

TRADABILITY AND THE LABOR-MARKET IMPACT OF IMMIGRATION: THEORY AND EVIDENCE FROM THE UNITED STATES

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In this paper, we study how occupation (or industry) tradability shapes local labor-market adjustment to immigration. Theoretically, we derive a simple condition under which the arrival of foreign-born labor into a region crowds native-born workers out of (or into) immigrant-intensive jobs, thus lowering (or raising) relative wages in these occupations, and we explain why this process differs within tradable versus within nontradable activities. Using data for U.S. commuting zones over the period 1980–2012, we find—consistent with our theory—that a local influx of immigrants crowds out employment of native-born workers in more relative to less immigrant-intensive nontradable jobs, but has no such effect across tradable occupations. Further analysis of occupation labor payments is consistent with adjustment to immigration within tradables occurring more through changes in output (versus changes in prices) when compared to adjustment within nontradables, thereby confirming our model’s theoretical mechanism. We then use the model to explore the quantitative consequences of counterfactual changes in U.S. immigration on real wages at the occupation and region level.

KEYWORDS: Immigration, tradability.

1. INTRODUCTION

HOW DO THE LABOR MARKETS impacts of immigration differ across workers within an economy? The literature has alternatively treated such impacts as varying at the national level according to a worker’s skill level (e.g., [Borjas \(2003\)](#), [Ottaviano and Peri \(2012\)](#)), at the regional level according to the attractiveness of a worker’s local labor market to arriving immigrants (e.g., [Altonji and Card \(1991\)](#), [Card \(2001\)](#)), at the sectoral level depending on whether or not a worker produces tradable manufactured goods or nontradable services (e.g., [Dustmann and Glitz \(2015\)](#)), and at the occupational level depending on whether or not requirements in a worker’s job (e.g., language, manual labor, math aptitude) are relatively favorable or unfavorable to the foreign-born ([Peri and Sparber](#)

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(2009), Hunt and Gauthier-Loiselle (2010)). Although we now know that impacts vary by skill, region, sector, and occupation, we know little about how effects across these dimensions interact to determine the employment and wage responses of native workers to an inflow of immigrants.

In this paper, we present theoretical analysis and empirical evidence showing how variation within regions in the tradability and foreign-labor-employment intensity of occupations, and across regions in the exposure to immigrant inflows shape how immigration affects native-born workers. To preview our approach, we consider the impact of an inflow of foreign-born labor in a U.S. region on employment and wages of U.S. native-born workers across more relative to less immigrant-intensive occupations, and examine how adjustment to labor inflows differs according to the tradability of occupations. Although textile production and housekeeping, for instance, are each intensive in immigrant labor, textile factories can absorb increased labor supplies by expanding exports to other regions (with small corresponding price reductions) in a way that housekeepers cannot. We derive a theoretical condition under which the arrival of foreign-born labor crowds native-born workers into or out of immigrant-intensive jobs and explain why this process differs within the sets of tradable tasks (e.g., textiles) and nontradable tasks (e.g., housekeeping). Empirically, we find support for our model's implications using cross-region and cross-occupation variation in changes in labor allocations, total labor payments, and wages for the United States between 1980 and 2012. Finally, we use our empirical estimates to calibrate our model in order to conduct counterfactual exercises that quantitatively examine the impact of changes in immigration on real wages both across regions and across occupations within each region.

Our model has three main ingredients. First, each occupation's output is produced using immigrant and native labor, where the two types of workers differ in their relative productivities across occupations and are imperfectly substitutable within occupations. Second, heterogeneous workers select occupations (Roy (1951)), creating upward-sloping labor-supply curves. Third, the elasticity of demand facing a region's occupation output with respect to its local price differs endogenously between more- and less-traded occupations. In this framework, the response of occupational wages and employment to immigration is shaped by two elasticities: the elasticity of local occupation output to local prices and the elasticity of substitution between native and immigrant labor within an occupation. When the elasticity of local occupation output to local prices is low, the ratio of outputs across occupations is relatively insensitive to an inflow of immigrants. Factors reallocate away from immigrant-intensive occupations, in which case foreign-born arrivals crowd the native-born out of these lines of work. By contrast, low immigrant-native substitutability results in crowding in. Because factor proportions within occupations are insensitive to changes in factor supplies, market clearing requires that factors reallocate toward immigrant-intensive jobs.¹ In general, native-born workers are crowded out by an inflow of immigrants if and only if the elasticity of substitution between native and immigrant labor within each occupation is greater than the elasticity of local occupation output to local prices. Because each occupation faces an upward-sloping labor-supply curve, crowding out (in) is accompanied by a decrease (increase) in the wages of native workers in relatively immigrant-intensive jobs.

