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OPENING THE FLOODGATES: PARTIAL AND GENERAL EQUILIBRIUM ADJUSTMENTS TO LABOR IMMIGRATION*

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We investigate the impact of a large immigration shock on occupational wages. We develop a general equilibrium model where individuals sort into occupations and confront testable hypotheses with data. To identify the effect of the labor supply shock, we introduce a novel instrument that exploits that immigrants systematically sort into different occupations than natives. We study the immigration wave to Norway after the Eastern enlargement and find that immigration led to lower relative occupational wages. A quantification of the general equilibrium shows welfare effects of immigration close to zero for natives, but negative effects for the preexisting population of immigrants.

1. Introduction

What is the impact of a large immigration induced labor supply shock on occupational wages and income in partial and general equilibrium? Although many studies have analyzed the wage impacts of immigration (Dustmann et al., 2016), there is still scant evidence on the occupational level adjustments of both wages and employment. This article fills this gap in the literature by developing a novel theoretical and empirical methodology that provides new empirical evidence on the impact of immigration on occupational wages in partial and general equilibrium.

Our starting point is a large wave of migrants to Norway following the 2004 and 2007 enlargements of the EU, which extended the common European labor market to include roughly 100 million individuals from the EU accession countries.[1] With real wages among the highest, and unemployment among the lowest, in Europe, Norway became a popular destination for labor migrants. Over the ensuing decade, Norway stands out among the developed countries as the country that received the largest inflow of migrants relative to country size. According to OECD data, the share of foreign-born relative to total population increased from 7.8% to 14.3%, a greater increase compared to all other OECD countries except Luxembourg.[2] In addition to the sheer magnitude of the immigration shock, the Norwegian case is particularly useful to study since the policy change was exogenous. As a part of the single

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[1] The EU accession countries are: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia (2004) and Bulgaria and Romania (2007). Norway is a member of the European Economic Area (EEA) and therefore part of the EU single market. Norway had few transitional restrictions on immigration from the accession countries compared to most EU countries (Dølvik and Eldring, 2008).

[2] See OECD Indicator of Foreign-born population; doi: 10.1787/5a368e1b-en; accessed on 5 May 2017.

market, but not a member of the EU, Norway was bound to adopt EU legislation without representation in the European Parliament and Commission. The policy change was instant, comprehensive, and externally imposed, providing a unique setting to study the impact of a labor supply shock.

We develop a general equilibrium model with a labor market consisting of many different occupations. On the labor demand side, firms hire workers in different occupations in order to produce. Occupations are imperfect substitutes, and as such firms will demand less of a certain occupation if the prevailing occupational wage rises. On the labor supply side, individuals sort into occupations governed by a Roy-type model, in the spirit of Lagakos and Waugh (2013), where their choice is determined by the individuals' idiosyncratic occupation-specific preferences and wages. In addition, their occupation choice may depend on their country background; workers born in a specific foreign country may be more likely to prefer certain occupations, all else equal. These differences in preferences may arise due to various degrees of mismatch between occupation characteristics and worker skills. For example, some occupations may require advanced local language skills, making them less attractive to individuals from linguistically distant countries. We document the existence of differences in sorting patterns for natives and immigrants.

We then proceed to estimating the partial equilibrium effect of the labor supply shock. We take the model to the data using high-quality and detailed administrative Norwegian data that includes employment and wages for every 7-digit occupation code and for workers from every source country, over the period 2003–2014. The labor demand side of the model delivers an estimable equation relating occupational wage growth to the labor supply shock, where the estimated elasticity is the inverse of the elasticity of substitution across 7-digit occupations. Of course, the ordinary least squares estimate is biased because high wage growth occupations also tend to attract immigrants. We therefore need an instrument. According to our model, employment growth in an occupation is governed by two factors. The first factor is the weighted average increase in labor supply from various source countries, where the weights are the initial immigrant shares for each country. Intuitively, if workers born in x initially sort into occupation y, then immigration from x will increase employment in occupation y relative to other occupations. The second factor is changes in relative occupational wages. In the model, the first component is exogenous with respect to wage growth, while the second factor is endogenous. We therefore use the first factor as our instrument for occupational labor supply shocks. The instrument resembles a standard Bartik-style instrument. However, the traditional approach uses variation across regions and source countries (past settlements), while we use the pre-shock distribution of immigrants across occupations and source countries. The past settlements strategy is based on the enclave hypothesis that new immigrants locate in the same regions as previous immigrants from the same source country. Our choice of instrument relies on the observation that there is substantial persistence in sorting of occupation choice among immigrants: Individuals migrating from a given country tend to sort into the same occupations as individuals migrating from the same country five years earlier.

The exclusion restriction of the instrument may be violated if, for example, immigrant intensive occupations have different wage growth even in the absence of immigration. We address this concern by controlling for a vector of occupational characteristics such as initial skill intensity and wages, as well as unobserved occupational trends by including fixed effects for the first digit of the occupation code. We also test for pre-trends by regressing wage growth on the instrument in the period *before* 2005. Reassuringly, we find no such relationship in the pre-period.

Our analysis confirms significant and economically important movements in relative occupational wages. The estimate implies that the wage growth of occupations highly exposed to the labor supply shock was 3% lower than the wage growth of occupations with low exposure (comparing the 90th versus 10th percentile of the instrument) over the 2005–2014 period.

We then proceed to quantifying the general equilibrium effect of the labor supply shock. Although the reduced form approach allows us to identify the wage impact of increased labor supply, it does not account for the wage impact of increased labor *demand* driven by immigrants raising aggregate product and labor demand. To address the real wage and income effects of the labor supply shock, we perform a simple quantification of our model, where we conduct a counterfactual analysis of the labor supply shock. The results point to substantial real wage losses in some occupations (as labor supply increases), whereas other occupations get modest real wage gains (as labor demand increases). Although real wages in some occupations decline, the average real income (expected utility) effect of the labor supply shock on natives is close to zero. The real income effect on the pre-existing population of immigrants, on the other hand, is negative. These asymmetric effects for natives and immigrants are related to the sorting patterns emphasized above: natives are more likely work in occupations that are more insulated from immigration, whereas immigrants are less likely to do so.

This article makes three main contributions. First, we focus on wage adjustments for narrowly defined occupations. This allows us to zoom in on and observe labor market outcomes for exactly those parts of the labor market that were exposed to the immigration shock.[3] Second, we propose an instrumental variable and identification strategy based on the initial sorting pattern into occupations, which turns out to be a powerful instrument for labor supply. This may be useful for future research in contexts where a conventional past settlement instrumental variable is not applicable (see Altonji and Card, 1991).[4] Third, we develop a simple economic framework that ties together both the partial and equilibrium effect of immigration. The framework delivers testable reduced-form expressions derived from general equilibrium theory that map directly to the variables in our data set. We believe that the general equilibrium model and empirical methodology can be used in many different contexts to analyze the effect of migration following major disruptions—both for other time periods and other countries.

Our article relates to the extensive literature on how immigration affects the wage structure in the economy, see, for example, Borjas (2003), Dustmann et al. (2005), and Manacorda et al. (2012). Recent contributions also include Monras (2020) and Ottaviano et al. (2013), while Dustmann et al. (2016) offer a review of different approaches and provides a framework for discussing why parameter estimates differ and how they should be interpreted.

