11]The model predicts that firms that hire immigrants are more likely to export, which provides a micro foundation for the empirical literature looking at the relationship between exports and immigration (Bonadio, 2020; Cardoso and Ramanarayanan, 2019; Gould, 1994; Hiller, 2013).

Foreign firms also pay the iceberg trade costs to export their goods but do not have to pay a fixed cost to export.

Labor Supply:

Consumers are either firm owners, whose income are firms' profits, or workers who earn wages. We treat workers as heterogeneous in their sectorial skills by combining tools from the Eaton and Kortum (2002) model of trade and the Roy (1951) model of occupational selection. Specifically, we assume that each country $o = \{g; x\}$ has an exogenous number of workers born in o (N_o). Each worker i from o draws a sector k, location ℓ specific ability ($\epsilon^{o}_{i;\ell;k}$) from a Frechet distribution with shape parameter $\theta > 1$, and scale parameter $A_{o;k}$ as in equation 13:

$$F(\epsilon) = exp\left(-\sum_{k} A_{o;k}(\epsilon)^{-\theta}\right) \tag{13}$$

where $A_{o;k}$ can be interpreted as the comparative advantage of workers from o in industry k. Workers within a country are ex-ante identical but ex-post heterogeneous due to different ability draws across sectors, while workers from different countries also differ in that they draw their abilities from different distributions. Workers choose the industry and country that yield the highest utility as shown in equation 14:

$$U^{o}_{i;\ell;k} = \frac{w_{\ell;k}\,\epsilon^{o}_{i;\ell;k}}{P_{\ell}}\,\tau^{-1}_{o;\ell;k} \tag{14}$$

where $\frac{w_{\ell;k}\,\epsilon^{o}_{i;\ell;k}}{P_{\ell}}$ is the real wage, and $\tau_{k;o;\ell}$ are iceberg frictions for workers from country o to work in industry k and country ℓ. The iceberg cost captures both the cost of working in a given sector and the migration cost of moving. For example, if Germany is very restrictive in letting migrants into the country, $\tau_{k;o=x;\ell=g}$ will be very high. For simplicity, we will assume the cost of migration out of Germany is infinity, such that German workers are immobile across countries. Following the properties of the Frechet distribution, the fraction of workers from country o who choose to work in industry k in destination location ℓ can be expressed as in equation 15:

$$\pi_{o;k;\ell} = \frac{A_{o;k}\left(\frac{w_{\ell;k}}{P_{\ell}}\,\tau^{-1}_{o;\ell;k}\right)^{\theta}}{\sum_{\ell;k} A_{o;k}\left(\frac{w_{\ell;k}}{P_{\ell}}\,\tau^{-1}_{o;\ell;k}\right)^{\theta}} \tag{15}$$

This expression shows that reducing migration costs from any o to Germany increases the supply of immigrants into the country.

Equilibrium and Market Clearing:

The equilibrium in this model can be defined as a set of prices, wages, and labor allocations such that: Workers optimally choose the industry and destination country ℓ, k to work for, consumers in each location choose how much of each variety to purchase to maximize utility, firms choose the sourcing strategy and export status to maximize profits, labor markets clear, and trade is balanced. Appendix C includes the main equilibrium conditions.

4.1 Firm Heterogeneity and Welfare Gains

In this section, we show that ignoring heterogeneity in the immigrant share across firms may lead to biased estimates of the welfare gains of immigration. To that end, we compare the analytical welfare gains of a simplified version of our fully heterogeneous model with that of a model that ignores heterogeneity in immigrant share (but allows for heterogeneity in innate productivity).[12] We will refer to these models as the "heterogeneous model" and the "homogeneous model," respectively. The homogeneous model can be a special case of the heterogeneous model with $f_{imm} = f_j = 0$, or any model in the class of heterogeneous and homogeneous models following the Arkolakis et al. (2012) framework. Alternatively, it could be a model with CES preferences over goods coupled with the canonical production framework of immigration, with constant elasticity of substitution between immigrants and natives (Card, 2009; Dustmann and Glitz, 2015; Ottaviano and Peri, 2012; Peri and Sparber, 2009).

To simplify the model, we focus on a closed economy with one sector. We assume that native workers are homogeneous and set $f_{imm} = 0$, but leave the firm-specific fixed cost f_j unrestricted. In this model, the welfare gains of immigration are given by the increase in real wages $\frac{w_d}{P}$ as shown in equation 16:

$$dlog \frac{w_d}{P} = \frac{\sum_j \omega_j dlog(s_{dj})}{1} = \underbrace{\frac{dlog(S^{agg})}{1}}_{\text{Prediction without heterogeneity in } s_{dj}} \frac{1}{1 + (\quad) \underbrace{\Gamma(\{s_{dj}; \omega_j\})}_{0}} \tag{16}$$

where ω_j is the market share of firm j (ω_j $\frac{p_j y_j}{\int p_j y_j dj}$) and measures firm j's weight in the consumption basket, S^{agg} stands for the immigrant share in the total wage bill in the economy, while Γ is a function that depends on the joint distribution of firm-level market shares (ω_j) and native shares (s_{dj}).

The first component of expression 16 coincides with the welfare prediction of models that ignore heterogeneity in s_{dj}. In these models, immigration reduces the unit cost of production for all firms and, as firms become more competitive, they increase their scale of production, demand for native labor, and wages. The size of these gains depends on the size of the inflow and on as it regulates how substitutable immigrants and natives are in the labor market. The more substitutable immigrants and natives are, the lower the productivity gains for firms, and the

[12] All derivations are included in Appendix D.

lower the welfare gains for natives.

The welfare predictions of the homogeneous model may be biased if there is heterogeneity in the presence of immigrants across firms. Under heterogeneity, a new adjustment mechanism arises, because native workers reallocate across firms with different immigrant intensities. Such reallocation has two main implications. First, when firms are heterogeneous, the aggregate elasticity of substitution between immigrants and natives depends on the within-firm elasticity ( ) and the elasticity of substitution across firms or goods ( ). Thus, having different immigrant-intensities across firms allows natives to specialize in working for specific employers, which can make them more or less substitutable with immigrants in the aggregate labor market. Second, there is a complementarity between firm efficiency and the firm-specific endogenous productivity gains from immigration. As these gains are largely concentrated among the largest and most productive employers, there is an additional aggregate productivity gain that is not present in the homogeneous model. Hence, even if we estimate the homogeneous model with the same aggregate elasticity than the one predicted by the heterogeneous model, there can still be first-order differences between their welfare predictions.

When firms are heterogeneous in their immigrant share, the ***aggregate*** elasticity of substitution between immigrants and natives (^{agg}) is a weighted average between the elasticity of substitution within the firm ( ) and the elasticity of demand or elasticity across firms ( ):

$$^{agg} = (1 \quad) \quad + \tag{17}$$

where , and hence ^{agg}, depend on the distribution of s_{dj}. The weight is proportional to the cost-weighted variance of immigrant shares and lies between zero and one (see Oberfield and Raval (2021) for a derivation), taking the value of zero if firms employ the same immigrant share. The first term, (1) , measures the substitution effect within firms; whereas the second term, , measures a reallocation effect across firms with different immigrant-intensities.

In the edge case of $=$, the substitution and scale effects cancel out, immigrants do not crowd-in or crowd-out native workers, and native employment at the firm level does not change.[13] Given that the reallocation of natives across firms is muted, the demand response for native labor and welfare gains are the same as those predicted by the homogeneous model.

When the elasticity of substitution within the firm is stronger than the elasticity of demand ($>$), immigrants crowd-out natives from immigrant-intensive firms, and natives are reallocated towards native-intensive firms. Such increase in specialization between natives and immigrants in producing different varieties makes them less substitutable in the labor market than when

[13]The relative change in employment of natives across firms is proportional to the change in immigrant share. Let $\tilde{x}$ $dlog(x)$, then $\tilde{d}_j$ $\tilde{d}_{j'} = \frac{}{1}$ $\tilde{s}_{dj}$ $\tilde{s}_{dj'}$ and, to a first order approximation, $\tilde{s}_{dj}$ (1)(1 s_{dj})($\tilde{w}_{imm}$ $\tilde{w}_d$). Thus, the drop in relative wage of immigrants induced by an immigration inflow reallocates natives toward native-intensive firms if $>$ and toward immigrant-intensive firms if $<$.

natives do not reallocate across firms. Given that this reallocation adjustment is absent if firms employ the same immigrant share, the increase in both, the aggregate demand for natives and welfare are larger in the heterogeneous world.

When the elasticity of substitution is weaker than the elasticity of demand ($<$), the opposite happens. Immigrants crowd-in natives toward immigrant-intensive firms, and this reallocation pattern increases the concentration of immigrants and natives in producing a similar set of varieties. As a result, immigrants and natives become more substitutable in the labor market when compared to the homogeneous world, and the increase in real wages and welfare are lower.

Overall, equation 16 shows that the sign of the bias depends on the race between and . In Section 5, we estimate these elasticities and find that $\hat{} > \hat{}$, suggesting that welfare gains predicted by the homogeneous model are downward biased. Equation 16 also shows that the size of the bias depends not only on these two elasticities, but also on the joint distribution of firm size and immigrant share through $\Gamma(\{s_{dj}, \omega_j\})$. We estimate our model to match moments on the joint distribution of s_{dj} and ω_j and find that the homogeneous model underestimates welfare by 11%.[14]

As noted by Arkolakis et al. (2012), there is a class of heterogeneous and homogeneous models where, if calibrated to the same aggregate elasticity and change in aggregate share, would yield the same welfare gains. In our case, however, we would still expect a bias even if we assign the same aggregate elasticity to both models. The reason is that the endogenous productivity gains generated by firms choosing their s_{dj} are stronger for larger and more productive firms, an adjustment channel that is absent in the homogeneous model. Intuitively, conditioning on $\{s_{dj}\}$, ^{agg} is independent from ω_j, meaning that ^{agg} is not informed by *which* firm benefits by how much (e.g., the joint distribution of $\{s_{dj}, \omega_j\}$). Consequently, ^{agg} will not capture the first-order heterogeneous response and resulting reallocation of natives across firms that arises when firms are heterogeneous.

The discussion on whether the fully heterogeneous firm model provides new welfare implications of immigration has similarities and differences with the discussion offered by Melitz and Redding (2015) about the welfare implications of trade. Similar to their paper, our heterogeneous model differs from the homogeneous model in that the elasticity (of substitution) is endogenous, and the homogeneous model does not capture the extra adjustment mechanism that arises when we allow for heterogeneity. However, opposite of their paper, the differences in welfare predictions in our setup are of first-order importance and do not vanish for small immigration

[14] Additionally, equation 16 shows that the size of immigration shock does not affect the size of the bias, which we also corroborate quantitatively in Appendix G.3.

inflows.[15]

5 Estimation

As discussed in Section 4.1, the key parameters of the model are , , and parameters that determine the joint distribution of firm productivities and fixed costs to hire immigrants. In this section, we explain how we use the German administrative data to estimate these key parameters of the model.

Elasticity of Demand

We use micro-data to identify the elasticity of demand that firms face. Following Oberfield and Raval (2014), we infer the demand elasticity from firms' markups, i.e., the ratio of revenue to total costs. According to the model, the following condition holds for every firm j:

$$\frac{Revenue_j}{Cost_j} = \frac{\quad}{\quad 1}$$

where $Revenue_j$ stands for the revenues of firm j, and $Cost_j$ denotes production costs. Although the model assumes that the only production costs are labor costs, we compute total cost as the sum of wage bill and material bill. The average markup is 1.4 which implies that the elasticity of demand is 3.08. This estimate is consistent with the values used in the literature, where this parameter takes values between 3 and 4.

We use data on markups for exporters relative to non-exporters in the tradable sector to back out the implied demand elasticity from the RoW. The observed markup for exporters can be expressed as a weighted average between the domestic markup (depending on) and the export markup (depending on $_x$). Using the exports as a share of revenues as weights, we calibrate $_x = 3.62$.[16]

Elasticity of Substitution Between Native Workers and Immigrants

In the model, firm j's demand of immigrant labor relative to native labor is given by (18):

$$ln\left(\frac{w_j^d}{w_j^x}\right) = ln\left(\frac{k}{1 \quad k}\right) \quad \frac{1}{\ } ln\left(\frac{d_j}{x_j}\right) \tag{18}$$

[15] In Section 7.2, we show quantitatively that the welfare prediction of the homogeneous model with the aggregate elasticity generated by the heterogeneous model reduces, but does not eliminate the bias. Such bias remains large even for inflows of immigrants as small as 0.1%.

[16] More specifically, we use the following equation: markup exporters $=$ share exports $\frac{_x}{_x \ 1}$ $+$ (1 share exports) $\frac{\quad}{\ 1}$. As we observe the markup for exporters and export share in the data, we can back out $_x$ using our estimated value of .

where w_j^d is the effective wage paid by firm j to native workers, and d_j is native employment in effective units, w_j^x is the effective wage paid for the immigrant labor bundle, and x_j is the composite immigrant labor defined by 6.

Estimating equation (18) presents a number of challenges. First, effective wages and quantities are not observed directly in the data. Second, estimating equation (18) by OLS would yield biased estimates of , since unobserved demand shocks at the firm level can affect the relative quantities of immigrants and natives and the wages firms pay to each labor type.

To address these challenges, we proceed sequentially. First, as we explain in Appendix E.2, we use the structure of the model to estimate the immigrant composite x_j based on observed data on labor quantities and wages across origin countries and industries. Second, we propose an instrument to structurally estimate from equation (18).