¹This is the classic Ryczynski (1955) effect, derived under fixed output prices, in which changes in factor supplies draw native labor into expanding sectors, which obviates the need for changes in wages. Empirical evidence on this mechanism is mixed (Hanson and Slaughter (2002); Gandal, Hanson, and Slaughter (2004); and Gonzalez and Ortega (2011)). Foreign labor appears to be absorbed by within-industry rather than between-industry labor reallocation (Card and Lewis (2007); Lewis (2011); and Dustmann and Glitz (2015)).

The tradability of output matters in our model because it shapes the elasticity of local occupation output to local prices. The prices of more-traded occupations are (endogenously) less sensitive to changes in local output. In response to immigration, the increase in output of immigrant-intensive occupations is larger and the reduction in price is smaller for tradable than for nontradable tasks. The crowding-out effect of immigration on native-born workers is systematically weaker (or, equivalently, the crowding-in effect is stronger) in tradable than in nontradable jobs. Since factor reallocation and wage changes are linked by upward-sloping occupational-labor-supply curves, an inflow of immigrants causes wages of more immigrant-intensive occupations to fall by less (or to rise by more) within tradables than within nontradables. Because these results on greater crowding out of natives by immigrants within nontradables (compared to tradables) involve comparisons across native workers within a region, they do not imply that native workers in immigrant-intensive jobs within nontradables must lose from immigration.

We provide empirical support for the adjustment mechanisms in our model by estimating the impact of increases in local immigrant labor supply on the local allocation of domestic workers across occupations in the United States. We instrument for immigrant inflows into an occupation in a local labor market following [Card \(2001\)](#). Using commuting zones to define local labor markets, measures of occupational tradability from [Blinder and Krueger \(2013\)](#) and [Goos, Manning, and Salomons \(2014\)](#), and data from Ipums over 1980–2012, we find that a local influx of immigrants crowds out employment of U.S. native-born workers in more relative to less immigrant-intensive occupations within nontradables, but has no such effect within tradables. Additional support for the adjustment mechanism in our framework comes from occupation total labor payments, which in our model are proportional to occupational revenue. A regional inflow of foreign labor leads to a larger increase in labor payments for immigrant-intensive occupations in tradables when compared to nontradables, which is consistent with tradable occupations adjusting relatively more through changes in local output and nontradable occupations adjusting relatively more through changes in local prices. Analysis of wage changes in response to immigration provides further support for our mechanism.

The empirical estimates guide parameterization of an extended version of our model, which allows for geographic labor mobility (e.g., [Borjas \(2006\)](#), [Cadena and Kovak \(2016\)](#)), and relaxes restrictions (e.g., small open economy) used to obtain our analytic results. We conduct counterfactual analyses to demonstrate numerically that our theoretical results are robust to a range of generalizations and to evaluate how immigration affects real wages both across regions and across occupations within each region. In one exercise, motivated by recent policy debates, we reduce the number of immigrants from Latin America, who tend to have low education levels and to cluster in specific U.S. regions. Unsurprisingly, the average wage of low-education relative to high-education native-born workers rises by more in high-settlement cities such as Los Angeles than in low-settlement cities such as Pittsburgh. More distinctively, for both education groups this shock raises wages for native-born workers in more-exposed nontradable occupations (e.g., house-keeping) relative to less-exposed nontradable occupations (e.g., firefighting) by much more than for similarly differentially exposed tradable jobs (e.g., textile-machine operation versus technical support staff). Regarding welfare, reducing immigration lowers real wages for native-born workers except in the most immigrant-intensive nontraded jobs in the most-exposed regions. In many commuting zones (CZ), the within-CZ variation in wage changes across occupations dwarfs the variation in average wage changes across CZs, which highlights the new sources of worker exposure to immigration elucidated by our framework.

A second counterfactual exercise, in which we double high-skilled immigration, clarifies how the geography of labor-supply shocks conditions labor-market adjustment. Because the spatial correlation of changes in occupation labor demand is higher in response to high-skill immigration than in response to Latin American immigration, adjustment within tradables more closely resembles adjustment within nontradables in the former case when compared to the latter case. For the nontradable–tradable distinction in adjustment to be manifest, regional labor markets must be differentially exposed to a particular shock.