However, there are only a handful of papers exploring the relationship between immigration and occupation adjustments. Our focus on occupation adjustments is possible due to the access to very rich and detailed administrative data for the universe of employees in Norway. It allows us to develop an IV strategy that relies on occupational variation in immigration intensity, which complements the standard IV strategy in the literature that rather relies on regional variation. Depending on the context, one or the other techniques may be more suitable.

This article also differs from the majority of contributions to the literature as we extend the empirical analysis with a counterfactual analysis that sheds lights on the general equilibrium effects of immigration. It shows that product market, and in turn labor demand, effects may work in the opposite direction and therefore dampen, or compensate completely, the direct negative effects of immigration on real wages.

Our work is most closely related to the recent study by Burstein et al. (2020) who examine the impact of immigration on occupational adjustments, emphasizing the role of occupation tradability. However, while they build on Card (2001) and exploit variation in immigrant intensity within and across local labor markets, our identification strategy exploits variation in immigrant intensity across highly disaggregated occupational groups. Our study is also related to Bratsberg and Raaum (2012), but their approach relies on variation in certification requirements across tasks and and they limit their analysis to one single sector in the economy. Hoen

[3] In contrast, the skill-cell approach normally observes outcomes for much more aggregate groups, for example, education-experience cells.

[4] In the Norwegian context, there was no regional ethnic enclaves prior to the immigration shock, implying that a past settlements Bartik instrument does not satisfy the relevance assumption.

(2020) uses similar data as us, but focuses purely on the impact of immigration on natives and relies furthermore relies on a different identification strategy. Peri and Sparber (2009) similarly acknowledge that occupations differ in the demand for communication skills, and investigate how the variation in skills across occupations encourages natives and immigrants to specialize in different occupations. Their study also differs from ours in their choice of identification strategy.

Less closely related to our work is a line of quantitative research where labor reallocation plays an important role in shaping the spatial distribution of activity. An exception is the study by Caliendo et al. (2021) that focus specifically on the EU enlargement and build a spatial dynamic general equilibrium model to examine the welfare effects of the enlargement. Although they have a rich quantitative model that takes into account both trade and immigration channels, they do not explore occupational adjustments.

The rest of the article is organized as follows. Section 2 describes the data and the immigration shock, while Section 3 develops the theoretical framework that guides the subsequent empirical analysis. Section 4 analyses the partial equilibrium impact of the labor supply shock, Section 5 presents the general equilibrium impact of the shock. Section 6 concludes.

2. DATA AND BACKGROUND

2.1. *Data.* The empirical analysis of the immigration shock is based on two data sets. The first data set is matched employer–employee data, which includes information on wages and occupations by person-firm-year. The Norwegian nomenclature (STYRK) for occupations is based on the International Standard Classification of Occupations (ISCO–88) prepared by ILO and further developed by the EU and provides us with 7-digit occupational codes.

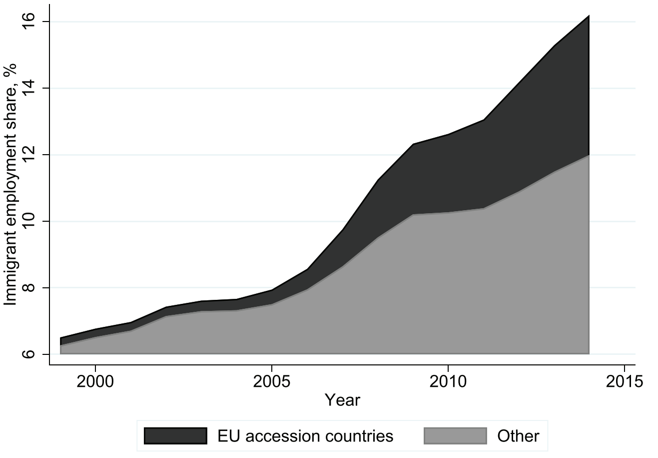
The second data set is demographic data about workers. Importantly, we observe the country of birth n for each worker. Workers born in other countries than Norway are defined as "immigrants." The demographics data also include information about workers' number of years of education, gender and age. In the empirical analysis, we will calculate the average of these variables for each occupation, and use them as occupational control variables.

Although we have data on most variables from 1999 onward, information on occupations is only available from the year 2003. As the immigration shock started in 2004, this limitation does not affect the main analysis, but it will have implications for the design of a falsification test. We return to this below.

We combine the two data sets and limit the analysis to occupations with more than 20 employees in 2003. This leaves us with 3,184 occupations that is used for the main analysis. The following key variables are used throughout the analysis: (i) occupational employment L_o is measured as the total man-years employed in occupation o.[5] (ii) Wages w_o are measured as total wage payments relative to L_o. (iii) The number of workers from country n in occupation o is L_{no}. We define the immigrant share as $\mu_{no} = L_{no}/L_o$, that is, the share of workers employed in occupation o originating from country n; and the occupation share as $\Pi_{no} = L_{no}/L_n$, that is, the share of employment in occupation o among workers from country n.

2.2. *Background.* We focus on a period characterized by high growth in immigration from the new EU member countries, starting with the EU Eastern enlargement in 2004. As shown in Figure 1, over the period 2004–2014 the share of immigrants in total employment rose from 8% to 16%. About 40% of the migrants came from the EU accession countries. Almost 70% of the population growth in Norway over this period was due to net immigration. Figure 1 shows that up until the Eastern enlargement of the EU, Norway had relatively few migrants from the accession countries. Before 2004, accession country citizens had limited access to the

[5] We include both worker-firm spells that continue over the whole year and spells lasting for less than a year, and weigh them according to duration. Both part- and full-time workers are included, weighted according to time worked.

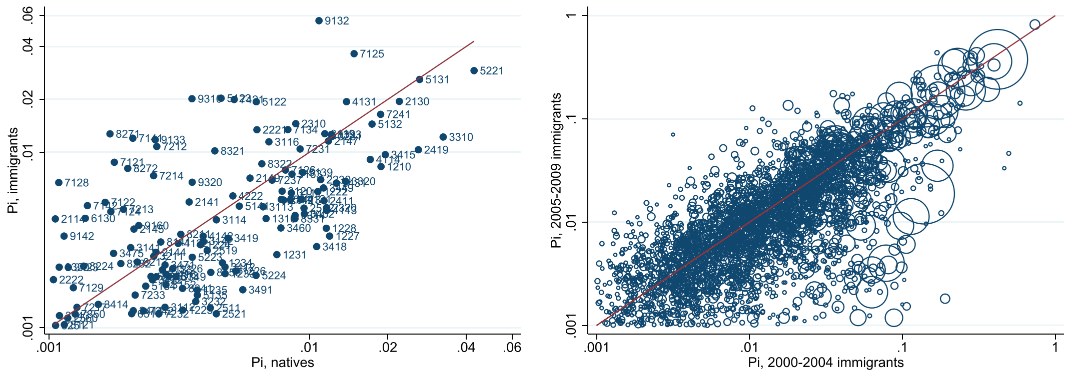


NOTES: The figure shows the share of immigrants in employment in percent over the period 1999–2014. The black area refers to employees from EU accession countries, whereas the gray area refers to all other immigrant employees.

FIGURE 1

IMMIGRANT EMPLOYMENT SHARE, 1999–2014

(a) (b)



NOTES: The left figure shows $\Pi_{no} = L_{no}/L_n$ in 2004 for $n =$ immigrants (y-axis) and natives (x-axis). The right figure shows Π_{no} for new immigrants entering between 2000 and 2004 (x-axis) and between 2005 and 2009 (y-axis), for all source countries n and occupations o. Circle size denotes employment L_{no} in 2000–2004. Axes on log scales. Occupations with $\Pi_{no} < 0.001$ are dropped. The unit of observation is a 4-digit occupation.