To summarize our empirical strategy, we construct a shift-share instrument that exploits immigrant networks to create a supply push at the local labor market level that is plausibly independent from demand shocks at the firm level. We bootstrap the standard errors to account for using generated regressors. The first stage is strong with an F-stat above 20, and our preferred estimate for is 4.28, which is close to the estimates of Burstein et al. (2020), who find an elasticity of substitution between immigrants and natives within occupations of 5. Appendix E.2 describes the dataset construction, instruments, and results in detail.

Additional Parameters

Given the estimates for the elasticity of demand and the elasticity of substitution between immigrants and native workers, we calibrate the parameters of the model by simulated method of moments to match micro- and macro-level moments. This approach serves as a bridge between aggregate data on trade and immigration and what we have learned about firm heterogeneity from the firm-level data.

As a first step, we proceed to do some normalizations, since not all parameters can be separately identified. The mean fixed costs of hiring immigrants ($_{f;k}$), the mean productivity of immigrants ($A_{o;k}$), and the migration cost ($_{o;`;k}$) cannot be separately identified from the immigrant share in the production function ($_{k}$), so we normalize the first one to 0 and the remaining two to 1. We assume the mean productivities in each sector are equal to 1 ($_{;k} = 1$) and set the elasticity of labor supply $= 6{:}17$ following Morales (2019). Finally, we calibrate the Cobb Douglas parameter $= 0{:}68$ to match the domestic expenditures in the tradable and non-tradable sectors using World Input-Output Tables (WIOT).

As a second step, we are left with fourteen parameters, which we jointly estimate using a SMM approach by minimizing the distance between fourteen moments simulated by the model and fourteen empirical moments computed from the data. While all parameters are estimated together, there is strong intuition regarding which parameters identify which moments. The variance of log revenues conditional on the immigrant share and exporter status is used to identify the dispersion parameter on productivities $_{;k}$. The observed variance of the immigrant-share relative to the domestic share identifies the variability of fixed costs $_{f;k}$, while the difference in the mean of $s_{d;j}$ between firms in percentile 90 relative to percentile 50 are used to identify the correlation between productivities and hiring costs $_{;f;k}$. These three parameters for each sector estimate the joint distribution between size and immigrant intensity, a key ingredient for the quantitative model.

For the remaining parameters, we use the aggregate immigrant share by sector to identify $_{k}$, the distributional share parameter in the production function. The fraction of firms that hire immigrants helps identify the base fixed hiring costs $f_{imm;k}$. The average immigrant share across all firms and sectors is used to identify , the elasticity on how the immigrant cost changes with the mass of countries the firm hires from. For trade moments, we match the mean ratio of export to domestic revenues for exporters to identify the iceberg cost and the fraction of firms that export in the tradable sector to match the fixed cost of exporting f_x. Finally, we use aggregate data to compute the relative GDP per capita between Germany and the RoW, which helps identify the mean productivity of the RoW $\bar{\ }^{x}$.

Table 1 shows the fourteen moments that are targeted in the estimation, their observed values in the data and the ones generated by the model. For all fourteen moments, the model does a good job in approximating their observed values. Table 2 contains the final calibration of the fourteen parameters that minimize the distance between simulated and empirical moments.

While the model matches the targeted moments, we want to make sure it also matches non-targeted moments that are relevant to our main mechanisms. As shown in Appendix E.2, the model does a good job in matching the cross-sectional means and medians of the immigrant share by size decile.

Table 1: Simulated vs data moments

Moment description	Simulated	Data	Moment description	Simulated	Data
Aggregate $s_{d;T}$	0.91	0.91	$E(s_{d;NT;p90}) \quad E(s_{d;NT;p50})$	0.009	0.008
Aggregate $s_{d;NT}$	0.93	0.93	Share of firms hiring immigrants, T	0.57	0.62
$Var(log(rev_j)js_{d;j};exporter_j)$, T	1.38	1.38	Share of firms hiring immigrants, NT	0.63	0.61
$Var(log(rev_j)js_{d;j})$, NT	1.23	1.29	GDP per capita RoW to Germany	0.32	0.32
$Var((1 \quad s_{d;T})=s_{d;T})$	1.36	1.39	Share of firms exporting, T	0.34	0.37
$Var((1 \quad s_{d;NT})=s_{d;NT})$	1.48	1.58	E(Export to Domestic Rev$_j$), T	0.80	0.79
$E(s_{d;T;p90}) \quad E(s_{d;T;p50})$	0.015	0.021	$E(s_d)$	0.93	0.93

Table 2: Parameter estimates using Simulated Method of Moments

Parameter description	Parameter	Estimate	Parameter description	Parameter	Estimate
Share of natives, T	${}_T$	0.84	Covariance of and f_j, NT	${}_{;f;NT}$	8.17
Share of natives, NT	${}_{NT}$	0.86	Fixed cost of immigrants, T	$f_{imm;T}$	3.41E-04
Dispersion in ${}_j$, T	${}_{;T}$	1.02	Fixed cost of immigrants, NT	$f_{imm;NT}$	9.66E-04
Dispersion in ${}_j$, NT	${}_{;NT}$	0.35	Productivity in RoW	${}_x$	1.52
Dispersion in f_j, T	${}_{f;T}$	1048	Fixed cost of exporting	f_g	0.011
Dispersion in f_j, NT	${}_{f;NT}$	1710	Iceberg trade cost		1.49
Covariance of and f_j, T	${}_{;f;T}$	-2.65	Elasticity s_d to n		0.013

6 Model Validation: Heterogeneous Response

Before quantifying the aggregate implications of a change in the number of immigrants in Germany, we evaluate whether the data validates the main mechanisms proposed by the model. First, the model predicts that large firms, who are more immigrant-intensive than small firms, will experience a larger increase in terms of revenues. Second, given that $\hat{} > \hat{}$, larger firms will increase their immigrant share relative to smaller firms. Such heterogeneity in the response to immigration is expected to be larger in the tradable sector, where the relationship between size and immigrant intensity is stronger.

We begin by estimating a regression as shown in equation 19:

$$ln(y_{j;m;k;t}) = {}_1 S^{agg}_{m;t} + {}_2 S^{agg}_{m;t} \, log(emp_{j;t \ 1}) + {}_3 X_{j;t} + {}_j + {}_{k;t} + {}_m t + {}_{j;m;k;t} \qquad (19)$$

where $y_{j;m;k;t}$ is an establishment-level outcome such as sales, for establishment j located in labor market m, industry k, in year t. The regressor $S^{agg}_{m;t}$ is the share of immigrants in the total wage bill of labor market m in year t, $emp_{j;t \ 1}$ is establishment size measured by employment, and $X_{j;t}$ are establishment-level control variables. This model allows for labor markets to be in different linear trends as captured by ${}_m t$. It also includes industry-time fixed effects to control for factors affecting all establishments in an industry over time and an establishment fixed effect to control for unobservable characteristics that are time-invariant.

We define the immigrant shock $S^{agg}_{m;t}$ at the local labor market level as we aim to understand how different establishments adjust within a labor market whenever there is an immigration influx. The key parameter of interest is ${}_2$: if positive, it implies that a rise in the share of immigrants in a labor market promotes faster growth for larger establishments compared to smaller ones in the same market. Thus, ${}_2 > 0$ will suggest that larger establishments respond more to immigration than small establishments.

Even though the fixed effects and controls included in the empirical specification aim to capture unobservable shocks and establishment heterogeneity, ordinary least squares (OLS) estimates will be upward biased if, for example, productivity shocks at the local labor market level improve establishment outcomes and attract migration inflows into the region. To address these endogeneity concerns, we follow an IV approach inspired by Card (2001) and Ottaviano et al. (2018), and define a shift-share instrument as shown in equation 20:

$$Z_{m;t} = \sum_{o} \frac{\text{Wage Bill}_{o;m;2003}}{\text{Wage Bill}_{m;2003}} \frac{1 + {}^{GER}_{o;t}}{1 + {}^{GER}_{t}} \tag{20}$$

where Wage $\text{Bill}_{o;m;2003}$ is the wage bill earned by immigrants from origin country o in labor market m in our initial year 2003. Wage $\text{Bill}_{m;2003}$ is the total wage bill spent across all foreign origin countries in 2003 ($\sum_{o}$ Wage $\text{Bill}_{o;m;2003}$). The initial share is interacted with a time-shifter that captures the national growth rate, from 2003 to year t, of immigrants from origin o relative to the working-age population growth in Germany. Thus, this shift-share instrument interacts country-specific flows of migration with their initial differential presence in local labor markets in Germany. The validity of this instrument relies on the assumption that the geographic distribution of immigrants by origin in 2003 is not correlated with local economic conditions in any year t once we control for fixed effects that capture unobservable differences across establishments, industries, and local labor markets. The interaction term is instrumented by $Z_{mt}\ log(emp_{j;2003})$.

For the sake of the economic interpretation of the effect of an immigration shock, we compute the elasticity or semi-elasticity of $y_{j;m;k;t}$ to $S^{agg}_{m;t}$, denoted as ${}^{y}_{j;m;k;t}$, as follows:

$${}^{y}_{j;m;k;t} \quad {}_{1} + {}_{2}\ log(emp_{j;t\ 1})\ \ S^{agg}_{m;t} \tag{21}$$

when the outcome variable of the regression is $log(y)$, ${}^{y}_{j;m;k;t}$ equals the elasticity of y, and when the regression outcome variable is y, it equals the semi-elasticity.[17] The elasticity of firm j's outcome $y_{j;m;k;t}$ to an immigration shock depends on both its size and the share of immigrants in the labor market where it operates.

6.1 Results

We present the estimates of equation 19 using total revenues and the ratio of immigrant to native wage bill as the outcome variable to show that larger firms expand more and become more immigrant-intensive in response to an immigration shock.

Table 3 presents estimates for total revenues for the full sample in columns 1 to 3 and separately for the tradable and non-tradable sectors in columns 4 and 5. Columns 6 to 8 present results

[17] Specifically, equals $\frac{@y_{j;m;k;t}}{@S^{agg}_{m;t}} \frac{S^{agg}_{m;t}}{y_{j;m;k;t}}$ and $\frac{@y_{j;m;k;t}}{@S^{agg}_{m;t}} S^{agg}_{m;t}$, respectively.

using the immigrant to native wage bill ratio as the outcome. The OLS estimate in column 1 shows that, on average, establishments in local labor markets with larger increases in the share of immigrants register larger revenue growth. Column 2 shows that the 2SLS estimate is lower than the OLS estimate consistent with the hypothesis that OLS estimates are upward biased.[18] The 2SLS estimate suggests that immigration into a local labor market has no statistically significant impact on establishments' revenues. However, the average effect masks significant heterogeneity, uncovered in column 3. After accounting for the heterogeneous effect across establishment sizes, the average effect is negative and strong. That is, an increase in the share of immigrants in the labor market shrinks firms' revenues on average, and increases the revenue of large establishments relative to small establishments. The implied threshold size of the establishment, above which the elasticity is positive, is 71 employees.

Columns 4 and 5 show that the heterogeneity in size is driven primarily by establishments in the tradable sector, where large establishments grow their revenues significantly more than small establishments. Establishments in the non-tradable sector do not seem to differentially respond to the immigration shock, consistent with the patterns in Figure 3, where establishments in the non-tradable sector presented a low correlation between immigrant share and size.

Columns 6 to 8 show the the 2SLS estimates for the firm-level ratio between immigrant and native wage bill. Column 6 suggests that immigration into a local labor market has no impact on the immigrant intensity of establishments, but once again, this result masks significant heterogeneity across sectors. Column 7 shows that large firms in the tradable sector increase their immigrant-intensity relative to small firms: firms with more than 33 employees increase their immigrant-intensity, while smaller firms become more native-intensive. However, Column 8 shows that this heterogeneous effect across firm size is absent in the non-tradable sector, as expected based on the relatively flat relationship between firm size and the immigrant-share shown in Figure 3.

Table 4 presents the results in terms of elasticities by firm size and sector, which will be used to compare the elasticities implied by our quantitative model. In the tradable sector, a 1% increase in the immigrant share decreases establishments' revenues in the lowest size decile by 0.42% while increasing establishments' revenues in the highest decile by 2.16%. The elasticity of revenues in the non-tradable sector, on the other hand, seems to be similar across establishments of different size.

We find a similar pattern in each sector when looking at the response of the relative wage bill between immigrants and natives across size deciles. In the tradeable sector, a 1% increase in the share of immigrants in the labor market would increase the ratio of an establishment in the lowest decile by 0.01 while increasing the ratio for an establishment in the highest decile by 0.21. The elasticities across deciles in the non-tradable sector seem to be decreasing with

[18] First stages can be found in Appendix Table 16.

size but are not statistically significant.