The quantitative analysis also allows us to evaluate alternative explanations for our empirical result on greater immigrant crowding out of natives within tradables relative to within nontradables. One is that crowding out occurs because immigrant–native substitution elasticities are higher in nontradable occupations than in tradables, rather than because the price elasticity of output is lower in nontradables than in tradables. If we set the immigrant–native substitution elasticity to be higher in nontradables than in tradables, there is stronger immigrant crowding out within nontradables than within tradables but there are also counterfactual changes in total labor payments. Other explanations for stronger immigrant crowding out within nontradables, such as relatively high factor adjustment costs or low supply elasticities in tradables, would have to confront the observation that over time employment shares change by more across tradable jobs than across nontradable jobs.

Many scholars have considered how immigration and output tradability interact. [Dustmann and Glitz \(2015\)](#) find that in response to an influx of immigrants, native wages fall in nontradables (nonmanufacturing) but not in tradables (manufacturing); [Peters \(2017\)](#) finds that the manufacturing share of employment rises in regions that are more exposed to refugee inflows in post-World War II Germany. While our analysis encompasses variation in impacts between tradable and nontradable aggregates, this variation is orthogonal to the adjustments on which we focus. Our theory implies that we should compare jobs within tradables (e.g., immigrant-intensive textiles versus non-immigrant-intensive technical support) and jobs within nontradables (e.g., immigrant-intensive housekeeping versus non-immigrant-intensive firefighting). We use such within-aggregate comparisons to validate our model empirically.

In other work on immigration and trade, [Ottaviano, Peri, and Wright \(2013\)](#) examine a partial equilibrium model of a sector in which firms may hire native and immigrant labor domestically or offshore production. Freer immigration reduces offshoring and has theoretically ambiguous impacts on native sectoral employment, which empirically they find to be positive. Our paper characterizes when crowding out (in) occurs in a general equilibrium context, as well as how native employment and wage impacts differ for more and less tradable jobs.

In line with our prediction for differential crowding out within tradables versus within nontradables, [Cortes \(2008\)](#) finds that a city-level influx of immigrants reduces the local prices of six immigrant-intensive nontraded activities while having a small and imprecisely estimated impact on the prices of tradables, either for those with low or those with high immigrant employment intensities. Industry case studies further support our framework's implications. A local influx of foreign labor crowds out native-born workers in immigrant-intensive nontraded occupations, including manicurist services ([Federman, Harrington, and Krynski \(2006\)](#)), construction ([Bratsberg and Raaum \(2012\)](#)), and nursing ([Cortes and Pan \(2014\)](#)). While these results for nontradables appear to contradict the [Ottaviano, Peri, and Wright \(2013\)](#) finding of immigrant crowding in of native workers for tradables, our theoretical model is fully consistent with stronger crowding in for tradables versus

stronger crowding out for nontradables, thereby rationalizing ostensibly discordant evidence on immigrant displacement of natives.

In related work on whether immigrant arrivals crowd out native-born workers on the job, evidence of displacement effects is mixed (Peri and Sparber (2011)). While higher immigration occupations or regions do not in general have lower employment rates for native-born workers (Friedberg (2001); Cortes (2008)), affected regions do see lower relative employment of native-born workers in manual-labor-intensive tasks (Peri and Sparber (2009)). Our analysis suggests that previous work, by imposing uniform adjustment for sectors that have similar factor intensities, incompletely characterizes immigration displacement effects. It is the combination of immigrant intensity *and* nontradability that predisposes an occupation to the crowding out of native labor by foreign labor.

Our analytic results on immigrant crowding out of native-born workers are parallel to theoretical insights on capital deepening in Acemoglu and Guerrieri (2008) and on offshoring in Grossman and Rossi-Hansberg (2008) and Acemoglu, Gancia, and Zilibotti (2015). The former paper, in addressing growth dynamics, derives a condition for crowding in (out) of the labor-intensive sector in response to capital deepening in a closed economy; the latter papers demonstrate that a reduction in offshoring costs has both productivity and price effects, which are closely related to the forces behind crowding in and crowding out, respectively, in our model. Relative to these papers, we show that crowding out is weaker where local prices are less responsive to local output changes, prove that differential output tradability creates differential local price sensitivity, and provide empirical evidence consistent with these predictions.

Sections 2 and 3 present our benchmark model and comparative statics. Section 4 details our empirical approach and results on the impact of immigration on the reallocation of native-born workers, changes in labor payments, and changes in wages for native-born workers. Section 5 summarizes our quantitative framework and discusses parameterization, while Section 6 presents results from counterfactual exercises. Section 7 offers concluding remarks. Appendices A–D are available in the Online Supplemental Appendix (Burstein, Hanson, Tian, and Vogel (2020)). Appendices E–L are supplied in the supplemental replication zip file that can be downloaded from the journal webpage.