FIGURE 2

OCCUPATIONAL SORTING: NATIVES VERSUS IMMIGRANTS

Norwegian labor market. Work permits were provided via domestic employers in need of specialist competence, or on a temporary 3-month seasonal basis, typically for agricultural work.

Our analysis relies on heterogeneous sorting, that is, that occupational sorting differs across occupations and migrant groups. It is this variation that underlies both the identification strategy presented Section 4 and the model presented in Section 3. We end this section by documenting the extent of these differences in sorting.

The difference in occupational structure between natives and immigrants is displayed in the left panel of Figure 2. Since the figure has the occupation shares Π_{no} for natives on the x-axis and immigrants on the y-axis for different 4-digit occupation codes, all the points would to line up on the 45° line if natives and immigrants sort into the same occupations. We observe clear departures from this, for example, occupation 3310 (primary education teaching) and 2419 (public service administrative professionals) are biased toward natives, whereas 9132 (helpers and cleaners in offices) and 7125 (carpenters and joiners) are biased toward immigrants. The right panel of Figure 2 shows the persistence of sorting over time. Specifically, we have calculated Π_{no} for all country-occupation pairs for immigrants entering Norway between 2000 and 2004 (x-axis) and between 2005 and 2009 (y-axis). There is a clear pattern in the data: individuals migrating from n after 2005 tend to sort into the same occupations as individuals migrating from n five years earlier.[6]

3. THEORETICAL FRAMEWORK

We introduce a simple theoretical framework to guide the empirical framework in Section 4 and the quantitative general equilibrium analysis in Section 5. The main objective of the model is to allow us to analyze how an immigration shock affects employment and wages across occupations while accounting for general equilibrium effects. The labor supply side features a Roy–Frechet type model in the spirit of Lagakos and Waugh (2013) and Burstein et al. (2020), and follows the same approach as recent analyses of spatial distribution of activities, see, for example, Monte et al. (2018) and Redding (2016).[7]

3.1. *The Model.* Production uses labor from $o = 1, \ldots, O$ occupations. The economy is populated by a measure L of workers. Workers come from different source countries n, so that $\sum_n L_n = L$. Immigrants and natives are perfect substitutes within narrowly defined occupations.[8]

Production. Production requires the use of various occupations. The production function is given by

$$y = \left(\sum_o (\phi_o L_o)^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)}, \tag{1}$$

where L_o is employment of occupation o, ϕ_o is an occupation-specific demand/productivity shifter, and σ is the elasticity of substitution between occupations.

Labor Demand. Demand for occupation o is then

$$L_o = \phi_o^{\sigma-1} w_o^{-\sigma} P^{\sigma-1} W, \tag{2}$$

where W is the total wage bill, $W = \sum_o w_o L_o$ and P is the CES wage index, $P^{1-\sigma} = \sum_o (w_o/\phi_o)^{1-\sigma}$. The product market is perfectly competitive, and therefore P is also the price charged for the final good. The inverse labor demand function can then be written as

$$w_o = L_o^{-1/\sigma} \phi_o^{(\sigma-1)/\sigma} P^{(\sigma-1)/\sigma} W^{1/\sigma}. \tag{3}$$

3.2. *Occupational Choice and Labor Supply.* Workers come from various source countries n. Workers have idiosyncratic preferences for which occupation to work in and their utility is described by

$$U_{vno} = z_{vno} y_v, \tag{4}$$

[6] A simple regression of $\Pi_{no}^{2005-2009}$ on $\Pi_{no}^{2000-2004}$ yields a slope coefficient of 0.73 (s.e. 0.006).

[7] Other recent contributions using a Roy framework to model the choice of industry or occupation are Galle et al. (forthcoming) and Curuk and Vannoorenberghe (2017).

[8] Although previous research finds evidence of imperfect substitutability between natives and immigrants (see, e.g., Ottaviano et al., 2013), the evidence is mostly based on comparisons within broad skill groups or broad occupation groups, whereas this article focuses on narrowly defined occupation groups. We present empirical evidence consistent with perfect substitutability within occupations in Section 4.3.2.

where y_v is their consumption of y and z_{vno} is the idiosyncratic shock to the utility of worker v from country n who chooses occupation o. z_{vno} reflects the heterogeneity among workers in their preferences for occupations. We model the heterogeneity in z_{vno} following Eaton and Kortum (2002), and let the idiosyncratic shock be drawn independently from a Fréchet distribution

$$F_{no}(z) = e^{-A_{no}z^{-\kappa}},$$

where the shape parameter $\kappa > 1$ controls the dispersion of preferences. For a small κ, a worker typically has very different draws across occupations, while for a large κ the preference draws are relatively close to each other. The idiosyncratic preference shock implies that workers make different occupational choices even when faced with the same wages, and furthermore that wages may differ across occupations in equilibrium.

The scale parameter $A_{no} > 0$ controls the average preferences for occupation o for a worker from country n. A greater A_{no} implies that a high utility draw in occupation o from a worker from country n is more likely. Differences in average preferences may arise from various degrees of mismatch between skills required in occupation o and average skills offered by workers from country n. For example, the mismatch might be greater for workers from linguistically distant countries in occupations that require advanced mastering of the local language.

Each worker chooses an occupation that maximizes her ex ante utility, and she offers her entire labor endowment to this occupation. Given the preferences specified in Equation (4), the corresponding ex post indirect utility function is $U_{vno} = z_{vno}w_o/P$. Since indirect utility is a monotonic function of the draws z_{vno}, indirect utility also has a Fréchet distribution. Following Eaton and Kortum (2002), we exploit the properties of the distribution of indirect utility and express the probability that a worker from country n choose occupation o as

$$\Pi_{no} \equiv \frac{L_{no}}{L_n} = \frac{A_{no}w_o^{\kappa}}{\Phi_n^{\kappa}}, \tag{5}$$

where $\Phi_n^{\kappa} \equiv \sum_o A_{no}w_o^{\kappa}$. Due to differences in A_{no}, the shares Π_{no} will differ between natives and immigrants and between immigrant groups. As shown in Section 2.2, this assumption is supported by empirical evidence on heterogeneity in sorting. Total labor supply to occupation o can then be written as

$$L_o = \sum_n \Pi_{no}L_n. \tag{6}$$

3.3. *General Equilibrium.* In general equilibrium, the product market and all labor markets clear. Total expenditure equals total labor income,

$$Py = W = \textstyle\sum_o w_oL_o. \tag{7}$$

Labor demand must equal labor supply for each occupation o, that is, L_o from equation (2) must equal equation (6).

From the indirect utility function above, the expected utility for a worker from n across occupations is

$$\begin{aligned} \bar{U}_n &= \delta\left[\sum_o \frac{A_{no}w_o^{\kappa}}{P}\right]^{1/\kappa} \\ &= \frac{\delta}{P}\Phi_n, \end{aligned} \tag{8}$$

where $\delta = \Gamma((\kappa - 1)/\kappa)$ and $\Gamma(\cdot)$ denotes the Gamma function.

In this class of models, expected utility for a worker from n from choosing occupation o is the same across all occupations. On the one hand, higher wages in an occupation raises expected utility from choosing that occupation. On the other hand, higher wages attract workers with lower idiosyncratic utility draws z_{vno}, which reduces expected utility. With a Fréchet distribution of utility, these two effects cancel each other out. Therefore, although real wages w_o/P differs across occupations, expected utility (the expectation of $w_o z_{vno}/P$) is the same across occupations (for all workers from n).