Table 3: Heterogeneous benefits of immigration

	Log of Revenues					Immigrant-Native Wage Bill		
Sector	All	All	All	Tradable	Non-Tradable	All	Tradable	Non-Tradable
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	5.83***	2.99	-31.86***	-57.56***	6.81	0.2	-3.13*	6.14
	(1.98)	(3.29)	(11.47)	(16.95)	(17.78)	(1.7)	(1.72)	(4.12)
2			7.49***	13.28***	-0.44	0.18	0.9**	-1.07
			(2.46)	(3.66)	(3.48)	(0.36)	(0.43)	(0.78)
Average ^{y}			0.28	0.54	0.26	0.06	0.08	0.05
N observations	3507	3507	3507	1974	1533	3507	1974	1533
N establishments	949	949	949	532	417	949	532	417
Estimation	OLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
1st stage F-stat		372.23	35.85	29.47	15.53	35.85	29.47	15.53

Note. $= p < 0.01$; $= p < 0.05$; $= p < 0.1$. We restrict the sample to years between 2008 and 2011. We control for establishment fixed effects, 2-digit industry-time fixed effects, local labor market time trends, and lagged firm level controls such as log employment and investment. Standard errors are clustered at the establishment level. Sample is restricted to establishments with more than 30 employees.

Table 4: Response to immigration by firm size

	Size deciles									
Tradeable	1	2	3	4	5	6	7	8	9	10
Revenues	-0.42	-0.28	-0.06	0.03	0.2	0.41	0.57	0.81	1.41	2.16
Relative Immigrant WB	0.01	0.02	0.03	0.05	0.07	0.08	0.1	0.11	0.16	0.21
Non-Tradeable	1	2	3	4	5	6	7	8	9	10
Revenues	0.25	0.23	0.24	0.13	0.22	0.22	0.21	0.21	0.2	0.27
Relative Immigrant WB	0.14	0.11	0.1	0.08	0.07	0.06	0.04	0.03	0	-0.06

Note. We rank establishments in terms of employment and for each decile, compute the mean elasticity of revenues and semi-elasticity of spending in immigrants relative to natives in response to a 1 percent change in the local labor market immigrant share. We compute the average of 21 for each decile using the same sample as in Table 3.

In Appendix F, we also show that export revenues are more elastic than domestic revenues, as predicted by the model. These estimates imply that for every 1% increase in the immigrant share of the labor market, domestic revenues increase by 0.44%, whereas export revenues increase by 1.15%. Since the response of export revenues is stronger than domestic revenues, this channel can explain part of the heterogeneous effects found in Table 3. Large establishments, which are more likely to be exporters, may adjust more to the immigration shock because they are able to expand their export revenues, whereas for small firms, expansion is constrained by the size of the domestic market.

Appendix F also shows alternative specifications of equation 19, where we remove the industry-time fixed effects, the local labor market time trends, and the firm controls. Overall, the qualitative implications of our results hold under the alternative specifications. We also run a set of specification tests to verify the validity of our instrument following the recent literature on shift-share instruments as suggested by Goldsmith-Pinkham et al. (2020) and Borusyak et al. (2021), among others. We find no evidence of pre-trends, and other labor market characteristics drive little variation in the initial shares used to construct the shift-share instrument.

6.2 Predicted Treatment Effects: Data vs. Model

As a final step, we assess whether our model can generate counterfactual predictions that match the observed heterogeneous treatment effects across employer sizes estimated in Table 4. This is a key validation of the model as the reduced form estimates in this section have not been targeted at all for the estimation of the model. First, we use our estimated model to compute, for each firm, the revenue and relative wage bill elasticities in response to a 1% change in the immigrant share in each sector. Then, we divide the firms in the model into size deciles and calculate the mean elasticity for each decile.[19] Second, we take the estimated elasticities by decile from Table 4 and compare them to the estimated elasticities in the model.

As shown in Figure 4, the model does a good job in replicating the relative treatment effects from our empirical exercise. The changes in the tradable sector predicted by the model replicate the revenue responses in the data almost exactly until decile seven and predict a more conservative response to immigration for firms in the highest three deciles. For the non-tradable sector, the model does a good job in replicating the treatment effects in the data across deciles, where establishments of different sizes do not respond differently to the immigration shock. The model also captures that large firms become more immigrant-intensive than small firms, particularly in the tradable sector.[20]

7 Aggregate implications

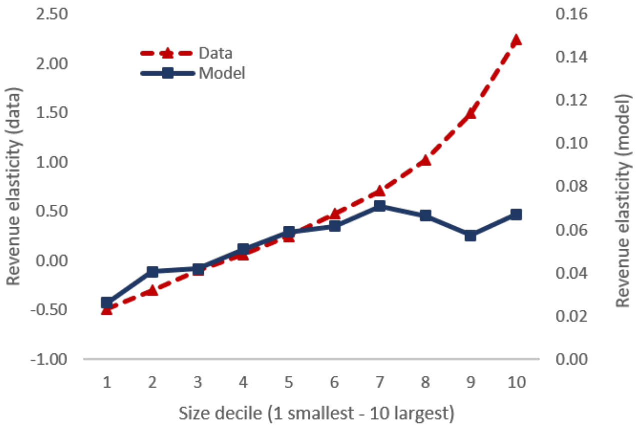
We proceed to quantify the economic and welfare consequences of an inflow of immigrants into Germany. Section 7.1 evaluates the main forces shaping the adjustment of the economy to the immigration shock. Section 7.2 quantifies the bias in the estimated welfare gains for native workers when using a model that does not capture the observed heterogeneity in the

[19] Similar to the counterfactual discussed in Section 7, we lower migration costs to each sector such that the total number of immigrants in Germany increases by 1%.

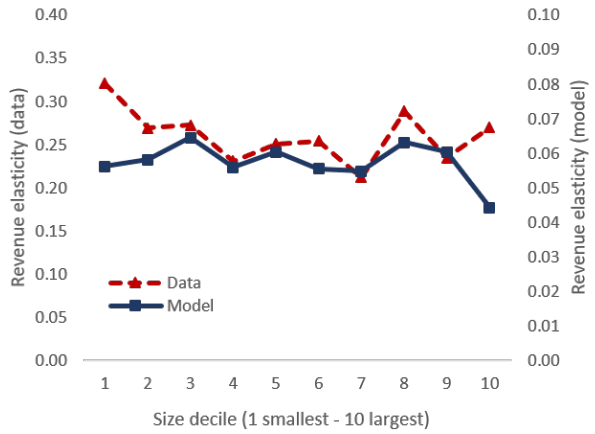
[20] The model-generated elasticities include general equilibrium changes in prices and quantities due to immigration, while in the data, we control for aggregate changes through industry-time fixed effects and local labor market trends. Given this discrepancy, we should not expect the *levels* of the elasticities to necessarily match between model and data. Instead, the key object to compare when judging whether the model can replicate the heterogeneous responses observed in the data is the *relative* elasticity across size deciles.

Figure 4: Predicted treatment effects: Model vs data

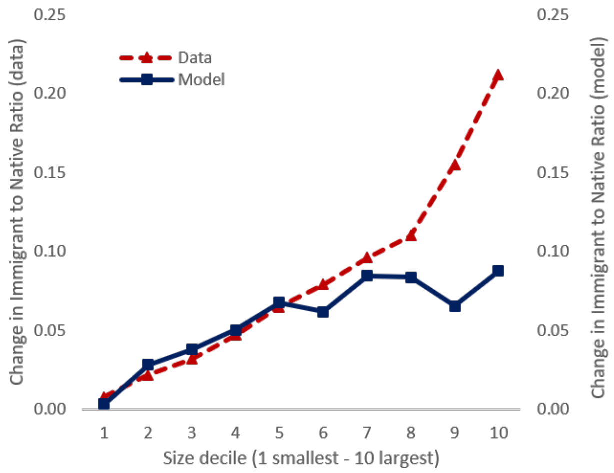
(a) Revenues - Tradable sector



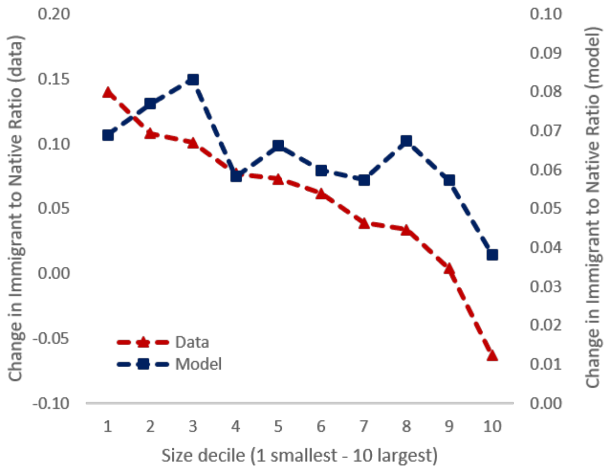
(b) Revenues - Non-Tradable sector



(c) Relative Wage Bill - Tradable sector



(d) Relative Wage Bill - Non-Tradable sector



Note. For the model, we rank establishments in terms of revenues into 10 deciles, with decile 1 being the establishments with lowest revenues. In the top two panels, we compute the elasticity of revenues to a 1% increase in the immigrant share and calculate the mean elasticity for firms in each decile. For the data, we use the sector-specific elasticities by size decile presented in Table 4. In the bottom two panels, we calculate, for each establishment, the change in the ratio between the wage bill of immigrants and the wage bill of natives in response to a 1% change in the immigrant share. We then compute the average for each size decile in both the data and the model.

immigrant share across firms. Finally, Section 7.3 discusses the role of trade for our quantitative results.

7.1 Quantitative Exercise

The economic adjustment to the immigration shock takes the form of equilibrium changes in prices, wages, welfare, and the reallocation of workers across sectors and firms. The size of the shock mimics the magnitude of the immigration wave that occurred in Germany between 2011 and 2017. According to the OECD, the total number of immigrants in Germany went from 10.55 million in 2011 to 12.74 million in 2017, a 20.7% increase. While our data ends in 2011, we can use the model to calculate the new equilibrium when the total number of immigrants in Germany increases exogenously by 20%. To do so, we change the migration cost from the RoW to Germany, $_{k;x;g}$, such that it increases the total stock of immigrants by 20%.[21] For our quantitative results, we set the numeraire to be the wage in the RoW, w_x.

We define welfare of natives, denoted by W_g, as their real labor income:

$$W_g = \frac{\sum_k (L_{g;k} w_{g;k})/N_g}{P_g} \tag{22}$$

As shown in Table 5, the welfare of native workers would increase by 0.24%, which represents \$113 per native worker every year or \$4 billion for the aggregate economy. Such welfare gains are mainly explained by the drop in the cost of the consumption basket: 70% of the gains can be explained by the drop in the price index, while only 30% is explained by the increase in per capita labor income. The decrease in the price index is mainly driven by the tradable sector because its price index drops more strongly than the non-tradable sector, and because it accounts for a larger share of the consumption basket of Germans (almost 70%). Welfare also increases because wages are higher due to immigration, as the increase in the scale of production and associated demand for native labor offsets the substitution effect between natives and immigrants.

The welfare gains of firm owners is significantly larger than for native workers because they experience the same price decreases but do not compete with immigrants in the labor market. Their real income from firm profits increase by 1.22% due to the drop in production costs and increase in profits induced by immigration, amounting to a gain of \$15 billion.

Table 6 narrows the analysis to the sector level and shows the sectoral effects on employment and wages in terms of labor units (i.e., number of workers) and effective units. The influx of immigrants decreases the relative wage between immigrants and natives, and both sectors become more immigrant-intensive. As they become more competitive, both sectors expand

[21] In Appendix G, we show our results for different changes in the stock of immigrants.

Table 5: Effect of immigration on welfare

	Real Income	Price Index	Nominal Income	Monetary Gains
Native Workers	0.24%	-0.17%	0.07%	$4B
Firm Owners	1.22%	-0.17%	1.04%	$15B

Note. We compute the changes on the key endogenous variables of going from the observed equilibrium to an equilibrium where the number of immigrants is 20% higher. Income refers to wages for workers and profits for firm owners. Monetary gains are computed using average wages PPP adjusted at 2019 dollars and total workforce numbers from the OECD. We use data from LIAB to separate the share of the wage bill by sector.

their production and total employment in terms of effective units. Employment of native workers decreases in the tradable sector as the least productive native workers are substituted by immigrants, and they reallocate to the non-tradable sector. This result differs from the well-known Rybczynski (1955) theorem, which predicts that production of the immigrant-intensive sector increases and production of the native-intensive sector decreases, so natives reallocate from the native-intensive sector to the immigrant-intensive sector. This theorem builds on the assumption that the domestic share of labor does not respond to an immigration shock, which does not hold in our setting. In our model, the domestic share decreases in both sectors but decreases more in the immigrant-intensive sector. Thus, even though output increases more in the immigrant-intensive sector than in the native-intensive sector, the immigrant-intensive sector does it by hiring more immigrants. Some of these immigrants replace less productive native workers, who are now reallocated to the native-intensive sector.

Wages per native worker increase in both sectors. In the tradable sector, this is due to selection as lower ability natives reallocate to the non-tradable sector, and those natives who stay in the tradable sector are, on average, of higher ability. In the non-tradable sector, there are two counteracting effects. On one hand, lower ability natives get in the sector decreasing average wages. On the other hand, the additional domestic demand created by the new immigrants increases demand for the sector pushing effective wages up. Overall, the latter effect dominates, and workers in both sector earn higher wages due to immigration.