2. MODEL

Our model combines three ingredients. First, following Roy (1951), we allow for occupational selection by heterogeneous workers, inducing an upward-sloping labor-supply curve to each occupation and differences in wages across occupations within a region. Second, occupational tasks are tradable, as in Grossman and Rossi-Hansberg (2008), and we incorporate variation across occupations in tradability, which induces occupational variation in producer price responsiveness to local output. Third, as in Ottaviano, Peri, and Wright (2013), we allow for imperfect substitutability within occupations between immigrant and domestic workers.

2.1. Assumptions

There are a finite number of regions, indexed by $r \in \mathcal{R}$. Workers are either immigrant (i.e., foreign born) or domestic (i.e., native born), indexed by $k = \{I, D\}$. Workers are further distinguished by their education level, indexed by e . Within each region there is a continuum of workers with a given education level, e , and nativity, k , indexed by $\omega \in \Omega_{re}^k$,

each of whom inelastically supplies one unit of labor. The measure of Ω_{re}^k is N_{re}^k . Each worker is employed in one of O occupations, indexed by $o \in \mathcal{O}$.²

Each region produces a nontraded final good combining the services of all occupations,

$$Y_r = \left(\sum_{o \in \mathcal{O}} \mu_{ro}^{\frac{1}{\eta}} (Y_{ro})^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \quad \text{for all } r,$$

where Y_r is the absorption (and production) of the final good in region r , Y_{ro} is the absorption of occupation o in region r , and $\eta > 0$ is the elasticity of substitution between occupations in the production of the final good. The absorption of occupation o in region r is itself an aggregator of the services of occupation o across all origins,

$$Y_{ro} = \left(\sum_{j \in \mathcal{R}} Y_{jro}^{\frac{\alpha-1}{\alpha}} \right)^{\frac{\alpha}{\alpha-1}} \quad \text{for all } r, o,$$

where Y_{jro} is the absorption within region r of region j 's output of occupation o and where $\alpha > \eta$ is the elasticity of substitution between origins for a given occupation.

Occupation o in region r produces output by combining immigrant and domestic labor,

$$Q_{ro} = A_{ro} \left((A_{ro}^I L_{ro}^I)^{\frac{\rho-1}{\rho}} + (A_{ro}^D L_{ro}^D)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \quad \text{for all } r, o, \tag{1}$$

where L_{ro}^k is the efficiency units of type k workers employed in occupation o in region r , A_{ro} and A_{ro}^k are the systematic components of productivity of all workers and of any type k worker, respectively, in this occupation and region, and $\rho > 0$ is the elasticity of substitution between immigrant and domestic labor *within* each occupation.³

Let Ω_{reo}^k denote the set of type k workers with education e in region r employed in occupation o , which has measure N_{reo}^k and must satisfy the labor-market clearing condition

$$N_{re}^k = \sum_{o \in \mathcal{O}} N_{reo}^k.$$

A worker $\omega \in \Omega_{re}^k$ supplies $Z_{reo}^k \varepsilon(\omega, o)$ efficiency units of labor if employed in occupation o and region r , where Z_{reo}^k denotes the systematic component of productivity and $\varepsilon(\omega, o)$ denotes the worker idiosyncratic component of productivity. The measure of efficiency units of type k workers with education e employed in occupation o within region r is

$$L_{reo}^k = Z_{reo}^k \int_{\omega \in \Omega_{reo}^k} \varepsilon(\omega, o) d\omega \quad \text{for all } r, e, o, k.$$

²While we allow occupational choice to respond to immigration, we take worker education as given. See Lull (2017) on how native education responds to immigration. Whereas in the model of this section the supply of immigrant workers in a region is exogenous, in the empirical and quantitative analysis, we allow it to be endogenous; see Klein and Ventura (2009), Kennan (2013), di Giovanni, Levchenko, and Ortega (2015), and Caliendo, Oromolla, Parro, and Sforza (2017) for models of international migration based on cross-country wage differences.

³All our analytic results hold if occupation production functions are instead common Cobb–Douglas aggregators of our labor aggregate in (1) and a composite input.

Within each occupation, efficiency units of type k workers are perfect substitutes across workers of all education levels.⁴ The measure of efficiency units of type k workers employed in occupation o within region r is thus given by $L_{ro}^k = \sum_e L_{reo}^k$.