3.4. *Comparative Statics.* Consider a shock to labor supply L_n, keeping all else constant. To simplify notation, we let $\hat{x} \equiv x'/x$ express the relative change in a variable, where x and x' denote the values in the initial and counterfactual equilibrium, respectively. Using "exact hat algebra" from Dekle et al. (2007), we can express the key relationships of the model in changes. Detailed derivations are provided in Appendix A.1. Based on Equation (6), we summarize the impact of a labor supply shock in the following proposition.

PROPOSITION. *Consider a shock to labor supply L_n, keeping all other parameters constant. The change in occupation o employment is*

$$\hat{L}_o = \sum_n \mu_{no} \hat{\Pi}_{no} \hat{L}_n, \tag{9}$$

where $\mu_{no} = L_{no}/L_o$ is the initial share of workers from n in occupation o, and $\hat{\Pi}_{no} = \hat{w}_o^\kappa / \sum_o \Pi_{no} \hat{w}_o^\kappa$.

According to Equation (9), occupation employment growth is determined by a weighted average of the supply shocks $\hat{L}_n$ and the relative wage adjustments $\hat{\Pi}_{no}$, where the weights are the initial immigrant shares μ_{no}. Therefore, the initial immigrant shares μ_{no} partly determine growth in occupation employment following an immigration shock. The impact of initial immigrant shares motivates our instrument in the empirical analysis. The economic intuition is that the initial shares convey information about the attractiveness of that occupation for new immigrants entering the labor market, that is, that the immigrant shares contain information about the relative A_{no} parameters.

Appendix A further shows that the general equilibrium can be solved in changes by iterating on the following fixed point:

$$\hat{w}_o^{1+\kappa/\sigma} = \left(\sum_n \mu_{no} \frac{\hat{L}_n}{\sum_o \Pi_{no} \hat{w}_o^\kappa} \right)^{-1/\sigma} \left(\sum_o \omega_o \hat{w}_o^{1-\sigma} \right)^{-1/\sigma} \left(\sum_o \omega_o \hat{w}_o^{1+\kappa} \sum_n \mu_{no} \frac{\hat{L}_n}{\sum_o \Pi_{no} \hat{w}_o^\kappa} \right)^{1/\sigma}, \tag{10}$$

where $\omega_o = w_o L_o / W$ is the initial income share of occupation o. After calculating the nominal wage, the relative change in the price index is simply $\hat{P} = \sum_o \omega_o \hat{w}_o^{1-\sigma}$, and the change in indirect utility is $\hat{U}_n = \hat{\Phi}_n / \hat{P}$, where $\hat{\Phi}_n^\kappa = \sum_o \Pi_{no} \hat{w}_o^\kappa$.

4. THE PARTIAL EQUILIBRIUM IMPACT OF THE LABOR SUPPLY SHOCK

In this section, we estimate the partial equilibrium effect of the labor supply shock on occupational wages. We study adjustments over the period 2005–2014 (i.e., a long first difference instead of annual changes). This time period captures the first and most prominent wave of immigrants that moved to Norway following the EU Enlargement, see Figure 1. In Section 5, we provide an analysis of the general equilibrium effects of the labor supply shock.

4.1. *Empirical Specification and Identification.* Our point of departure is the inverse labor demand equation (3), which states that wage growth is inversely related to employment growth. Taking logs and expressing the relationship in changes over the period 2005–2014 yields

$$\Delta \ln w_o = \alpha - \frac{1}{\sigma}\Delta \ln L_o + \epsilon_o, \tag{11}$$

where $\alpha = ((\sigma - 1)\ln \hat{P} + \ln \hat{W})/\sigma$ is a general equilibrium term and where the structural interpretation of the error term is the demand shifter, $\epsilon_o = [(\sigma - 1)/\sigma]\Delta \ln \phi_o$, which is potentially correlated with employment L_o. Log wages are computed as the log of total wage payments relative to total man-years employed in occupation o. The regression coefficient identifies $1/\sigma$, the inverse of the elasticity of substitution between narrowly defined occupations.

Identification. Estimating this demand elasticity without an instrument is impossible, as high wage growth occupations are also likely to attract workers. When employment shocks across occupations are driven by immigrants, we expect them to be positively correlated with wage growth (i.e., the error term), producing a positively biased estimate. Our instrument is inspired by the Proposition in Section 3.4, which states that labor supply to occupation o is determined by the weighted average of (a) the source country-specific labor supply shocks and (b) the relative wage adjustments, where the weights are the initial immigrant shares for each source country. The first component (a) is exogenous with respect to wage growth, both because the increase in country-specific labor supply, L_n, was driven by the elimination of migration barriers in Europe, and because the immigrant shares, μ_{no}, are measured before the shock to labor supply. The second component (b) is clearly endogenous because workers are attracted to occupations with higher wage growth. Therefore, our proposed instrument is

$$\Delta \ln L_o^{IV} = \sum_n \mu_{no}\Delta \ln L_n, \tag{12}$$

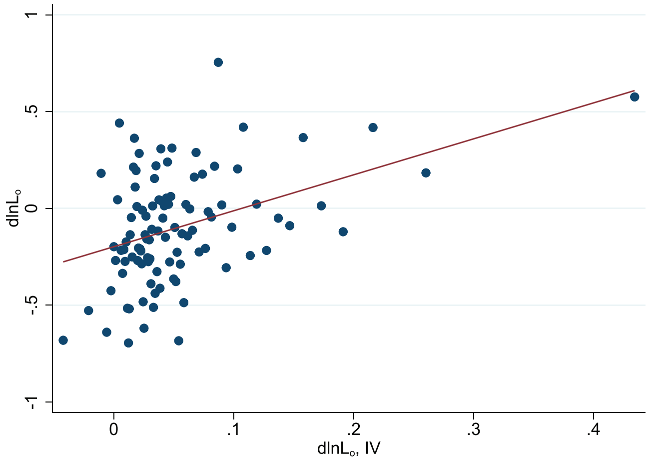
where the initial immigrant shares, μ_{no}, are calculated using 2004 data.

Our instrument exploits the fact that occupations differ in terms of (mis)match between occupations o and workers from source country n, and that this induces heterogeneous sorting of workers to different occupations. Empirically, this is clearly the case in the Norwegian labor market, as shown in Section 2.2 above.

Since the shares μ_{no} are time-invariant, our instrument is potentially subject to the criticism of the "past settlement" strategy when the inflow of immigrants is autocorrelated, such that the impact of immigration today also captures the longer term adjustments to previous inflows (Jaeger et al., 2018). As the immigration shock we study was instant, comprehensive and externally imposed, we expect this bias to be of minor importance.

The exclusion restriction of our instrument is that $\Delta \ln L_o^{IV}$ is only related to wage growth through the impact of greater labor supply. A potential concern is that $\Delta \ln L_o^{IV}$ is also related to other occupation characteristics such as skill intensity, and it may happen that wage growth is correlated with these characteristics. We deal with this issue by controlling for a wide range of initial occupational characteristics: skill intensity (measured as average years of education), the log average wage, experience (measured as average age), and the share of females in occupation o. In addition, we also report results with 1-digit occupation fixed effects, so that identification is only driven by within 1-digit occupation changes in L_o^{IV}.