The benefit of immigration for firms is large in the aggregate, but it masks significant heterogeneity for firms of different sizes in the tradable sector. From the top panel of Figure 5, three facts stand out. First, there is a large dispersion in the within-sector price responses and the initial exposure to the immigration shock, which can be a quantitatively important determinant of the aggregate results described before. Second, the cross-sectional differences in the initial exposure $(1 \quad s_{dj})$ go a long way in explaining differences in price responses (Figure 5a). Third, the exposure to the shock is significantly higher for larger firms (Figure 5b). Thus, the positive relationship between firm size and immigrant intensity, as observed in the data, drives the positive relationship between firm size and price decrease in the model. Larger firms, by virtue of being immigrant-intensive, are more exposed to the decrease in immigrant wage than smaller

Table 6: Effect of immigration on employment and wages

	Labor units		Effective units	
Employment	Tradable	Non-Tradable	Tradable	Non-Tradable
Total	2.49%	2.09%	4.49%	3.78%
Native	-0.11%	0.23%	-0.09%	0.20%
Immigrant	20.01%	20.01%	16.51%	16.51%
Wages				
Natives	0.07%	0.07%	0.05%	0.11%
Immigrants	-6.32%	-6.26%	-3.51%	-3.45%

Note. We compute the changes on the key endogenous variables of going from the observed equilibrium to an equilibrium where the number of immigrants is 20% higher.

firms, and their unit cost of production and price decrease more than the cost of small firms. As a result of immigration, larger firms increase their market share. Even though larger firms gain market share to small firms (Figure 5c), they reduce their share in the labor market of natives (Figure 5d) because immigrants crowd-out natives at immigrant-intensive firms (large firms), and these natives are reallocated to native-intensive firms (small firms).

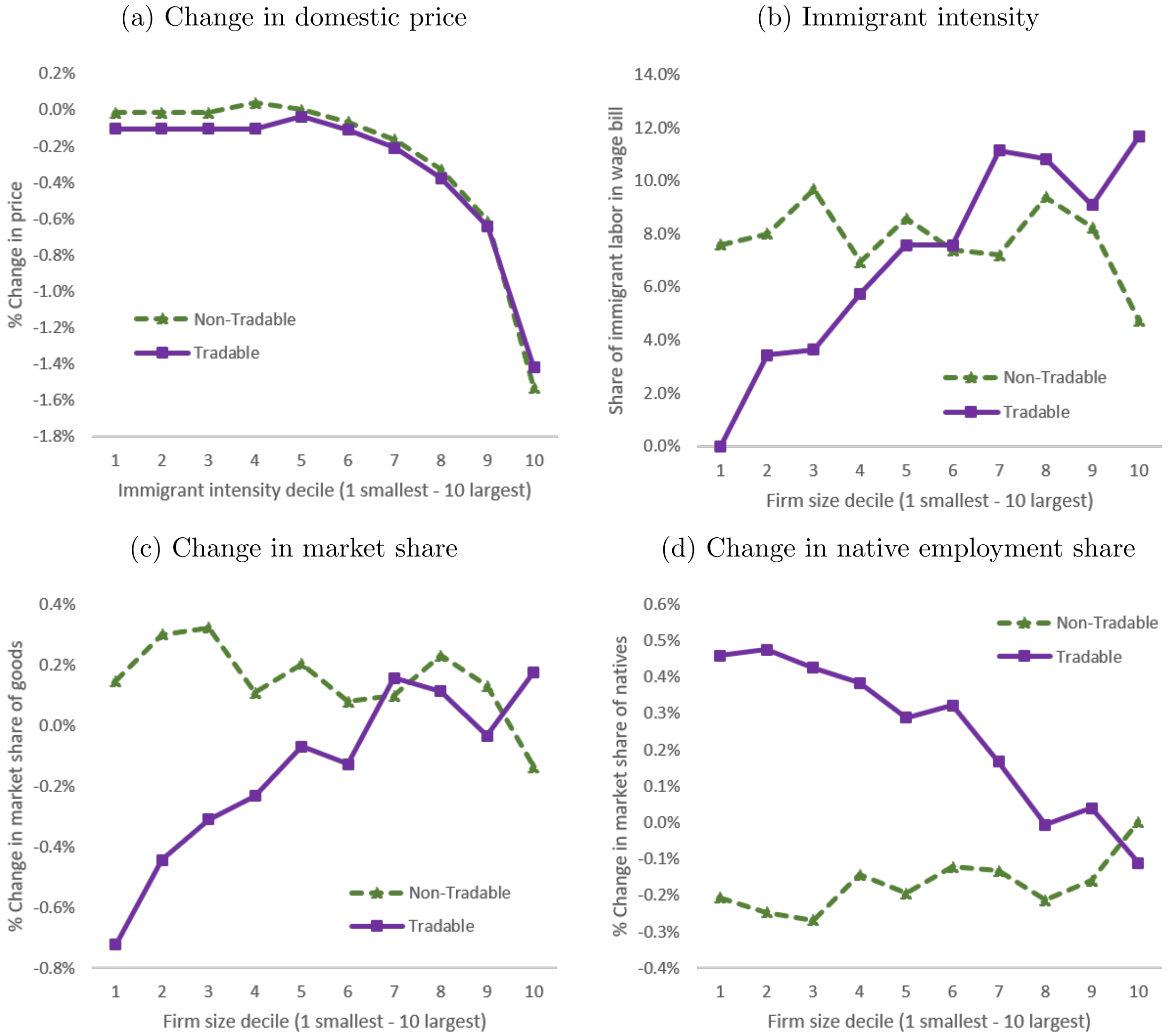
7.2 Role of Heterogeneity in Immigrant Share

In this section, we asses the importance of the documented heterogeneity in quantifying the adjustment of the German economy to an immigration inflow. To that end, we compare the model predictions to the same immigration shock across two models: the ***heterogeneous model*** and the ***homogeneous model***. The heterogeneous model is the general model presented in Section 4, whereas the homogeneous model is a particular case where the parameters generating the heterogeneity in immigrant share are turned off. Importantly, both models are recalibrated to match the same aggregate moments and are subject to the same immigration shock (20% increase in the stock of immigrants).[22] The homogeneous model, however, does not match the observed cross-sectional heterogeneity in the immigrant share; that is, $Var(s_{dj})$, $Cov(s_{dj}; rev_j)$, and the share of firms hiring immigrants. To estimate the homogeneous model, we impose the following restrictions: ${}_{f;T} = {}_{f;NT} = {}_{;f;T} = {}_{;f;NT} = f_{imm;T} = f_{imm;NT} = 0$.

As shown in the last row of Table 7, the homogeneous model underestimates the welfare gains by 11% because it predicts a weaker increase in workers' income and a weaker drop in the price index. As explained in section 4.1, the increase in real wages is stronger in the heterogeneous model because firms choose different immigrant shares. Hence, immigration increases the specialization of immigrants and natives in producing different varieties, which makes them less

[22]In terms of equation 16, it means that in both economies, $dlog(S^{agg})$ is the same. The estimates of parameters that are not estimated by SMM (e.g. and) are the same in both models. Appendix G.3 presents the recalibrated parameters under homogeneity.

Figure 5: Responses to immigration across sectors and firms.



Note: The x-axis of figure 5a groups firms into deciles in terms of their immigrant intensity (1 s_{dj}), and the ex-axis of figure 5b, 5c, and 5d does it in terms of their total revenues. The y-axis in all figures measures the average change in the variable in the counterfactual equilibrium where immigrant stock increases by 20% relative to the initial equilibrium.

substitutable in the aggregate. Since the competition faced by natives in the labor market due to immigration is weaker, there is a lower downward pressure on the wages of natives. The stronger drop in prices in the heterogeneous model, especially in the tradable sector, is explained by larger firms being more immigrant-intensive: large firms, by virtue of being immigrant-intensive, experience a relatively strong drop in the price of the good they produce and, given that they account for a larger share of the consumption basket, their price drops affect the aggregate price index of the economy.

The results of this section highlight the importance of firm-level hiring decisions in understand-

Table 7: Welfare effects with and without firm heterogeneity on the immigrant share

	Welfare Workers	Nominal Wage	Price Index	Price Index Tradable	Price Index Non tradable
Heterogeneous	0.24%	0.07%	-0.17%	-0.18%	-0.15%
Homogeneous	0.22%	0.06%	-0.16%	-0.16%	-0.15%
Homog/Heterog	89%				

Note. For both models, we compute the changes on the key endogenous variables of going from the observed equilibrium to an equilibrium where the number of immigrants is 20% higher. The heterogeneous model is our baseline model. The homogeneous model is an alternative model where all firms are equally intensive on immigrants.

ing the consequences of immigration. Immigration leads to within-industry reallocations of native workers across firms. One reason why this reallocation matters in the aggregate is that it affects the (endogenous) immigrant-native elasticity of substitution. However, even with the same aggregate elasticity, the homogeneous model would underestimate the welfare gains of immigration. In Appendix G, we quantify the welfare gains of the homogeneous model with the same aggregate elasticity that the one implied by the heterogeneous model, and show that the bias is not eliminated and remains large (8% approx.). Thus, even after conditioning on the same change in domestic labor share and aggregate native-immigrant elasticity of substitution, the micro structure of the economy affects the measurement of the welfare gains from immigration.

7.3 The Quantitative Role of Trade

Exports and trade have a key role in the quantitative results of increasing immigration and the size of the bias. We compare our baseline model with an alternative model where Germany and the RoW are in autarky, such that trade is not allowed between countries. This model is analogous to a model where the fixed cost of selecting into trade goes to infinity (e.g., $f_x \to \infty$).

As shown in Table 8, if countries cannot engage in international trade, the price decrease induced by immigration is too strong. The model with no trade overstates the decrease in the price index by more than double the decrease predicted by the baseline model. Both trade and migration lower the marginal cost of production and, in turn, the price index. When trade is not allowed, migration becomes more important as a source of reducing the cost for consumers as they cannot adjust their consumption through trade.

However, the relationship between trade and welfare goes in the opposite direction when considering the wage component. In the baseline model with trade, demand is more elastic, and total production expands more than in the no-trade model in response to immigration. The more elastic product demand increases labor demand for both immigrants and natives and partially compensates the competition effect in the local labor market. As shown in Table 8, the model with no-trade predicts a negative impact on wages, as demand does not respond as much, and the competition effect between natives and immigrants dominates. As explained by Burstein et al. (2020), if immigrants work for a sector where goods are traded, immigration imposes less of a downward pressure on wages because the demand is more inelastic. While both effects are at play, the change in price index dominates the quantitative difference in terms of real wages between the baseline and the no-trade model. The model with no trade overstates the welfare gains of immigration by 41%.

Finally, we compare the no-trade model with a model with no trade and homogeneous immigrant intensities. The homogeneous model underestimates the gains from immigration by 9%, which is lower than the bias in the model with trade (11%). Trade amplifies the inequality in sizes across firms in the tradable sector, which in turn, amplifies the differences in immigrant intensities across firms.

Table 8: Comparing the baseline model with a model no-trade model

	Welfare	Nominal Wage	Price Index	Revenues
Baseline	0.24%	0.07%	-0.17%	1.05%
No Trade	0.34%	-0.04%	-0.37%	0.98%
No Trade and homogeneous	0.31%	-0.02%	-0.33%	0.98%

Note. The values represent the percent change of key variables after a 20% increase in the stock of migrants.

8 Comparing our results with the literature

To put our results into context, it is important to understand the institutional framework in Germany during our study period. We focus on the years between 2003 and 2011, before Germany unified its labor market with other EU countries. Hence, this is a period where a majority of immigrants needed a guaranteed employment offer in order to migrate. Such policy context is important because firms had a fundamental role in determining what immigrants came into the country. Similar setup can be found in the United States, the largest destination country of immigrants, through the H-1B, H-2B, and L-1 visa programs, among others. In these programs, firms need to sponsor workers' visas for them to be able to migrate to the country. The Canadian immigration system is similar with its point-based system, where immigrants with a guaranteed employment offer get substantially more points to qualify for immigration.

Differences in immigration policy across countries can reconcile why firm-level studies find, what at first may seem contradictory. Mitaritonna et al. (2017) find that larger French firms are more immigrant-intensive, but small and low-productivity firms experience the most gains from immigration. Arellano-Bover and San (2020) find that immigrants in Israel initially select into small firms, while Mahajan (2020) finds that high-productivity firms in the United States benefit the most from immigration. In the context studied by Mitaritonna et al. (2017) and Arellano-Bover and San (2020), immigrants were easily available to firms, while in our setup and Mahajan (2020), migration policy required firms to invest resources for recruiting and sponsoring immigrants. Therefore, our framework is well suited to study immigration whenever migrants are not easily available in the labor market, and firms have an active role in deciding which immigrants come into the country.

In terms of the magnitude of our findings, our quantitative estimates are somewhat larger than those estimated by Caliendo et al. (2021), who predict immigration after the EU labor market integration increases welfare for the original EU members by just 0.04%. Our larger gains can be explained due to allowing immigrants and natives to be imperfect substitutes, while in Caliendo et al. (2021) they are considered perfect substitutes within skill group. Their estimates also are mainly driven by the UK, which opened their goods and labor market simultaneously. They conclude that a phased policy like Germany, where the labor market was opened in a later period, would likely have created higher welfare gains.

9 Conclusion

In this paper, we document a large degree of heterogeneity across employers regarding their immigrant share, and revisit the old question of the impact of immigration on the welfare of native workers. When immigration increases by 20%, our model predicts that both the tradable and non-tradable sectors expand in terms of revenues and profits due to the drop in unit cost induced by the inflow of immigrants. This expansion is more pronounced in the tradable sector, where firms are more intensive in immigrant labor. The immigration inflow also induces the tradable sector to become more immigrant-intensive, which triggers a reallocation of the least productive natives from the tradable sector toward the non-tradable sector. We find that native workers and firm owners in both sectors experience higher wages and profits, respectively, and lower prices due to immigration. The welfare gains amount to $4 billion for native workers and $15 billion for firm owners.