We assume that each $\varepsilon(\omega, o)$ is drawn independently from a Fréchet distribution with cumulative distribution function $G(\varepsilon) = \exp(-\varepsilon^{-(\theta+1)})$, where a higher value of $\theta > 0$ decreases the within-worker dispersion of efficiency units across occupations.⁵

The services of an occupation can be traded between regions subject to iceberg trade costs, where $\tau_{rjo} \geq 1$ is the cost for shipments of occupation o from region r to region j and we impose $\tau_{rro} = 1$ for all regions r and occupations o . The quantity of occupation o produced in region r must equal the sum of absorption (and trade costs) across destinations,

$$Q_{ro} = \sum_{j \in \mathcal{R}} \tau_{rjo} Y_{rjo} \quad \text{for all } r, o. \tag{2}$$

We assume trade is balanced in each region, all markets are perfectly competitive, and labor is freely mobile across occupations but immobile across regions (an assumption we relax in Section 5).

Four remarks regarding our approach are in order. First, our baseline model abstracts from variation across occupations in the elasticity of substitution between immigrant and domestic workers, ρ , which prevents such variation from being a source of differential adjustment to immigration within tradables as compared to within nontradables. In Section 5, we show that assuming a higher value of this elasticity for less traded occupations implies stronger crowding out within this group (consistent with our data) but has counterfactual predictions for how labor payments and prices respond to immigration. Second, the equilibrium conditions we derive are identical to those for a model in which occupation output is produced using a continuum of tasks, and domestic and immigrant labor are perfect substitutes (up to a task-specific productivity differential) within each task (see Appendix E). In this alternative setting, the parameter ρ controls the extent of comparative advantage between domestic and immigrant labor across tasks within occupations. Thus, while our baseline model imposes imperfect substitutability between immigrant and native workers at the *occupation* level, it can be grounded in a framework that entails perfect substitutability at the *task* level.⁶ Analogously, the trade elasticity in gravity models has alternative microfoundations (see, e.g., [Arkolakis, Costinot, and Rodriguez-Clare \(2012\)](#)), which all generate similar aggregate implications. Third, and by extension to the second remark, the equilibrium conditions we derive are identical to those for a model (e.g., [Eaton and Kortum \(2002\)](#)) in which occupation output is produced using a continuum of varieties and regions' outputs are perfect substitutes (up to a variety-specific

⁴Because education groups specialize in different occupations, this assumption—similar to [Llull \(2017\)](#)—does *not* imply that immigration leaves the skill premium unchanged for native or immigrant workers. We examine changes in the skill premium in response to alternative changes in the relative supply of immigrants in the counterfactual exercises presented in Section 6.

⁵In marrying Roy with [Eaton and Kortum \(2002\)](#), our work relates to analyses on changes in labor-market outcomes by gender and race ([Hsieh, Hurst, Jones, and Klenow \(2016\)](#)), technological change and wage inequality ([Burstein, Morales, and Vogel \(2016\)](#)), and regional adjustment to trade shocks ([Galle, Rodriguez-Clare, and Yi \(2015\)](#)), among other topics in a rapidly expanding literature. We assume a Fréchet distribution because it is convenient to derive our analytic comparative statics and to parameterize the model in the presence of a large number (50) of occupations.

⁶See Appendix F for a model in which imperfect substitutability between immigrant and native workers at the occupation level emerges from imperfect substitutability between skilled and unskilled workers.

productivity differential) within each variety. In this alternative setting, the parameter α controls the extent of comparative advantage across regions. Fourth, since we focus on long-run changes (1980–2012 in our empirics), we abstract from transition dynamics arising from costs to reallocating labor across occupations and (or) regions (e.g., [Monras \(2015\)](#); [Caliendo et al. \(2017\)](#)).

2.2. Equilibrium Characterization

Final-good profit maximization in region r implies

$$Y_{ro} = \mu_{ro} \left(\frac{P_{ro}^y}{P_r} \right)^{-\eta} Y_r, \tag{3}$$

where

$$P_r = \left(\sum_{o \in \mathcal{O}} \mu_{ro} (P_{ro}^y)^{1-\eta} \right)^{\frac{1}{1-\eta}} \tag{4}$$

denotes the final good price and where P_{ro}^y denotes the absorption price of occupation o in region r . Optimal regional sourcing of occupation o in region j implies

$$Y_{rjo} = \left(\frac{\tau_{rjo} P_{ro}}{P_{jo}^y} \right)^{-\alpha} Y_{jo}, \tag{5}$$

where

$$P_{ro}^y = \left(\sum_{j \in \mathcal{R}} (\tau_{jro} P_{jo})^{1-\alpha} \right)^{\frac{1}{1-\alpha}} \tag{6}$$

and where P_{jo} denotes the output price of occupation o in region j . Equations (2), (3), and (5) imply

$$Q_{ro} = (P_{ro})^{-\alpha} \sum_{j \in \mathcal{R}} \mu_{jo} (\tau_{rjo})^{1-\alpha} (P_{jo}^y)^{\alpha-\eta} (P_j)^\eta Y_j. \tag{7}$$