4.2. *Empirical Results.* To investigate the effect of the immigration shock on occupation wages, we estimate equation (11) and use $\Delta \ln L_o^{IV}$ as an instrument for $\Delta \ln L_o$. Figure 3 illustrates the first-stage regression using a binned scatterplot, after controlling for the set of occupational characteristics described above. The instrument is strongly correlated with the endogenous variable and the first stage F-statistic is 24.14.



NOTES: The figure shows the binned scatterplot of $\Delta \ln L_o^{IV}$ and $\Delta \ln L_o$. $\Delta \ln L_o^{IV}$ is grouped into 100 equal-sized bins, and the figure shows the scatterplot of the mean of $\Delta \ln L_o^{IV}$ and $\Delta \ln L_o$ within each bin. The x and y variables are residualized on controls before plotting. The controls are average years of education, average wage, share of females, average age of the workforce in the initial year (2004). Changes refer to the time period 2005–2014. The unit of observation is a 7-digit occupation.

FIGURE 3

FIRST-STAGE REGRESSION

TABLE 1
LABOR SUPPLY AND WAGES. 2SLS AND OLS ESTIMATES

Dep. var. $\Delta \ln w_o$	2SLS				OLS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta \ln L_o$	-0.12^a	-0.11^a	-0.12^a	-0.11^a	0.01^c	0.01^c	0.02^b	0.02^b
	(0.04)	(0.03)	(0.04)	(0.04)	(0.01)	(0.01)	(0.01)	(0.01)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
1-dig. occ. FE	No	No	Yes	Yes	No	No	Yes	Yes
	First-Stage Estimates							
$\Delta \ln L_o^{IV}$	1.90^a	2.16^a	1.91^a	1.76^a				
	(0.40)	(0.41)	(0.39)	(0.40)				
Observations	3184	3184	3184	3184	3184	3184	3184	3184

NOTE: Robust standard errors in parentheses. Changes refer to the time period 2005–2014. The unit of observation is a 7-digit occupation. The controls are: average years of education, average age, the share of female workers, and the log wage (initial values). Regressions are weighted by initial log employment. ^{a} $p < 0.01$, ^{b} $p < 0.05$, ^{c} $p < 0.1$.

The impact of the labor supply shock on occupational wages is reported in Table 1. Columns (1)–(4) present the 2SLS results, while columns (5)–(8) present the OLS results. Columns (1) and (5) do not include any controls or fixed effects, columns (2) and (6) control for occupational characteristics while columns (3)–(4) and (7)–(8) also include 1-digit occupation fixed effects. The 2SLS estimates show that increased labor supply caused a decline in relative occupational wages. The empirical results are robust to the inclusion of fixed effects and occupational controls. Interestingly, the IV results are highly significant and negative, while the OLS results are positive and close to zero, consistent with the hypothesis that immigrants tend to more (less) frequently enter occupations with high (low) wage growth.

Economic magnitudes. According to the model, the regression coefficient equals $-1/\sigma$, where σ is the elasticity of substitution between occupations. The point estimate is -0.12 across specifications, which yields an elasticity of substitution of roughly 8. Our results

TABLE 2

LABOR SUPPLY AND WAGES. 2SLS ESTIMATES. FALSIFICATION TEST

Dep. var. $\Delta \ln w_o^{1999-2003}$	(1)	(2)	(3)	(4)
$\Delta \ln L_o$	-0.08^a	−0.01	−0.00	−0.03
	(0.02)	(0.02)	(0.02)	(0.02)
Controls	No	Yes	Yes	No
1-dig. occ. FE	No	No	Yes	Yes
	First-Stage Estimates			
$\Delta \ln L_o^{IV}$	1.87^a	2.14^a	1.88^a	1.75^a
	(0.40)	(0.40)	(0.39)	(0.40)
Observations	3150	3150	3150	3150

NOTE: Robust standard errors in parentheses. The change in $\Delta \ln L_o$ and $\Delta \ln L_o^{IV}$ refer to the time period 2005–2014. The change in $\Delta \ln w_o^{1999-2003}$ refer to the time period 1999–2003. The unit of observation is a 7-digit occupation. For the years 1999–2002, occupation assignment is extrapolated from the 2003 assignment (the first year available with occupation data). The controls are: average years of education, average age, the share of female workers, and the log wage (initial values). ^{a} $p < 0.01$, ^{b} $p < 0.05$, ^{c} $p < 0.1$.

indicate that a 10% increase in labor supply to a given occupation reduces wages by 1.2%. Put in the context of the existing literature, these results are in line with studies finding an adverse impact of immigration on wages, however, our estimated elasticity is smaller (in absolute value) compared to, for example, Borjas (2003), who finds that a 10% increase in supply reduces wages by 3–4%, and estimates reported by previous Norwegian studies of relative wage effects (Bratsberg and Raaum, 2012; Bratsberg et al., 2014; Hoen, 2020).

What were the economic magnitudes of the immigration shock? Splitting occupations into percentiles according to their exposure to the labor supply shock, we get that the predicted change in the labor supply (based on the first-stage regression) was 1% and 25% for the 10th and 90th percentile occupations, respectively. Based on our estimates, this suggests that the immigration shock caused a 3% decline in wages in the most exposed relative to least exposed occupations over the 2005–2014 period.[9]

Over the sample period, average log wages increased nominally by 43%. Therefore, although relative wages declined in response to the labor supply shock, even the most affected occupations experienced wage growth. We conclude that the migration shock led to economically substantial wage adjustments, where occupations highly exposed to immigration experienced significantly lower wage growth compared to less exposed occupations.

4.3. *Robustness and Discussion of Assumptions.* This section presents a number of robustness checks and discusses key assumptions in the article.

4.3.1. *Falsification test.* *Falsification test.* A potential concern is that immigrant intensive occupations, that is, occupations with a high $\Delta \ln L_o^{IV}$, are occupations with in general lower wage growth than other occupations—even after controlling for relevant occupational characteristics such as occupation skill-intensity. To address this concern, we perform a placebo test and regress the 1999–2003 change in log wages on employment growth between 2005 and 2014, using the same instrument as in the baseline model. As described in Section 2.1, occupation codes are missing in the employer–employee data for the years 1999–2002. We circumvent this by extrapolating a worker's 2003 occupation code to the years prior to 2003. Table 2 shows the 2SLS results for this placebo. Reassuringly, the 2SLS estimates are close to zero, showing that the employment in the post-shock period is not correlated with wage growth in the pre-period 1999–2003.

[9] Calculated as $(0.25 - 0.01) \times (-0.12)$ based on the results in Table 1.

TABLE 3
LABOR SUPPLY AND RELATIVE WAGES. 2SLS ESTIMATES

Dep. var. $\Delta \ln(w_o^{Immigrant}/w_o^{Native})$	(1)	(2)	(3)	(4)
$\Delta \ln L_o$	.02	-.00	.05	.10
	(.17)	(.12)	(.15)	(.18)
Controls	No	Yes	Yes	No
1-dig. occ. FE	No	No	Yes	Yes
Observations	2,712	2,712	2,712	2,712

NOTE: Robust standard errors in parentheses. Changes refer to the time period 2005–2014. The unit of observation is a 7-digit occupation. The controls are: average years of education, average age, the share of female workers, and the log wage (initial values). Regressions are weighted by initial log employment. $^a p < 0.01$, $^b p < 0.05$, $^c p < 0.1$.