Most of the literature has assumed that firms are homogeneous in terms of hiring decisions of immigrants, which is at odds with the data and leads to biased welfare gains from immigration. First, when firms are homogeneous, the elasticity of substitution between immigrants and natives in the labor market coincides with the within-firm elasticity. However, when firms are heterogeneous, the aggregate immigrant-native elasticity of substitution depends on the within-firm elasticity and the elasticity of substitution across firms or goods. Thus, having different immigrant-intensities across firms allows for natives and immigrants to specialize in working for different employers, which makes them less substitutable in the aggregate labor market. Second, when firms are heterogeneous, the gains are largely concentrated among the largest and most productive employers, which induces an additional aggregate productivity gain. These two forces lead to potentially large biased estimates of the welfare gains from immigration. We find that if we ignore this heterogeneity, the welfare gains from an increase in immigration would be underestimated by 11%.

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A Summary statistics

In Table 9, we present the average employment, college employment, and immigrant distribution by origin region for our sample. We split the establishments in the sample into the tradable and non-tradable sectors and calculate summary statistics for years 2003 and 2011.

Table 9: Descriptive Statistics

	Tradable		Non-Tradable	
	2003	2011	2003	2011
N establishments (unweighted)	1,530	1,426	2,148	2,379
Mean Employment	45.0	45.9	39.2	36.5
Mean Employment - College	4.5	5.8	3.0	2.9
Share of employment by origin region				
Germany	90.97%	91.15%	92.66%	91.13%
EU (FR, GB, NL, BE, AT, CH, FI, SE)	1.03%	0.97%	0.74%	0.70%
EU (ES, IT, GR, PT)	1.94%	1.69%	1.22%	1.40%
EU, joined after 2004	0.63%	0.74%	0.68%	1.22%
Europe, other	0.80%	1.10%	0.73%	1.02%
Turkey	2.73%	2.55%	1.71%	2.06%
Former Yugoslavia	0.79%	0.61%	0.73%	0.70%
Asia - Pacific	0.41%	0.52%	0.76%	0.64%
Africa and Middle East	0.52%	0.46%	0.63%	0.75%
Americas	0.16%	0.21%	0.14%	0.36%

Note: The sample is restricted to establishments with more than 10 employees.

B Empirical Evidence for Fixed Cost Assumptions

This section presents stylized facts that motivate the modeling assumption that firms face fixed costs to hire immigrants and that these costs have to be paid whenever the firm expands the set of countries where it hires immigrants from. In the data, countries of origin are grouped in nine blocks as explained in Section 2.

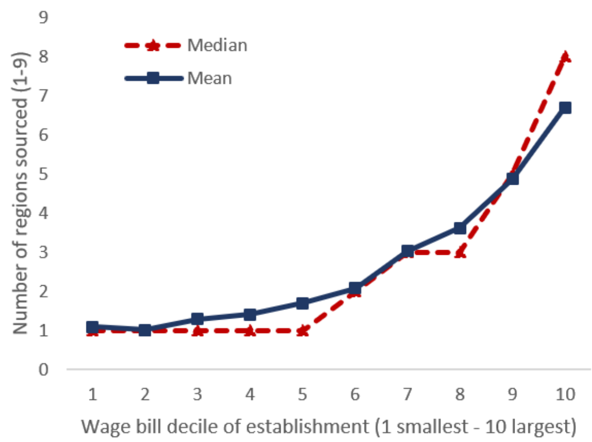
First, as shown in Table 10, there is a significant mass of small firms that do not hire any immigrants. If immigrants and natives are imperfect substitutes, as documented extensively in the literature (Peri and Sparber, 2009, 2011), firms would optimally choose to hire a strictly positive level of both native and immigrant workers, which contradicts the results in Table 10. This pattern could be rationalized if firms have to pay a fixed cost to hire immigrants. Even if immigrants and natives are complementary inputs, if profits earned by small firms are not enough to afford the fixed cost of hiring immigrants, their choice set is restricted to native workers. Fixed costs thus imply that small firms are more likely to hire only native workers, as shown in Figure 1.

Table 10: Share of firms that hire immigrants by firm size

Size deciles	1	2	3	4	5	6	7	8	9	10
Share of firms	0.39	0.36	0.43	0.50	0.53	0.63	0.66	0.80	0.87	0.97

Second, larger firms source immigrants from more countries. Figure 6 shows a positive relationship between firm size, measured by the wage-bill decile, and the median and mean of the number of origins the firm sources immigrants from. Table 11 shows the OLS estimate of a regression of the number of source countries on firm size in the previous year after controlling for sector-year fixed effects. The estimate is positive and statistically significant at a 1% confidence level.

Figure 6: Number of origin regions by establishment size



Note. We divide all establishments with more than 10 employees into total wage bill deciles, with decile 1 including the smallest establishments and 10 the largest.

Third, firms that increase the number of sourcing countries tend to do it by adding a single additional origin, as opposed to multiple origins at the same time. Each row in Table 12 shows the number of countries that an establishment sourced immigrants from in period $t-1$ (Nc_{t-1}), each column shows that number for period t (Nc_t), and each cell contains the number of establishments that keep or increase the number of countries between $t-1$ and t. Establishments that increase the number of origins where they hire immigrants from are more likely to go from Nc_{t-1} to $Nc_{t-1}+1$ than to any other number of countries. This fact would not arise if firms were supposed to pay a fixed cost to source immigrants from any origin as firms would optimally start hiring from all countries after paying that cost. However, if firms were supposed to pay a cost for every *additional* origin they source immigrants from, they would start hiring from one country at a time.

Table 11: Number of sourcing countries and firm size: OLS estimates

	Number of countries	Number of countries
Employment (in logs)	1.40***	
	(0.03)	
Wage Bill (in logs)		1.12***
		(0.03)
N observations	15,095	15,095
N establishments	2,478	2,478

Note. $= p < 0{:}01;$ $= p < 0{:}05;$ $= p < 0{:}1$. We control for 2-digit industry-time fixed effects and local labor market time trends. Standard errors are clustered at the establishment level. Sample is restricted to establishments with more than 10 employees.

Table 12: Number of immigrant origin countries

$Nc_{t\ 1}$	Nc_t									
	0	1	2	3	4	5	6	7	8	9
0	5,108	368	41	*	*	*	*	*	*	*
1		2,014	319	64	*	*	*	*	*	*
2			1,160	259	47	*	*	*	*	*
3				766	179	40	*	*	*	*
4					512	144	33	*	*	*
5						125	372	106	26	*
6							332	107	26	*
7								310	88	*
8									436	70
9										406

Note. Sample is restricted to establishments with more than 10 employees. Nc_t stands for the number of regions the establishment hires immigrants from at time t. Number of regions can go from 1 to 9. Cells with an "*" have less than 20 observations and cannot be disclosed.

Fourth, the year that the firm adds an additional country, it starts hiring a large number of employees from that country. This *jump* in the number of employees hired from the additional country is consistent with firms paying a *xed* cost for any additional sourcing country. If this were not the case and the cost were variable, firms would tend to start hiring small quantities of those immigrants. Table 13 shows the distribution of the number of new hires with respect to the size of the workforce of the firm for two sample of firms. The first sample ("All") is the sample of firms that started hiring from a new source country, and the second sample ("Top 5 deciles") is the subsample of them that are in the top 5 deciles of the employment size distribution. The first row of the following table shows that the average number of employees from the new source is 3.8% of the total employment of the firm, and there is a significant mass of firms (10%) that hire approximately 10% or more of their employment in new-country immigrants. These results do not seem to be driven by firms hiring only few workers that still represent a large share of their small workforce because results remain in the subsample of the Top 5 deciles.

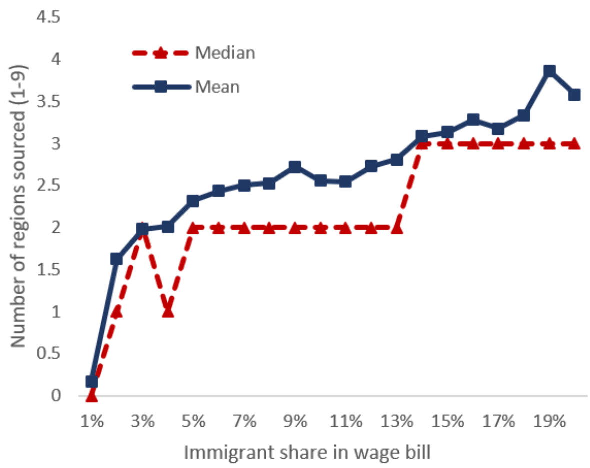
Table 13: Immigrants from new source as a share of firm total employment

Sample	Mean	Percentiles									N
		1%	5%	10%	25%	50%	75%	90%	95%	99%	
All	3.80	0.00	0.06	0.10	0.27	0.87	2.98	9.02	16.85	44.63	3617
Top 5 deciles	3.90	0.00	0.05	0.9	0.24	0.75	2.93	10.00	18.55	46.57	3224

Note: An observation is an establishment-year. We rank establishments who start hiring from a new origin region in terms of the employment from the new region relative to the establishment's total employment. The sample "All" includes those observations that increase the number and the sample "Top 5 deciles" contains the subsample of firms that belong to the top 5 deciles in terms of employment.

Fifth, firms hiring immigrants from more countries tend to be more immigrant-intensive. This is exactly what the model predicts in equation 10 and is corroborated by Figure 7, where we group firms by the percentage of their payroll spent on immigrants. Figure 7 shows that firms that are more intensive on immigrants also source immigrants from more countries.

Figure 7: Number of origin regions by immigrant share



Note. We group establishments by the share of the wage bill spent on immigrants into 20 bins (those who spend 0-1%, 1-2%, etc.). For firms in each bin, we plot the mean and median number of origin countries. In our sample, we have 9 immigrant origin regions, which are listed in section 2.

There may be a mechanical correlation between the number of sourcing countries and the number of immigrants, as the total number of immigrants that the firm hires can drive the observed relationship between number of countries and immigrant share. To suggest that the changes in immigrant share are mainly associated to the number of sources countries, Table 14 shows that, even after controlling for the total number of immigrants hired, the correlation between immigrant share and the number of countries is significant and strong. Moreover, a variance decomposition based on these estimates suggests that 10% of the variance in the immigrant share is explained by differences in the extensive margin (number of countries), and only 3% is explained by the intensive margin (number of immigrants).

Table 14: Immigrant share: Intensive vs Extensive Margin: OLS estimate

	Immigrant share	Immigrant share
N countries	0.016***	0.012***
	(0.0008)	(0.0009)
N immigrants		5.23e-03
		(1.07e-06)
N observations	17,501	17,501
N establishments	2,485	2,485

Note. $= p < 0.01$; $= p < 0.05$; $= p < 0.1$. We control for 2-digit industry-time fixed effects and local labor market time trends. Standard errors are clustered at the establishment level. Sample is restricted to establishments with more than 10 employees.

To conclude, we interpret these stylized facts as evidence in favor of an environment where large firms are more immigrant-intensive than small firms because they can afford to pay more fixed costs to hire immigrants from different origins.

C Model Derivations

C.1 Sourcing Decision Details

In this section, we describe step by step how we get to the immigrant wage index expression in equation 7. Following equation 6, we know the price index for foreign labor is as in equation 23:

$$W_{x;j} = \left(\int_{j} {}_{o} w_x^{1} \, do \right)^{\frac{1}{1}} \tag{23}$$

where ${}_o$ is a source-country specific productivity assumed to be a Pareto random variable with the following cumulative distribution and density function:

$$F(\ ) = 1 - \bar{} \quad \text{and} \quad g(\ ) = \bar{} \ {}^{1} \tag{24}$$

where $\bar{}$ and are the scale and shape parameters, respectively. Since the firm needs to pay a fixed cost f_j for each additional country they hire from, they will just hire from countries with a $>$ $_j$, for a given $_j$. The mass of countries that the firm hires from is then $n_j = F(>$ $_j) = ^{-}(_j)$. With this result, we can calculate the price index of foreign labor as in equation 25:

$$W_{x;j} = w_x^{1} \int_j \ _o^{-} \ ^1 d \ ^{\frac{1}{1}} = \frac{-}{} \ _j \ ^{1} \ ^{\frac{1}{1}} = \frac{-}{}(_j) ^{(\quad)} \ ^{\frac{1}{1}} \quad \text{if} \quad > 0 \tag{25}$$

Since the mass of countries the firm sources from is $n_j = ^{-}(_j)$, we can now compute the foreign price index as in equation 26:

$$W_{x;j} = w_x \underbrace{\frac{1}{\frac{-}{1}} \ \frac{}{} \ ^{\frac{1}{1}}}_{z} n \ ^{\frac{1}{\underbrace{1 \quad }_{z}}} \tag{26}$$

C.2 Equilibrium Equations

The equilibrium in this model is defined as a set of prices, wages, and labor allocations such that: workers optimally choose the industry and destination country $d; k$ to work for, consumers in each location choose how much of each variety to purchase to maximize utility, firms choose the sourcing strategy and export status to maximize profits, labor markets clear, and trade is balanced. We set the wage in the RoW (w_x) to be the numeraire. Formally, the equilibirum conditions are the following:

1) Consumer budget constraint. In a given country, natives and immigrants have identical preferences. The total expenditure in Germany (Y_g) and RoW (Y_x) are shown in equation 27:

$$Y_g = \sum_k (w_{g;k} L_{g;k} + w_{g;x;k} L_{g;x;k} + \Pi_{g;k}) \quad Y_x = w_x L_x + \Pi_x \tag{27}$$

where $L_{g;k}$ is the total number of German effective units of labor in sector k, $L_{g;x;k}$ is the number of effective immigrant units in Germany working in sector k, and $w_{g;k}$, $w_{g;x;k}$ are the respective effective wages. $\Pi_{g;k}$ are the total profits in sector k in Germany. w_x, L_x, and Π_x are the effective wages, effective labor, and total profits in RoW.