Profit maximization in the production of occupation o in region r implies

$$P_{ro} = \frac{1}{A_{ro}} \left((W_{ro}^I / A_{ro}^I)^{1-\rho} + (W_{ro}^D / A_{ro}^D)^{1-\rho} \right)^{\frac{1}{1-\rho}} \tag{8}$$

and

$$L_{ro}^k = (A_{ro} A_{ro}^k)^{\rho-1} \left(\frac{W_{ro}^k}{P_{ro}} \right)^{-\rho} Q_{ro}, \tag{9}$$

where W_{ro}^k denotes the wage per efficiency unit of type k labor, which is common across all education groups of type k employed in occupation o within region r and which we henceforth refer to as the *occupation wage*. A change in W_{ro}^k represents the change in the wage of a type k and education e worker in region r who does not switch occupations (for fixed

labor efficiency units).⁷ Because of self-selection into occupations, W_{ro}^k differs from the average wage of type k workers with education e in region r who are employed in occupation o , $Wage_{reo}^k$. In Section 5.3 we use changes in average wages, $Wage_{reo}^k$, across occupations to infer indirectly how immigration affects (unobserved) occupation-level wages.

Worker $\omega \in \Omega_{re}^k$ chooses to work in the occupation o that maximizes wage income $W_{ro}^k Z_{reo}^k \varepsilon(\omega, o)$. Idiosyncratic worker productivity implies that the share of type k workers with education e who work in occupation o within region r , $\pi_{reo}^k \equiv N_{reo}^k / N_{re}^k$, is

$$\pi_{reo}^k = \frac{(Z_{reo}^k W_{ro}^k)^{\theta+1}}{\sum_{j \in \mathcal{O}} (Z_{rej}^k W_{rj}^k)^{\theta+1}}, \tag{10}$$

which is increasing in W_{ro}^k . Total efficiency units supplied by workers in occupation o are

$$L_{reo}^k = \gamma Z_{reo}^k (\pi_{reo}^k)^{\frac{\theta}{\theta+1}} N_{re}^k, \tag{11}$$

where $\gamma \equiv \Gamma(\frac{\theta}{\theta-1})$ and Γ is the gamma function. Finally, trade balance implies

$$\sum_{o \in \mathcal{O}} P_{ro} Q_{ro} = P_r Y_r \quad \text{for all } r. \tag{12}$$

An equilibrium is a vector of prices $\{P_r, P_{ro}, P_{ro}^y\}$, wages $\{W_{ro}^k\}$, quantities produced and consumed $\{Y_r, Y_{ro}, Y_{rjo}, Q_{ro}\}$, and labor allocations $\{N_{reo}^k, L_{reo}^k\}$ for all regions r , occupations o , worker types k , and education cells e that satisfy (3)–(12).

3. COMPARATIVE STATICS

We next derive analytic results for the effects of infinitesimal changes in regional immigrant and native labor supplies, N_{re}^I and N_{re}^D , and region \times occupation productivity, A_{ro} , on occupation labor payments as well as factor allocations and occupation wages.⁸ We derive our analytic results in a simplified version of our model. In Section 3.1 we describe model restrictions and their implications. In Section 3.2 we hold regional labor supplies of natives as well as region–occupation productivities fixed. In Section 3.3 we generalize these results by allowing native labor supplies and region–occupation productivities to change. Lowercase characters, x , denote the logarithmic change of any variable X relative to its initial equilibrium level (e.g., $n_{re}^k \equiv \Delta \ln N_{re}^k$). Derivations and proofs are supplied in Appendix A.

3.1. Restrictions Imposed in Analytics

To build intuition, we focus on a special case of the model that satisfies three restrictions. First, we assume that each region operates as a small open economy. Second, we

⁷Occupation switching by workers may mitigate the potentially negative impact of immigration on wages (Peri and Sparber (2009)). The envelope condition implies that given changes in occupation wages, this occupation switching has no first-order effects on changes in individual wages, which solve $\max_o \{W_{ro}^k \times \varepsilon(\omega, o)\}$. Because this holds for all workers, it also holds for the average wage across workers.