4.3.2. *Substitutability between immigrants and natives.* Our theoretical framework is based on the assumption that immigrants and natives are perfect substitutes within narrowly defined occupations. Recent contributions to the literature often find imperfect substitutability between natives and migrants within similar broad skill or occupation groups (see, e.g., Manacorda et al., 2012; Burstein et al., 2020).[10] This section therefore provides supportive evidence for the assumption of perfect substitutability within narrowly defined occupations. When natives and immigrants are perfect substitutes, the occupational wage response should be identical for the two groups. Therefore, we estimate Equation (11) but replace the outcome variable $\Delta \ln w_o$ with the relative wage between natives and immigrants, $\Delta \ln w_o^{native} - \Delta \ln w_o^{immigrants}$. The results are presented in Table 3 for a different specifications with and without demographic controls and occupation fixed effects. The point estimates are close to zero, which is consistent with the hypothesis that the two groups are perfect substitutes within occupations. Appendix A.2 presents results for native and immigrant wages separately. The response on native wages are negative and significant, albeit with point estimates slightly smaller compared to the baseline results.

4.3.3. *Composition effects.* Our baseline measure of occupation wages w_o is total wage payments relative to total man-years L_o in occupation o. One concern is that the wage effects identified above reflect changes in the composition of the workforce. For example, immigration may lead to a younger or less educated workforce in occupations exposed to immigration as natives shift out of these occupations in response to the immigration shock. On the other hand, if low pay/skill workers are replaced by immigrants and leave the labor force, the average occupational wage will increase (Bratsberg and Raaum, 2012). Therefore, changes in composition can bias the estimate in both directions. We address this concern by constructing a residualized occupational wage that is purged of observable worker characteristics. Specifically, we estimate the following standard Mincer equation for each individual i over the full sample period,

$$\ln w_{it} = \alpha_t + \beta_1 Edu_{it} + \beta_2 Edu_{it}^2 + \beta_3 Age_{it} + \beta_4 Age_{it}^2 + \beta_5 Gender_i + \epsilon_{it},$$

where $\ln w_{it}$ is the log wage in year t, Edu_{it} is years of education, Age_{it} is age, and $Gender_i$ is the gender of worker i. We then take the weighted average of the residuals across all workers in occupation o.[11] The results are presented in Table 4. The point estimates are relatively sim-

[10] In studies based on a CES tree structure, for example, Manacorda et al. (2012), the degree of substitutability is defined within skill groups, often by education and age, or experience. When a labor supply shock from immigration is found to have more adverse effects on wages of earlier cohorts immigrants than on natives, the evidence suggests that the two groups are imperfect substitutes within skill group.

[11] The weights are the man-years L_i for worker i, implying that a worker spell only observed for one month in a given year is given by a 1/12 weight when calculating the average.

TABLE 4
LABOR SUPPLY AND WAGES. 2SLS ESTIMATES. RESIDUALIZED WAGES

Dep. var. $\Delta \ln w_o^{Res}$	(1)	(2)	(3)	(4)
$\Delta \ln L_o$	-0.08^b	-0.07^b	-0.08^b	-0.08^c
	(0.04)	(0.03)	(0.04)	(0.04)
Controls	No	Yes	Yes	No
1-dig. occ. FE	No	No	Yes	Yes

NOTE: $\ln w_o^{Res}$ refers to the weighted average of residualized wages from a Mincer regression of log wages on age, years of education (both squared), and gender. Robust standard errors in parentheses. Changes refer to the time period 2005–2014. The unit of observation is a 7-digit occupation. The controls are: average years of education, average age, the share of female workers, and the log wage (initial values). Regressions are weighted by initial log employment. $^a\ p < 0.01$, $^b\ p < 0.05$, $^c\ p < 0.1$.

TABLE 5
LABOR SUPPLY AND WAGES. ALTERNATIVE INSTRUMENT

Dep. var. $\Delta \ln w_o$	(1)	(2)	(3)	(4)
$\Delta \ln L_o$	-0.16^b	-0.11^a	-0.18^a	-0.21^b
	(0.07)	(0.04)	(0.06)	(0.09)
Controls	No	Yes	Yes	Yes
1-dig. occ. FE	No	No	Yes	Yes
	First-Stage Estimates			
$\Delta \ln L_o^{IV2}$	5.93^a	9.56^a	6.53^a	4.75^b
	(2.18)	(2.41)	(2.20)	(2.09)
Obs	3184	3184	3184	3184

NOTE: Robust standard errors in parentheses. Changes refer to the time period 2005–2014. The unit of observation is a 7-digit occupation. The controls are: average years of education, average age, the share of female workers, and the log wage (initial values). Regressions are weighted by initial log employment. $^a p < 0.01$, $^b\ p < 0.05$, $^c\ p < 0.1$.

ilar to the baseline results, but somewhat smaller. This suggests that the estimated wage impacts are not mainly driven by composition effects.[12]

4.3.4. *Alternative instrumental variable.* We end this section by introducing an alternative instrument for labor supply. Recall that the main instrument is based on the weighted average of country-specific labor supply shocks. Since the identifying variation to a large extent is driven by the removal of migration barriers for EU accession countries, we construct an alternative instrument that relies directly on the policy change:

$$\Delta \ln L_o^{IV2} = \sum_n \mu_{no} I[\text{EU Accession country}]_n,$$

where $I[\text{EU Accession country}]_n$ is an indicator variable for whether country n is an accession country or not. Intuitively, $\Delta \ln L_o^{IV2}$ only extracts the variation coming from the policy change itself, instead of using the full vector of country-specific labor supply shocks. Table 5 shows the 2SLS and first stage results when using the alternative instrument. The results are broadly similar to the main specification: The estimated elasticity is slightly more negative, and the first-stage estimates are also strong, especially after controlling for initial occupation characteristics.

[12] We have also estimated the model using residualized relative wages, $\Delta \ln(w_o^{Immigrant}/w_o^{Native})$, as the outcome variable. As in Table 3, we estimate coefficients close to zero.

TABLE 6
PARAMETER VALUES

Variable	
ω_o	Income share of occupation o
μ_{no}	Immigrant shares, L_{no}/L_o
Π_{no}	Occupation shares, L_{no}/L_n
$\hat{L}_n$	Relative change in country n immigration, $\hat{L}_n = L_{n2014}/L_{n2005}$
κ	3.23 (Cortes and Gallipoli, 2018)
σ	8 (estimated)

NOTE: All initial values refer to 2004 data.

5. THE GENERAL EQUILIBRIUM IMPACT OF THE LABOR SUPPLY SHOCK

Although the previous results inform us about the impact of the labor supply shock on relative wages, it does not capture the impact on real wages and welfare. The reason is that a reduced form approach can only identify relative effects, that is, the common effect of immigration across all occupations is not identified. However, immigration is likely to lead to more demand for both goods and labor. This section provides a complementary model-based analysis of the general equilibrium impact of the labor supply shock.

This section emphasizes a first-order general equilibrium effect: labor demand. As such, we abstract from other margins of adjustment, such as automation (Lewis, 2011) and offshoring (Olney and Pozzoli, 2021). We have chosen to ignore such adjustment because we lack well-identified parameters for these margins. We leave it to future research to add additional general equilibrium mechanisms to the quantitative framework.