2) Trade balance. Total income from exports in Germany is equal to the total import expenditure as in equation 28:

$$\sum_j \mathbb{1}\left(exporter_{g;j}=1\right) p^T_{j;x;g} y^T_{j;x;g} = \sum_j \mathbb{1}\left(exporter_{x;j}=1\right) p_{j;g;x} y_{j;g;x} \tag{28}$$

3) Total labor market clearing. In each industry, the expenditure of labor by industry k equals the number of effective units supplied by the labor market times the effective wage paid by that industry. The market clearing conditions 29-31 require that demand for effective units of native and immigrant labor equals supply in each industry and country:

$$\sum_j d_{j;k} = A_{g;k}^{\frac{1}{}} (\;_{g;k})^{\frac{\;}{}\,1} \bar{H} N_g \tag{29}$$

$$\sum_j \sum_o x_{j;o;k} = \; A_{x;k}^{\frac{1}{}} (\;_{x;g;k})^{\frac{\;}{}\,1} \bar{H} \;\; N_x \tag{30}$$

$$\sum_j d_{j;x} = \; A_{x;k}^{\frac{1}{}} (\;_{x;x;k})^{\frac{\;}{}\,1} \bar{H} \;\; N_x \tag{31}$$

Equation 29 stands for the market clearing condition for natives in Germany, equation 30 for the market clearing condition for immigrants in Germany, and equation 31 for the market clearing of workers that stay in RoW. The parameter $\bar{H}$ stands for the Gamma function evaluated at $1 \;\; \frac{1}{}$

D Welfare Response to Immigration

We focus on a closed economy with one sector, we choose the wage of natives as the numeraire, and assume that the fixed cost f_{imm} is zero (but the firm-specific fixed cost f_j is unrestricted). We present the expression for the change in the welfare of natives workers in four steps.

Step 1: Express $dlog(s_{dj})$ as proportional to $dlog(s_{d1})$.

The profit function and the corresponding first order condition with respect to s_{dj} are:

$$\Pi_j = A \;\;_j\;^1 s_{dj} \quad B f_j (s_{dj}^{\;1} \quad 1)^{\;+1}$$

$$_j\;^2 s_{dj}^{\;\;+1+} = f_j C (1 \quad s_{dj})$$

where $A; B$, and C are general equilibrium variables that are common to all firms, $\; = \frac{1}{1} > 0$ and $\; = (\quad 1)^{\;1} \quad 1 > 0$.

The first order condition for firm j and firm 1 implies that:

$$(\quad + 1 + \quad + \frac{}{1 \quad s_{dj}}) \, dlog(s_{dj}) = (\quad + 1 + \quad + \frac{}{1 \quad s_{d1}}) \, dlog(s_{d1})$$

or

$$dlog(s_{dj}) = \frac{{}_j}{{}_1} \, dlog(s_{d1}) \quad with \quad {}_j = \frac{1}{+1+ \quad + \ (1 \quad s_{dj})^{\ 1}} > 0 \tag{32}$$

Step 2: Express $dlog(s_{dj})$ as proportional to $dlog(S_d^{agg})$.

By definition, the aggregate domestic share is the total wage bill spent on natives divided by the total wage bill:

$$S_d^{agg} = \frac{\sum_j WB_{dj}}{\sum_j WB_j} = \sum_j \underbrace{\frac{WB_j}{\sum_j WB_j}}_{\omega_j^{WB} = \omega_j} s_{dj} = \sum_j \omega_j s_{dj}$$

where ω_j^{WB} is the share of firm j in the wage bill of natives and happens to also be the share in revenues, ω_j. In what follows, we use this fact and keep the notation as ω_j.

The change in the aggregate domestic share is then given by:

$$dlog(S_d^{agg}) = \sum_j \underbrace{\frac{\omega_j s_{dj}}{\sum_j \omega_j s_{dj}}}_{\omega_j^S} \quad dlog(\omega_j) + dlog(s_{dj}) \tag{33}$$

where ω_j^S is the share of firm j in the aggregate domestic share.

Next, we find an expression for $dlog(\omega_j)$ as a function of $dlog(s_{dj})$. To that end, we use firm j's optimal demand for natives and the definition of ω_j:

$$WB_j = \frac{1}{}r_j = \frac{D}{{}_j} s_{dj} \quad \rightarrow \quad dlog(WB_j) = dlog(D) \quad\quad dlog(s_{dj})$$
$$\omega_j = \frac{WB_j}{\sum_l WB_l} \quad \rightarrow \quad dlog(\omega_j) = dlog(WB_j) \quad\quad \sum_l \omega_l dlog(WB_l)$$

where D is a general equilibrium variable common to all firms.
The expression of $dlog(\omega_j)$ as a function of $dlog(s_{dj})$ follows from combining these last two expressions:

$$dlog(\omega_j) = \quad\quad dlog(s_{dj}) \quad\quad \sum_l \omega_l \, dlog(s_{dl}) \tag{34}$$

This expression, together with 32 and 33, implies that the change in aggregate share can be expressed as a function of the change in s_{d1}:

$$\begin{aligned} dlog(S_d^{agg}) &= \sum_j !_j^S \Big(\quad dlog(s_{dj}) \quad \sum_l !_l \, dlog(S_{dl}) \quad + dlog(s_{dj}) \Big) \\ dlog(S_d^{agg}) &= \sum_j !_j^S \quad (\quad {}_j \quad \sum_l !_l \quad {}_l) + \quad {}_j \;\; dlog(s_{d1}) \end{aligned} \tag{35}$$

In a more compact way, it reads as:

$$dlog(S_d^{agg}) = \sum_j !_j^S \underbrace{(\quad {}_j \quad \bar{\ }) + \quad {}_j}_{j} \; dlog(s_{d1}) \tag{36}$$

with $\bar{\ } \quad \sum_l !_l \quad {}_l$.[23]

Expressions 37 and 32 let us express individual changes in domestic share as a function of the aggregate change:

$$dlog(s_{dj}) = \frac{\ {}_j}{\ } dlog(S_d^{agg}) \quad with \quad = \sum_l \quad {}_l \tag{37}$$

Step 3: Express welfare change into a component observable with aggregate data and a component that requires micro-level data.

The welfare gains from immigration in this simplified model are given by the drop in the price index induced by immigration. The change in the price index (relative to the numeraire good) is a weighted average of the changes of individual prices which, in turn, are proportional to the change in the domestic share:

$$\begin{aligned} dlog(P) &= \sum_j !_j^{rev} dlog(p_j) \\ &= \sum_j !_j^{rev} dlog(u_j) \\ &= \sum_j !_j^{rev} \quad dlog(w_d) + \frac{dlog(s_{dj})}{1} \\ &= dlog(w_d) + \frac{\sum_j !_j dlog(s_{dj})}{1} \end{aligned} \tag{38}$$

where we used the fact that $!_j = \frac{p^1}{P^1}$, $\sum_j !_j^{rev} = 1$, and equations 5 and 8.

We can express the change in the price index as a function of the change of the aggregate share and an additional factor by plugging equation 37 into equation 38.

[23] If all firms choose the same immigrant-share, $dlog(S_d^{agg}) = dlog(s_{dj})$.

The last two expressions and the optimal pricing implies:

$$dlog\left(\frac{P}{w_d}\right) = \frac{dlog(S_d^{agg})}{1} \underbrace{\sum_j \omega_j \frac{\ _j}{\ }}_{\tilde{\ }\left(\{s_{dj};\omega_j\};\ ;\ \right)}$$

This expression shows that the change in the price index can be computed only if firm-level data on the market share and immigrant intensity are available.

Step 4: Determine if the bias is larger or smaller than one.

For the sake of the mathematical exposition, we work with the inverse of $\tilde{\Gamma}$, which takes the following shape:

$$\tilde{\Gamma}\left(\{s_{dj};\omega_j\};\ ;\ \right)^{-1} = \frac{\sum_j \omega_j^S\ _j}{\sum_j \omega_j\ _j} = \frac{\sum_j \omega_j^S\left(\ (\ _j - \bar{\ }) + \ _j\right)}{\bar{\ }}$$

and can be rewritten as in 39 by adding and subtracting $\sum_J \omega_j^S \bar{\ }$:

$$\tilde{\Gamma}\left(\{s_{dj};\omega_j\};\ ;\ \right)^{-1} = 1 + \frac{\ }{1}\ \frac{\sum_j \omega_j^S\ _j - \sum_j \omega_j\ _j}{\sum_j \omega_j\ _j} \tag{39}$$

The bias will be higher or lower than one, depending on whether   is larger than , as the sign of the second term on the right side is always negative. To see this, notice that there is a tight relationship between ω_j and ω_j^S:

$$\omega_j^S = \omega_j \frac{s_{dj}}{\sum_j \omega_j s_{dj}}$$

which implies that the weighting system ω^S assigns lower weight to immigrant-intensive firms than the weighting system ω. Given that $\ _j$ is strictly increasing in the immigrant-share of the firm, the average of $\ _j$ under the weighting system ω^S must be lower than that under ω_j and

$$\frac{\sum_j \omega_j^S\ _j - \sum_j \omega_j\ _j}{\sum_j \omega_j\ _j} < 0$$

Thus, if $\ >\ $, equation 39 shows that $\tilde{\Gamma}\left(\{s_{dj};\omega_j\};\ ;\ \right)^{-1}$ is lower than one and vice versa.

It also follows that $\Gamma\left(\{s_{dj};\omega_j\}\right)$ in Section 4.1 is always positive:

$$\Gamma\left(\{s_{dj};\omega_j\}\right)\ \ \frac{1}{1}\ \frac{\sum_j \omega_j^S\ _j - \sum_j \omega_j\ _j}{\sum_j \omega_j\ _j} > 0$$

E Estimation of

E.1 Dataset Description

To estimate the elasticity of substitution between native and immigrant effective units, , we use an alternative administrative dataset called SIAB, which is also provided by the German Social Security Administration.[24] SIAB contains the full labor biographies for 2% of the German workforce between 1975 to 2014 and includes information on employer size, citizenship, workplace, industry, occupation, and other covariates similar to the labor market component of our main dataset LIAB. A few advantages of SIAB include a representative sample of the German workforce, a longer time span, and a significantly larger sample size. As will be explained in section E.2, the estimation procedure requires constructing generated regressors at the firm-time-origin level and control for a rich set of time-varying fixed effects. Given these constraints, this alternative dataset allows us to exploit the larger sample size and longer time panel.

One limitation of the SIAB dataset is that it does not contain information on every employee at the establishments in the sample. Since we need the migrant and native employment at the establishment level, we group establishments in SIAB into bins by time, geographic district, three-digit industry, and size quartile. We then construct our firm level dataset by considering all employees in the sample working for establishments in a given bin as if they would work for the same "synthetic" firm.

E.2 Estimation Details

To get an expression for the immigrant composite, we start from the supply side of the model. Using the Frechet properties, we can write the number of effective units supplied to firm j in industry k by workers from origin country o as in equation 40.:

$$x_{j;o} = \underbrace{A_{o;k}^{\frac{1}{}} \left({}_{o;k;\ell} \right)^{\frac{1}{}} \bar{H}}_{Z_{o;k}} N_j^o \tag{40}$$

where N_j^o is the number of workers employed at firm j, and the expression ${}_{o;k}$ is the average ability per worker from o at firm j.