⁸Changes in productivity, A_{ro} , are isomorphic to changes in demand, μ_{ro} .

group occupations into sets in which they are equally traded. Third, we assume that distinct education groups within each worker nationality type ($k = D, I$) differ only in their absolute productivities (rather than in their relative productivities across occupations). Our quantitative analysis in Section 5 dispenses with these restrictions.

Small open economy. We assume region r is a small open economy, in that it constitutes a negligible share of exports and absorption in each occupation for each region $j \neq r$. This assumption implies that, in response to a region r shock, prices and output elsewhere are unaffected: $p_{jo}^y = p_{jo} = p_j = y_j = 0$ for all $j \neq r$ and o . It does not imply that region r 's producer prices are fixed. The log derivative of equation (6) is thus

$$p_{ro}^y = (1 - S_{ro}^m) p_{ro},$$

where S_{ro}^m denotes region r 's share of imports in occupation absorption. Similarly, the log derivative of equation (7) is

$$q_{ro} = -\alpha p_{ro} + (1 - S_{ro}^x)(\alpha - \eta) p_{ro}^y + (1 - S_{ro}^x)(\eta p_r + y_r),$$

where $S_{ro}^x \equiv 1 - S_{ro}^x$ denotes region r 's share of exports in occupation output. Combining these equations, we obtain

$$q_{ro} = -\epsilon_{ro} p_{ro} + (1 - S_{ro}^x)(\eta p_r + y_r),$$

where ϵ_{ro} represents the partial elasticity of demand for region r 's occupation o output to its output price and is given by

$$\epsilon_{ro} = (1 - (1 - S_{ro}^x)(1 - S_{ro}^m))\alpha + (1 - S_{ro}^x)(1 - S_{ro}^m)\eta. \quad (13)$$

The partial elasticity ϵ_{ro} is a weighted average of the elasticity of substitution across occupations, η , and the elasticity across origins, $\alpha > \eta$, where the weight on the latter is increasing in the extent to which the services of occupation o are traded, as measured by the region r share of exports in occupation output (S_{ro}^x) and share of imports in occupation absorption (S_{ro}^m). For occupation o with infinite trade costs, $S_{ro}^x = S_{ro}^m = 0$, so that $\epsilon_{ro} = \eta$. More traded occupations—with higher values of S_{ro}^x and S_{ro}^m —feature higher elasticities of demand for regional output to price (and lower sensitivities of regional price to output).⁹

Grouping occupations by trade shares. We assume that occupations are grouped into sets, $g = \{T, N\}$, where region r 's export share of occupation output and import share of occupation absorption are common across all occupations in set g . The term N is the set of occupations that produce nontraded services and T is the set of occupations that produce traded services, where all we require is that the latter is more tradable than the former. Because the export share of occupation output and the import share of occupation absorption are assumed common across occupations in g in region r , the elasticity of regional output to the regional producer price, ϵ_{ro} , is common across occupations in g . We denote by ϵ_{rg} the elasticity of regional output to the regional producer price for all $o \in g$, for $g = \{T, N\}$.¹⁰

⁹In Appendix A.3, we show that the absolute value of the partial own labor demand elasticity at the region-occupation level is increasing in ϵ_{ro} (consistent with Hicks-Marshall rules of derived demand) and, therefore, trade shares, a result related to findings in Rodrik (1997) and Slaughter (2001).

¹⁰Our results hold with an arbitrary number of sets. In the empirical analysis (see Appendix H), we alter the effective number of sets by varying the size of occupations of intermediate tradability which are excluded from the analysis (from zero to one-fifth of the total number of categories).

Restricting comparative advantage. Finally, we assume that education groups within each k differ only in their absolute productivities, $Z_{reo}^k = Z_{re}^k$. This assumption implies that education groups within k are allocated identically across occupations: $\pi_{reo}^k = \pi_{ro}^k$ for all e . In this case, the vector of changes in labor supplies by education level in region r , $\{n_{re}^k\}_e$, can be summarized by a single sufficient statistic,