We proceed by calibrating the general equilibrium model and calculating the counterfactual impact of the labor supply shock, holding all other parameters constant. Specifically, we examine the impact of an exogenous immigration shock that mirrors the observed increases in country-specific immigration $\hat{L}_n$ over the 2005–2014 period.[13] Recall from Section 3.4 that the relative change in general equilibrium wages can be calculated by iterating on the following fixed point:

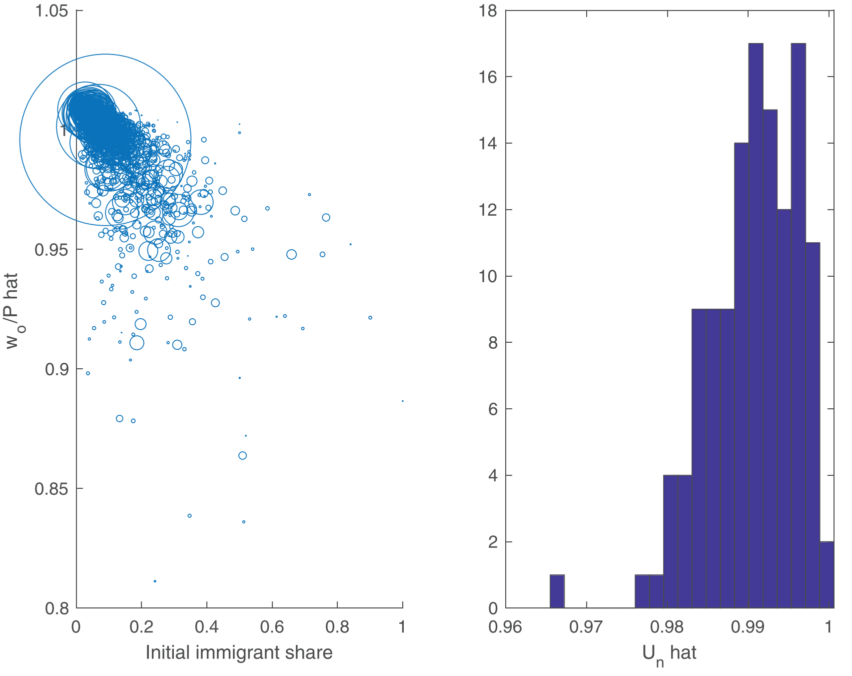
$$\hat{w}_o^{1+\kappa/\sigma} = \left(\sum_n \mu_{no} \frac{\hat{L}_n}{\sum_o \Pi_{no} \hat{w}_o^{\kappa}}\right)^{-1/\sigma} \left(\sum_o \omega_o \hat{w}_o^{1-\sigma}\right)^{-1/\sigma} \left(\sum_o \omega_o \hat{w}_o^{1+\kappa} \sum_n \mu_{no} \frac{\hat{L}_n}{\sum_o \Pi_{no} \hat{w}_o^{\kappa}}\right)^{1/\sigma}.$$

Solving the fixed point only requires data on initial (i) income shares ω_o, (ii) immigrant shares μ_{no}, (iii) occupation shares Π_{no}. All these variables are directly observed in our data, see Table 6. In addition, we require values for the elasticity of substitution σ and the labor supply elasticity κ in order to solve for the general equilibrium changes. σ was estimated in Section 4 to be $\sigma = 8$. The value of κ is not separately identified in this article, and we therefore rely on estimates from the previous literature ($\kappa = 3.23$ from Cortes and Gallipoli, 2018).

Results. We summarize the key comparative statics results for real wages and expected utility (real income) in Figure 4 focusing on differential effects across occupations and immigrant source countries. The left panel of Figure 4 shows the scatterplot between the initial immigrant share on the horizontal axis and real wage changes, $\hat{w}_o/\hat{P}$, across occupations on the vertical axis. The counterfactual analysis shows that real wages increase in some occupations, as final goods prices fall in response to the labor supply shock, whereas real wages fall in other occupations.[14] The real wage response is correlated with the occupation's initial exposure to immigration (i.e., the initial immigrant share).

[13] We do not increase native labor supply, that is, $\hat{L}_{Norway} = 1$. The results, however, are quantitatively very similar when also allowing native labor supply to change.

[14] The 90th and 10th percentile real wage change is 1.01 and 0.98, respectively.



NOTE: The left figure shows the scatterplot between initial immigrant share and $\hat{w}_o/\hat{P}$ across occupations. Circle size is determined by the initial income share of the occupation, ω_o. The right figure shows the density of $\hat{U}_n$ across source countries. The vertical axis denotes the number of occupations/source countries in each bin.

FIGURE 4

COUNTERFACTUAL CHANGE IN REAL WAGES AND EXPECTED REAL INCOME

The right panel of Figure 4 shows the density of indirect utility changes across workers' source countries, that is, $\hat{U}_n = \hat{\Phi}_n/\hat{P}$. The counterfactual results show that natives do not experience any change in indirect utility, that is, natives are in the far right of the histogram, while immigrants from all countries (immigrants already in Norway before the shock) experience a decline in indirect utility. This suggests that while real wages in some occupations decline, natives are less exposed to those occupations, and may also offset the negative impact by switching to higher wage occupations. We return to the role of occupation switching below. Existing immigrants, on the other hand, switch less to those occupations because their relative preferences (A_{no}) differ from those of natives.

Partial versus general equilibrium. We also aim to quantify the relative magnitude of the partial and general equilibrium effects of the immigration shock. To do so we rewrite the inverse labor demand equation (3) as

$$\frac{\hat{w}_o}{\hat{P}} = \hat{L}_o^{-1/\sigma} \times \left(\frac{\hat{W}}{\hat{P}}\right)^{1/\sigma}.$$

The term $\hat{L}_o^{-1/\sigma}$ is the partial equilibrium effect of the labor supply shock, whereas $(\hat{W}/\hat{P})^{1/\sigma}$ is the general equilibrium part. Our counterfactual results give us $(\hat{W}/\hat{P})^{1/\sigma} = 1.02$, suggesting that an occupation with zero immigration would get 2% higher real wages due to higher labor demand. We find that the positive general equilibrium effect is greater than the negative partial equilibrium effect for 73% of the occupations in our sample.[15]

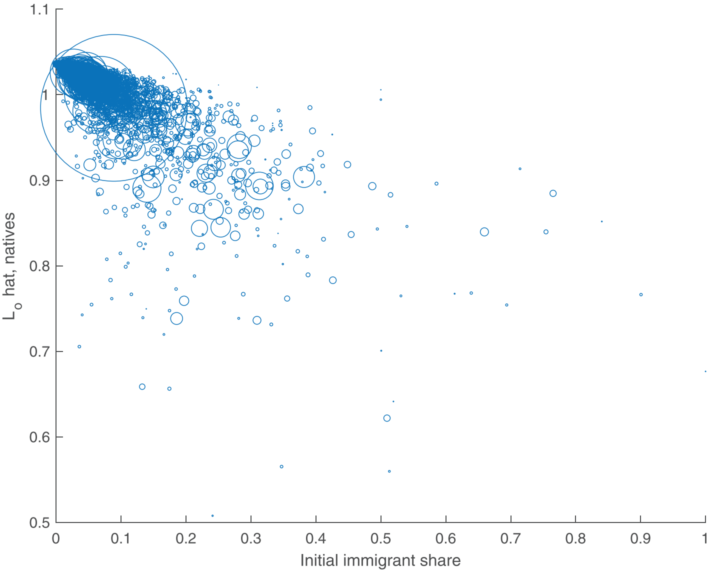
[15] Weighting occupations by the number of employees, the corresponding figure is 64%.