Using the first order condition of profits from firm j with respect to each $x_{j;o}$ relative to the first order condition with respect to a base origin country o^0, $x_{j;o^0}$, and using equation 40, we can get an expression as in equation 41:

[24] The data basis of this section of the paper is the weakly anonymous Sample of Integrated Labour Market Biographies (SIAB) 1975 - 2014. The data were accessed on-site at the Research Data Centre (FDZ) of the Federal Employment Agency (BA) at the Institute for Employment Research (IAB) and/or via remote data access at the FDZ. For more information on SIAB please check Antoni et al. (2016).

$$Ln\left(\frac{w_o x_{j;o}}{w_{o^0} x_{j;o^0}}\right) = Ln\left(\frac{{}_{o;k}}{{}_{o^0;k}}\right) + \frac{1}{} Ln\left(\frac{{}_{o;k} N_j^o}{{}_{o^0;k} N_j^{o^0}}\right) \tag{41}$$

Using equation 41 and assigning a value for , we can get to the first estimating equation, 42, which gives us an estimate for the average effective units provided by each migrant worker at firm j:[25]

$$Ln\ \text{Wage bill}_{o;j} \quad \frac{\hat{}\ 1}{\hat{}} Ln(N_j^o) = \underbrace{Ln(\ {}_{o;k}) + \frac{1}{} Ln(\ {}_{o;k})}_{{}_{o;k}\ \text{Origin-Industry FE}} + \underbrace{Ln(\ {}_{o^0;k}) \quad Ln(\ {}_{o^0;k} N_j^{o^0})}_{\text{Firm FE}} \tag{42}$$

To estimate equation 42, we pool all years between 1995 until 2014 and run a regression at the firm-origin-time level. We include origin-industry-time and firm-time fixed effects, such that we only exploit the cross-sectional variation to estimate the fixed effects. From equation 42, we obtain the fixed effects ${}_{o;k}$, which will allow us to compute the immigrant composite at the firm level using data on the number of immigrants by country, the ${}_{o;k}$ estimates, and the assigned value of as shown in equation 43:

$$\hat{x}_j = \sum {}_o x_{j;o}^{\frac{\hat{}\ 1}{\hat{}}}\ ^{\frac{\hat{}}{\hat{}\ 1}} = \sum {}_o(\ {}_{o;k} N_j^o)^{\frac{\hat{}\ 1}{\hat{}}}\ ^{\frac{\hat{}}{\hat{}\ 1}} = \sum e^{\hat{}_{o;k}}\ N_j^o\ ^{\frac{\hat{}\ 1}{\hat{}}}\ ^{\frac{\hat{}}{\hat{}\ 1}} \tag{43}$$

Once we calculate $\hat{x}_j$, we can proceed to estimate our key elasticity . We can use the firm first order condition with respect to the number of native effective units d_j and the immigrant composite x_j to get to estimating equation 44:

$$\underbrace{Ln\left(\frac{w^d_{j;t} d_{j;t}}{w^x_{j;t} x_{j;t}}\right)}_{\text{Relative wage bill}} = Ln\left(\frac{{}_k}{1 \quad {}_k}\right) + \frac{1}{} Ln\left(\frac{{}_{d;k} N_j^d}{\hat{x}_{j;t}}\right) \tag{44}$$

With some additional structure, we reach estimating equation 45, as shown in Section 5. We proceed to take logs and reorganize equation (18) into estimating equation 45:

$$Ln\left(\frac{\text{Wage bill Natives}_{j;t}}{\text{Wage Bill Immig}_{j;t}}\right) = \frac{1}{} Ln\left(\frac{N_j^d}{\hat{x}_{j;t}}\right) + \underbrace{Ln\left(\frac{{}^k_t}{1 \quad {}^k_t}\right) + Ln(\ {}_{d;k;t})}_{\text{Industry-time FE}} + {}_j + {}_{j;t} \tag{45}$$

[25] stands for the degree of substitution across immigrant origin countries for production. We assume $= 20$, close to the upper bound of the elasticity of substitution between immigrants and natives estimated by Ottaviano and Peri (2012). We show results are very robust to other values of between 10 and 30.

We assume the error term can be written as a firm fixed effect $\ _j$ and an unobserved component $\ _{j;t}$. We also use the labor supply property that the number of effective units of native workers can be expressed as an interaction between an industry-time constant $\ _{d;k;t}$ and the observed number of German workers at firm j, N_j^d as in equation 40. While the model is static, once again we add time subscripts as we pool several years of data to maximize our sample size.

The OLS estimates will not provide a consistent estimate of the elasticity of substitution under the presence of unobservable shocks affecting both the relative labor demand and relative wage. If, for example, firms face productivity shocks that are biased to immigrants, the OLS estimate will be upward biased. To address endogeneity concerns, we instrument the firm's relative demand of workers with the following shift-share instrument:

$$Z^f_{j;m;t} = \sum_{o} \frac{\text{Wage Bill}_{o;m;1995}}{\text{Wage Bill}_{m;1995}} \frac{\text{Employment}^{Imm}_{o;m;t}}{\text{Employment}^{Ger}_{m;t}} \tag{46}$$

The initial share component of the instrument is the wage bill of immigrants from origin o in market m in year 1995 relative to the total wage bill in market m in 1995.[26] We use "kreis" as the market concept (m) of this instrument, which is the finest geographical area in our dataset. The shift component of the instrument captures the employment level of immigrants from country o relative to Germans in market m in year t. This instrument exploits country-of-origin-driven variation in the relative supply of immigrant across markets and "assigns" the increase of immigrants from each origin in that market to firms according to their market-share in 1995.

The validity of the instrument depends on this market share not being correlated with shocks determining the relative wage that firms pay in period t. Larger firms tend to have a larger market share and may also tend to pay systematically different average wages to immigrants relative to natives. Even though we control for time-invariant firm heterogeneity, there may be serially correlated time-varying productivity shocks that affect the relative size of firms in 1995 and their hiring decisions in the future. This would bias the 2SLS estimate upward. The time-industry fixed effect will help control for unobserved time-varying shocks. Finally, we cluster standard errors at the firm level to account for the correlation within firm over time.

Table 15 presents the OLS and the 2SLS estimates of 45. The OLS estimate of $\frac{1}{\ }$ is larger than 1 and implies an unreasonable elasticity of substitution between immigrants and natives of -35.1. The 2SLS estimate in column 2 is lower than one and statistically significant. This estimate implies that the elasticity of substitution between immigrants and native workers within the firm is 4.28. As expected, the OLS estimate is upward biased, since the error term includes demand-side shocks that positively affect the wages and employment of immigrants

[26]While the data is available since 1975, we use 1995 as our base year since administrative data for East Germany only becomes available after 1993.

relative to natives. The instrument is strong, as shown by the F-stat in Table 15.

Table 15: Estimates for

	OLS	2SLS		First stage
Estimate for (1)=	1.029***	0.81***	Instrument	-0.00025***
	(0.003)	(0.355)		(0.00005)
Number of observations	458,308	458,308		458,308
Implied	-35.1	4.28	1st stage F-stat	21.29

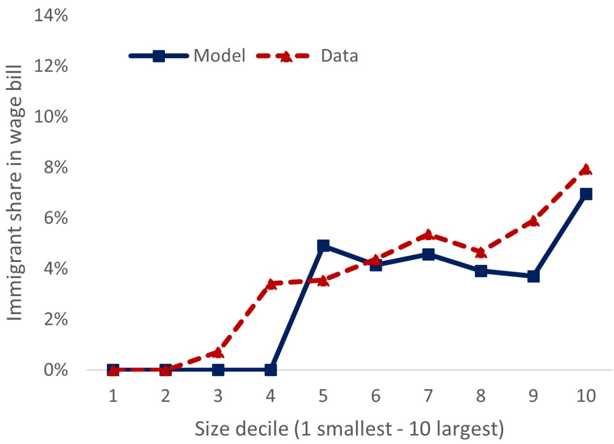
Note. $= p < 0{:}01;$ $= p < 0{:}05;$ $= p < 0{:}1$. OLS and 2SLS estimates for equation 45. We include industry-time and firm fixed effects. Industry-time FEs are defined according to our tradable and non-tradable industries used in the model. Standard errors are clustered at the firm level and bootstrapped with 200 repetitions. Time period used is 1995 to 2014.

Model Fit

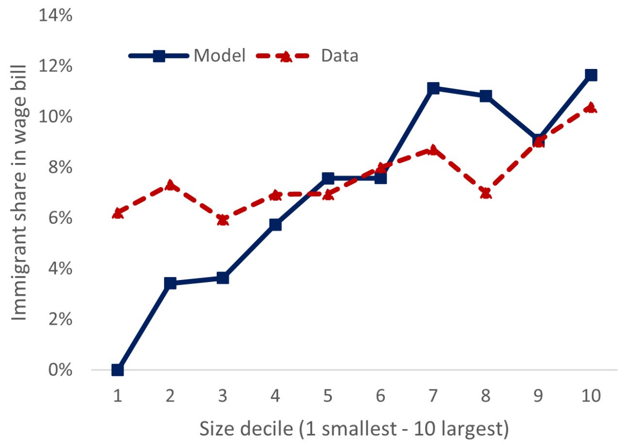
While the model matches the targeted moments, we want to make sure it also matches non-targeted moments that are relevant to our main mechanisms. As shown in Figure 8, the model does a good job in matching the cross-sectional means and medians of the immigrant share by size decile. The medians are completely untargeted by the estimation routine, and the model does a good job in replicating the positive slope in the tradable sector and somewhat misses the slight increasing slope in the non-tradable sector. However, the observed correlation between size and immigrant share in the non-tradable sector is weak and the model captures the levels reasonably well. The means are also informative of the distribution within decile. These are not completely untargeted since we are matching the mean immigrant share across all establishments in our estimation routine as well as the difference in the means of P90 and P50 for each sector. However, we are not targeting the mean by sector nor the relationship between any deciles other than 5 and 9. As shown in Figure 8, the model does a good job matching both means but underestimates the mean for the first deciles in the tradable sector.

Figure 8: Immigrant share across establishments: model vs data

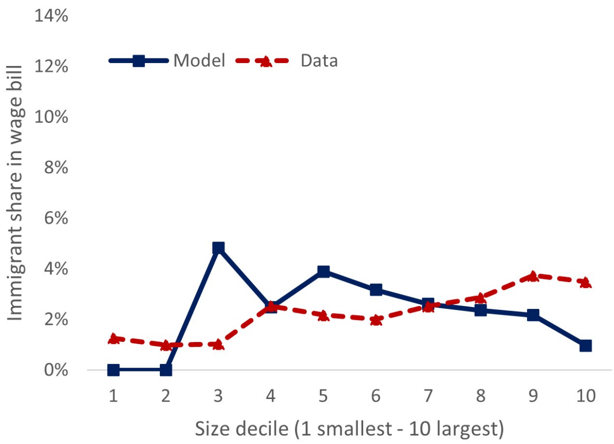
(a) Median Tradable



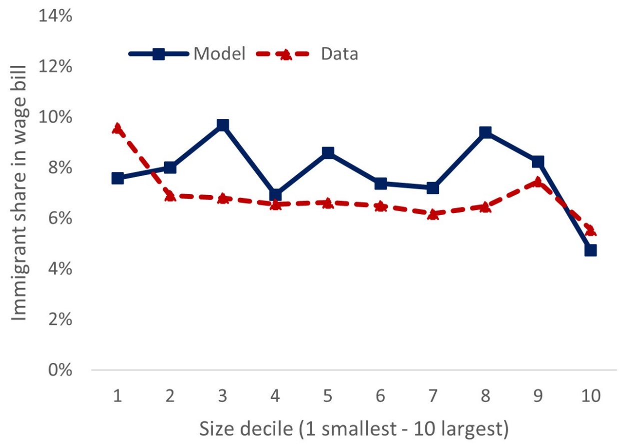
(b) Mean Tradable



(c) Median Non-Tradable



(d) Mean Non-Tradable



Note: We divide establishments in the model and the data into size deciles, where 1 groups the smallest establishments. We plot the mean and median for each decile and each sector as shown by the data as in Figure 1. For the model, we plot the size distribution predicted by our estimated model.

F Empirical Results Details

F.1 Heterogeneous Response to Immigration: Additional Results

Table 16: First stage regressions

	Full sample		Tradable sector		Non-Tradable sector	
	$s^{agg}_{m;t}$	$s^{agg}_{m;t}$ log(size)	$s^{agg}_{m;t}$	$s^{agg}_{m;t}$ log(size)	$s^{agg}_{m;t}$	$s^{agg}_{m;t}$ log(size)
$Z_{m;t}$	1.49***	0.59	1.35***	-0.86	1.50***	2.79
	(0.256)	(1.420)	(0.374)	(2.013)	(0.377)	(1.918)
$Z_{m;t}$ log(size)	-0.02	1.15***	0.02	1.45***	-0.07	0.61
	(0.05)	(0.298)	(0.069)	(0.413)	(0.074)	(0.241)
N	3507		1974		1533	
Kleinberg-Paap F-stat	35.86		29.48		15.53	

Note. $= p < 0{:}01$; $= p < 0{:}05$; $= p < 0{:}1$. We restrict the sample to years between 2008 and 2011. We control for establishment fixed effects, 2-digit industry-time fixed effects, local labor market-time trends, and lagged firm level controls such as log employment and investment. Sample is restricted to establishments with more than 30 employees. Standard errors are clustered at the establishment level.The Kleibergen-Paap F-stat tests for the joint significance of both instruments. The first two columns are the first stages for the full sample, columns 3 and 4 restrict the sample to establishments in the tradable sector, and columns 5 and 6 to the non-tradable sector.

Table 17 evaluates how the controls added to the regression affect our estimates. Column 2 removes the firm-level controls, column 3 removes the industry-time FEs, and column 4 removes the local labor market trends.

Table 18 presents the heterogeneous effects of the immigration shock on profits, total employment, and labor productivity. Profits are measured as revenues net of wage bill and material bill, and labor productivity is measured as the ratio between revenues and employment. The 2SLS estimates in Table 18 reassures the previous findings on the heterogeneous effect of immigration. Relative to small establishments, larger establishments hire more workers and show a larger labor productivity (columns 2 and 3). Estimates for profits are imprecisely estimated, so we cannot reject a null effect of changes in response to the immigrant share.

F.2 Export Revenues vs Domestic Revenues

A second prediction is that the drop in unit costs generated by immigration would expand export revenues more than domestic revenues because an exporter faces a demand curve from the RoW that is more elastic than its domestic demand.