Table 7

WAGE INEQUALITY ACROSS OCCUPATIONS

	Initial	Counterfactual
P90/P10 ln w_o	2.21	2.23
Std(ln w_o)	0.35	0.35
P90/P10 ln w_o, employment weighted	2.02	2.02
Std(ln w_o), employment weighted	0.27	0.28

Note: All initial values refer to 2004 data.



Note: The figure shows the scatterplot between initial immigrant share and $\hat{L}_o^{native}$ across occupations. Circle size is determined by the initial income share of the occupation, ω_o.

Figure 5

OCCUPATION SWITCHING

Inequality. The results show that wages in some occupations decline. A potential hypothesis is therefore that wage inequality across occupations increase. We test this by calculating the dispersion in occupation wages in the initial and counterfactual equilibrium. Table 7 shows two measures of dispersion; the 90th to 10th percentile ratio and the standard deviation of log wages. The first two rows are unweighed while the last two are weighed by the number of employees in each occupation. Across all specifications, our results indicate that the labor supply shock does not increase wage inequality across occupations. This suggests that the labor supply shock was not uniform among low-wage occupations.

Occupation switching. Finally, we can use the calibrated model to characterize the reallocation of native employment across occupations in response to the shock. The result above that expected income for native workers did not change, indicates that natives switch occupations in response to the shock. Figure 5 shows the initial immigrant share on the horizontal axis versus the relative change in native employment, $\hat{L}_o^{native}$ on the vertical axis. For occupations with a small initial exposure to immigration, native employment increases by 5% ($\hat{L}_o^{native} = 1.05$). In occupations with high exposure, conversely, natives leave the occupation.

6. CONCLUSIONS

We have developed a novel methodology that allows us to investigate the impact of a major immigration shock on occupational wages. We find that there is substantial uneven sorting of workers from different country backgrounds to occupations, which in turn lead to a differential labor supply shock in the aftermath of the EU 2004 and 2007 expansions. Immigration is shown to have put downward pressure on wages in those occupations most exposed to the supply shock. We calibrate a general equilibrium model in order to assess the effect of immigration on real wages and welfare. The results from this quantitative simulation suggest that the real income effect of the immigrant shock was close to zero for natives, but negative for the pre-existing population of immigrants.

APPENDIX

APPENDIX A: DERIVATIONS

Consider a shock to aggregate labor supply L_n, keeping all other parameters constant. Let $\hat{x} \equiv x'/x$ express the relative change in a variable, where x and x' denote the values in the initial and counterfactual equilibrium, respectively.

The relative change in $\hat{\Phi}_n$ is

$$\hat{\Phi}_n^{\kappa} = \frac{\sum_o A_{no} w_o^{'\kappa}}{\sum_o A_{no} w_o^{\kappa}}$$

$$= \sum_o \frac{A_{no} w_o^{\kappa}}{\sum_o A_o w_o^{\kappa}} \hat{w}_o^{\kappa}$$

$$= \sum_o \Pi_{no} \hat{w}_o^{\kappa}, \tag{A.1}$$

where $\Pi_{no} = L_{no}/L_n$.

From Equation (6), the relative change in occupation labor supply is

$$\hat{L}_o = \sum_n \frac{\Pi'_{no} L'_n}{\sum_n \Pi_{no} L_n}$$

$$= \sum_n \frac{\Pi_{no} L_n}{\sum_n \Pi_{no} L_n} \hat{L}_n \hat{\Pi}_{no}$$

$$= \sum_n \mu_{no} \hat{\Pi}_{no} \hat{L}_n, \tag{A.2}$$

where $\mu_{no} = L_{no}/L_o$ and $\hat{\Pi}_{no} = \hat{w}_o^{\kappa}/\hat{\Phi}_n^{\kappa} = \hat{w}_o^{\kappa}/\sum_o \Pi_{no} \hat{w}_o^{\kappa}$.

Using Equation (7), the relative change in aggregate income is

$$\hat{W} = \frac{\sum_o w'_o L'_o}{\sum_o w_o L_o}$$

$$= \sum_o \omega_o \hat{w}_o \hat{L}_o, \tag{A.3}$$

where $\omega_o = w_o L_o / W$.

TABLE B.1
LABOR SUPPLY AND WAGES. 2SLS RESULTS FOR NATIVES AND IMMIGRANTS

Dep. var. $\Delta \ln w_o$	Natives				Immigrants			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta \ln L_o$	-0.07^c	-0.07^b	-0.07^c	−0.06	−0.18	−0.14	−0.08	−0.05
	(0.04)	(0.03)	(0.04)	(0.04)	(0.16)	(0.11)	(0.13)	(0.14)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
1-dig. occ. FE	No	No	Yes	Yes	No	No	Yes	Yes
Obs	3184	3184	3184	3184	2712	2712	2712	2712

NOTE: Robust standard errors in parentheses. Changes refer to the time period 2005–2014. The unit of observation is a 7-digit occupation. The controls are: average years of education, average age, the share of female workers, and the log wage (initial values). Regressions are weighted by initial log employment. $^a\, p < 0.01$, $^b\, p < 0.05$, $^c\, p < 0.1$.

Using the expression for the CES price index in the main text, the relative change is

$$\hat{P}^{1-\sigma} = \frac{\sum_o (w'_o/\phi_o)^{1-\sigma}}{\sum_o (w_o/\phi_o)^{1-\sigma}}$$

$$= \sum_o \frac{(w_o/\phi_o)^{1-\sigma}}{\sum_o (w_o/\phi_o)^{1-\sigma}} \hat{w}_o^{1-\sigma}$$

$$= \sum_o \omega_o \hat{w}_o^{1-\sigma}, \tag{A.4}$$

where we in the last step used the fact that the labor demand equation (2) can be rewritten as

$$w_o L_o = \frac{(w_o/\phi_o)^{1-\sigma}}{\sum_o (w_o/\phi_o)^{1-\sigma}} W.$$

From Equation (3), the relative change in (inverse) labor demand is

$$\hat{w}_o = \hat{L}_o^{-1/\sigma} \hat{P}^{(\sigma-1)/\sigma} \hat{W}^{1/\sigma}.$$

Replacing $\hat{L}_o$, $\hat{P}$ and $\hat{W}$ with Equations (A.2)–(A.4) above, we get

$$\hat{w}_o = \left(\sum_n \mu_{no} \frac{\hat{w}_o^\kappa}{\sum_o \Pi_{no} \hat{w}_o^\kappa} \hat{L}_n\right)^{-1/\sigma} \left(\sum_o \omega_o \hat{w}_o^{1-\sigma}\right)^{-1/\sigma} \left(\sum_o \omega_o \hat{w}_o^{1+\kappa} \sum_n \mu_{no} \frac{\hat{L}_n}{\sum_o \Pi_{no} \hat{w}_o^\kappa}\right)^{1/\sigma}.$$

Rearranging,

$$\hat{w}_o^{1+\kappa/\sigma} = \left(\sum_n \mu_{no} \frac{\hat{L}_n}{\sum_o \Pi_{no} \hat{w}_o^\kappa}\right)^{-1/\sigma} \left(\sum_o \omega_o \hat{w}_o^{1-\sigma}\right)^{-1/\sigma} \left(\sum_o \omega_o \hat{w}_o^{1+\kappa} \sum_n \mu_{no} \frac{\hat{L}_n}{\sum_o \Pi_{no} \hat{w}_o^\kappa}\right)^{1/\sigma},$$

which is identical to Equation (10) in the main text. The equilibrium $\hat{w}_o$ is a fixed point of the equation above.

APPENDIX B: ADDITIONAL RESULTS

Table B.1.

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