Table 19 presents the estimated results of regression 19 for domestic revenues and export revenues for the sample of exporters. The average response of export revenues is stronger

Table 17: Robustness exercises for main specification

	Baseline	No firm-level controls	No industry-time FEs	No local labor time trends
1	-31.86***	-37.39**	-52.91***	-25.32**
	(11.47)	(15.41)	(12.79)	(10.99)
2	7.49***	8.56***	12.38***	5.93**
	(2.46)	(3.28)	(2.74)	(2.4)
N observations	3507	3507	3507	3507
N establishments	949	949	949	949
1st stage F-stat	35.85	8.76	33.67	18.18

Note. $= p < 0{:}01;$ $= p < 0{:}05;$ $= p < 0{:}1$. Dependent variable in all cases is log revenues. We restrict the sample to years between 2008 and 2011. We control for establishment fixed effects, 2-digit industry-time fixed effects, local labor market time trends, and lagged firm level controls such as log employment and investment. Standard errors are clustered at the establishment level. Sample is restricted to establishments with more than 10 employees. Column 1 shows the baseline specification with full controls. Column 2 removes the firm-level controls. Column 3 removes the industry-time fixed effects and controls only for time fixed effects. Column 4 removes the local labor time-trends.

Table 18: The impact of immigration on other outcomes

	Log Profits	Log employment	Log Revenue per employee
1	-136.7	-4.82	-26.99**
	(101.31)	(6.43)	(11.4)
2	29.6	1.64	5.83**
	(17.35)	(1.4)	(2.51)
Average ^{y}	0.47	0.18	0.09
Threshold size	101	19	102
N observations	2901	3507	3507
N establishments	853	949	949
Estimation	2SLS	2SLS	2SLS
1st stage F-stat	30	35.86	35.85

Note. $= p < 0{:}01;$ $= p < 0{:}05;$ $= p < 0{:}1$. We restrict the sample to years between 2008 and 2011. We control for establishment fixed effects, 2-digit industry-time fixed effects, local labor market time trends, and lagged firm level controls such as log employment and investment. Standard errors are clustered at the establishment level. Sample is restricted to establishments with more than 30 employees

than domestic revenues, and in both cases, the heterogeneous effect significantly favors large establishments relative to small establishments. These estimates imply that by each 1% increase of the labor market immigration share, domestic revenues increase by $0{:}44\%$, whereas export revenues increases by $1{:}15\%$. Since the response of export revenues is stronger than domestic revenues, this channel can explain part of the heterogeneous effects found in Table 3. Large establishments, which are more likely to be exporters, may adjust more to the immigration shock because they are able to expand their export revenues whereas for small firms, expansion is constrained by the size of the domestic market.

Table 19: Revenue regressions by sector and exporter status

	Log Export Revenues	Log Domestic Revenues
1	-87.99**	-78.45***
	(39.31)	(29.77)
2	20.64**	16.6***
	(8.07)	(5.92)
Average y	1.15	0.44
Threshold size	71	113
N observations	1654	1654
N establishments	466	466
Estimation	2SLS	2SLS
1st stage F-stat	20.72	26

Note. $= p < 0{:}01;$ $= p < 0{:}05;$ $= p < 0{:}1$. We restrict the sample to years between 2008 and 2011. We control for establishment fixed effects, 2-digit industry-time fixed effects, local labor market-time trends, and lagged firm level controls such as log employment and investment. Standard errors are clustered at the establishment level. Sample is restricted to establishments with more than 30 employess and that report positive export revenues.

To summarize our findings, the reduced-form evidence presented in this section shows that larger employers benefit more from an increase in the immigrant share of the local labor market than small establishments. Establishments' export revenues are more responsive than its domestic revenues. This evidence is consistent with the mechanisms put forward in the model: given that large firms are more immigrant-intensive than small firms (Figure 2a), large firms face a larger drop in the labor cost of production than small firms when the economy receives a new wave of immigrants. This drop in the cost of production drives large firms to expand their production at the expense of putting downward pressure on the market price of the good they sell. This downward pressure is weaker the more elastic the demand. Given that large firms are likely to export and foreign demand is more elastic, they find it optimal to increase production to all markets and especially to export markets. As a result, an influx of immigrants is mostly absorbed by large firms that find it profitable to expand production.

F.3 Shift-share Instrument Diagnostics

Our instrument falls into the category of shift-share instruments, and as such, we run a series of diagnostics suggested by the literature on the validity of shift-share instruments (Borusyak et al., 2021; Goldsmith-Pinkham et al., 2020). Our setup is not exactly the standard shift-share case because in addition to the shift-share instrument, we have an interaction between the instrument and the log size of the establishment. However, we can still use the guidance of these methodological papers to understand the variation driving our instruments.

As a first step, we follow the suggestions in Goldsmith-Pinkham et al. (2020) and Borusyak et al. (2021) and test for pre-trends. The shift-share design implies that the common shock is the main driver of the observed changes, so we need to make sure there were no preexisting differences explaining such observed changes. As shown in Table 20, we lag the outcome 5 years and 1 year and use them as outcomes in our baseline regression. The instrument is still strong, but the second stage coefficients are not significant. This corroborates that the observed changes are not driven by preexisting differences across establishments. Borusyak et al. (2021) also suggest that if the sum of the initial shares does not add up to one within local labor market, we should control for the sum of the exposure shares in our regression. We do so in a nonparametric fashion by including an establishment fixed effect in our regressions which would absorb the sum of initial shares at the local labor market level.

Table 20: Pre-trends tests

	Log Total Revenues t 5	Log Total Revenues t 1
1	2.51	-7.48
	(9.28)	(9.61)
2	-1.29	2.09
	(1.93)	(1.99)
N observations	3329	3434
N establishments	907	937
1st stage F-stat	41.16	40.85

Note. $= p < 0{:}01$; $= p < 0{:}05$; $= p < 0{:}1$. We restrict the sample to years between 2008 and 2011. We control for establishment fixed effects, 2-digit industry-time fixed effects, local labor market time trends and lagged firm level controls such as log employment and investment. Standard errors are clustered at the establishment level. Sample is restricted to establishments with more than 30 employess. The first column includes the outcome variable lagged by 5 periods, the second column includes the outcome variable lagged by one period.

As a second step, we focus on the case of testing for exogenous shares, and run a set of diagnostics proposed by Goldsmith-Pinkham et al. (2020). We perform the tests for a simplified version of equation 19, where we do not include the size interaction term nor the industry-time fixed effects and labor market trends. While the regression is different than our main specification, the analysis is still useful to understand what is driving the main shift-share instrument.

In our case, we can write the first stage coefficient on the shift-share instrument as a combination of the estimates of nine separate first stage regressions. Each of these "just identified" regressions uses an instrument that is constructed with the initial share and shock of only one of our nine origin regions. The weights in which each of these nine instruments affects the overall IV are called Rottemberg weights. We proceed to use the code provided by Goldsmith-Pinkham et al. (2020) to calculate such weights and denote them . Each origin region is affected each year by a national level shock we denote by G. The just identified coefficients are denoted by .

As shown in panel A of Table 21, 89% of the Rottemberg weights are positive, meaning that our regression is likely not subject to misspecification. In panel B, we show the correlation between the weights, the shocks, and the just-identified coefficients. Panel C shows the top five origin regions in terms of the Rottemberg weights. For the time period between 2003-2011, countries of former Yugoslavia have the largest weight with 0.28. These are followed by Asia-Pacific (0.24), other non-EU countries which include predominantly Russian immigrants (0.17), Africa and Middle East (0.15), and Turkey (0.07). These regions are expected to drive most of the variation in our instrument. It is reassuring however, that no single region accounts for a large majority of the variation in our instrument.

Table 21: Shift-share diagnostics

Panel A	Sum	Mean	Share
$_s$ 0	-0.014	-0.014	0.111
$_s > 0$	1.014	0.127	0.889
Panel B	$_s$	G	$_s$
$_s$	1	-	-
G	0.149	1	-
$_s$	0.013	-0.402	1
Panel C		G	
Countries of former Yugoslavia	0.28	0.98	1.54
Asia-Pacific	0.24	1.11	4.46
Europe other	0.17	1.23	3.89
Africa and Middle East	0.15	1.13	3.97
Turkey	0.07	0.83	1.47

*Note.*We run the shift-share diagnostics suggested by Goldsmith-Pinkham et al. (2020). Panel A shows the share of Rottemberg weights that are positive and negative. Panel B shows the correlation between the Rottemberg weights, the time-shifter shock G, and the just-identified coefficients . Panel C summarizes , G, and for the top 5 origin regions in terms of weights.

Finally, we look into the correlation between the initial shares used in the instrument and other covariates at the local labor market in the initial period. The intuition behind this exercise is that the variation in the initial shares should not be explained by other covariates that can also affect the change in outcomes at the regional level. As shown in Table 22, key characteristics at the regional level only explain 4.4% of the total variation in the shares, indicating that the shares are not significantly driven by other observables.

Table 22: Correlation between initial shares and observables

	Initial share 03
Avg Age	-0.0008
	(0.0003)
Share Female	-0.0086
	(0.007)
Share College	0.0207
	(0.014)
Share Manual Occupation	0.0096
	(0.009)
Share Services Occupation	0.0129
	(0.007)
Share Manufacturing	-0.004
	(0.002)
Average Wage	4.60E-07
	(1.08E-07)
N	936
R-sq	0.0436

*Note.*We pool 104 local labor market and 9 origin regions. Regressions include an origin region FE, but results are consistent to not controlling for origin FEs or running a separate regression for each origin. As covariates, we include average age, share of women, share of college graduates, share in manual and services occupations, share in manufacturing industry, and average wage. Key statistic for analysis is the R-squared.

G Additional Quantitative Results

G.1 Size of the Inflow of Immigrants

Table 23: Change in real wages for alternative counterfactuals

	Percent change in immigrant stock						
	0.1%	1%	5%	10%	20%	30%	50%
Real wages	0.001%	0.01%	0.06%	0.12%	0.24%	0.36%	0.58%
Homogeneous/Heterogeneous	0.82	0.88	0.90	0.89	0.89	0.89	0.89
Homogeneous (agg)/Heterogeneous	0.63	0.88	0.91	0.91	0.92	0.91	0.92
Aggregate Elasticity	4.154	4.216	4.224	4.206	4.203	4.202	4.185

*Note.*We compute real wage changes for different aggregate changes in the number of immigrants. The row "Homogeneous/Heterogeneous" presents the relative real wage changes between the homogeneous model and our baseline heterogeneous model. The row Homogeneous (agg)/Heterogeneous, computes the relative real wage changes between a homogeneous model and our baseline model, where the homogeneous model has the same aggregate elasticity than the one predicted by the heterogeneous model. The aggregate elasticity is the endogenous elasticity of substitution between immigrants and natives in the baseline heterogeneous model.

G.2 Homogeneous Model

This section presents the estimates of the parameters estimated by simulated method of moments for the homogeneous model, conditioning on $\hat{} = 4{:}28$, $\hat{} = 3{:}08$, and $\hat{}_x = 3{:}62$.

Table 24: Simulated vs data moments

Moment description	Simulated	Data	Moment description	Simulated	Data
Aggregate $s_{d;T}$	0.91	0.91	GDP per capita Row to Germany	0.32	0.32
Aggregate $s_{d;NT}$	0.93	0.93	Share of firms exporting, T	0.37	0.37
$Var(log(rev_j)js_{d;j}; exporter_j)$, T	1.38	1.38	E(Export to Domestic Rev$_j$), T	0.79	0.79
$Var(log(rev_j)js_{d;j})$, NT	1.29	1.29	$E(s_d)$	0.93	0.93

Table 25: Parameter estimates using simulated method of moments

Parameter description	Parameter	Estimate	Parameter description	Parameter	Estimate
Share of natives, T	$_T$	0.82	Productivity in RoW	$_x$	1.64
Share of natives, NT	$_{NT}$	0.84	Fixed cost of exporting	f_g	0.014
Dispersion in $_j$, T	$_{;T}$	1.03	Iceberg trade cost		1.55
Dispersion in $_j$, NT	$_{;NT}$	0.38	Elasticity s_d to n		0.014

G.3 Homogeneous Model with aggregate elasticity

This section presents the estimates of the parameters estimated by simulated method of moments for the homogeneous model, conditioning on the aggregate elasticity of substitution implied by the heterogeneous model ($\hat{\ } = 4.20$) and, as before, $\hat{\ } = 3.08$, and $\hat{\ }_x = 3.62$. We compute the aggregate elasticity of substitution implied by the heterogeneous model as the weighted average of the elasticity in the labor market for tradable and for non-tradable sector. The weights are given by the number of firms in each sector and equal to 0.5. The elasticity in each labor market is computed as follows:

$$= \frac{d \ln L_g / L_{g,x}}{d \ln w_{g,x} / w_g}$$

Table 26: Simulated vs data moments

Moment description	Simulated	Data	Moment description	Simulated	Data
Aggregate $s_{d,T}$	0.91	0.91	GDP per capita Row to Germany	0.32	0.32
Aggregate $s_{d,NT}$	0.93	0.93	Share of firms exporting, T	0.37	0.37
$Var(log(rev_j)\|s_{d,j}, exporter_j)$, T	1.38	1.38	E(Export to Domestic Rev$_j$), T	0.79	0.79
$Var(log(rev_j)\|s_{d,j})$, NT	1.29	1.29	$E(s_d)$	0.92	0.93

Table 27: Parameter estimates using simulated method of moments

Parameter description	Parameter	Estimate	Parameter description	Parameter	Estimate
Share of natives, T	$_T$	0.82	Productivity in RoW	$_x$	1.64
Share of natives, NT	$_{NT}$	0.84	Fixed cost of exporting	f_g	0.008
Dispersion in $_j$, T	$_{,T}$	1.03	Iceberg trade cost		1.56
Dispersion in $_j$, NT	$_{,NT}$	0.38	Elasticity s_d to n		0.014