$$n_r^k \equiv \sum_e \frac{S_{reo}^k}{S_{ro}^k} n_{re}^k, \tag{14}$$

with weights given by the share of labor income in region r and occupation o accruing to type k labor with education e , $S_{reo}^k \equiv \frac{w_{ro}^k L_{reo}^k}{\sum_{e',k'} w_{ro}^{k'} L_{re'o}^{k'}}$, relative to the share of labor income in region r and occupation o accruing to all type k labor, $S_{ro}^k = \sum_e S_{reo}^k$. The right hand side of (14) does not vary across occupations because $\pi_{reo}^k = \pi_{ro}^k$ implies that S_{reo}^k/S_{ro}^k is common across o . The term S_{ro}^I is the *immigrant cost share* in occupation o output in region r , which varies across occupations within a region according to the Ricardian comparative advantage of immigrant and native workers across occupations within a region. From the definition of S_{ro}^I and the assumption that $Z_{reo}^k = Z_{re}^k$, we have that $S_{ro}^I \geq S_{ro'}^I$ if and only if $\pi_{ro}^I/\pi_{ro'}^I \geq \pi_{ro}^D/\pi_{ro'}^D$. Along with (10), this implies $S_{ro}^I \geq S_{ro'}^I$ if and only if $(\frac{A_{ro}^I}{A_{ro}^D})^{\rho-1} \geq (\frac{A_{ro'}^I}{A_{ro'}^D})^{\rho-1}$.

3.2. Changes in Immigrant Labor Supply

We now study the impact of infinitesimal changes in regional immigrant labor supplies, $\{n_{re}^I\}_e$, on labor payments, factor allocations, and occupation wages across occupations within each group g .¹¹ To focus on the implications of n_{re}^I , in this section we hold native labor supply and region–occupation productivities fixed; we study the impacts of changes in native labor supply and region–occupation productivity in Section 3.3.

Occupation revenues, $P_{ro}Q_{ro}$, are equal to occupation labor payments, denoted by $LP_{ro} \equiv \sum_{ke} \text{Wage}_{reo}^k N_{reo}^k$. We focus on labor payments because they are easier to measure in practice than occupation quantities and prices. Infinitesimal changes in immigrant labor supplies, $\{n_{re}^I\}_e$, generate differential changes in labor payments for any $o, o' \in g$ that are given by

$$lp_{ro} - lp_{ro'} = \frac{(\epsilon_{rg} - 1)(\theta + \rho)}{\theta + \epsilon_{rg}} (S_{ro}^I - S_{ro'}^I) n_r^I \Phi_r^I, \tag{15}$$

where $\Phi_r^I = (w_{ro}^D - w_{ro}^I)/n_r^I$ denotes the elasticity of domestic relative to immigrant occupation wages (which are common across occupations in equilibrium under the assumption that $Z_{reo}^k = Z_{re}^k$) with respect to the supply of immigrants.¹² We do not provide an explicit solution for Φ_r^I ; rather, we assume that parameter values guarantee that the following law

¹¹Up to a first-order approximation, w_{ro}^k is equal to the change in average income of workers who were employed in occupation o in the initial equilibrium.

¹²As shown in Appendix A, we obtain (15) as follows. We combine the results described above that $q_{ro} = -\epsilon_{ro} p_{ro} + (1 - S_{ro}^x)(\eta p_r + y_r)$ and $w_{ro}^D - w_{ro}^I = n_r^I \Phi_r^I$ with the log derivatives of occupational output, $q_{ro} = \sum_k S_{ro}^k j_{ro}^k$, and the profit maximization condition, $l_{ro}^D - l_{ro}^I = -\rho(w_{ro}^D - w_{ro}^I)$, to obtain $p_{ro} = \frac{1}{\epsilon_{ro}}(1 - S_{ro}^x)(\eta p_r + y_r) - \frac{\rho}{\epsilon_{ro}} S_{ro}^I n_r^I \Phi_r^I - \frac{1}{\epsilon_{ro}} l_{ro}^D$. Combining the previous expression with the derivative of the labor supply equations, $l_{ro}^k = \theta w_{ro}^k - \theta(\sum_{j \in O} \pi_{rj}^k w_{rj}^k) + n_r^k$, and the log derivative of the occupation price, $p_{ro} = (1 - S_{ro}^I)w_{ro}^D + S_{ro}^I w_{ro}^I$, we obtain (15).

of demand is satisfied: all else equal, an increase in immigrant labor supply, $n_r^I \geq 0$, raises the occupation wage of natives relative to the occupation wage of immigrants, $\Phi_r^I \geq 0$.¹³

Consider two occupations $o, o' \in g$, where occupation o is *immigrant intensive* relative to o' (i.e., $S_{ro}^I > S_{ro'}^I$). According to (15), an increase in the supply of immigrant workers in region r , $n_r^I > 0$, increases labor payments in occupation o relative to o' if and only if $\epsilon_{rg} > 1$. Intuitively, an inflow of immigrants, $n_r^I > 0$, raises relative output and lowers relative prices of immigrant-intensive occupations within g (i.e., within tradables or within nontradables). A higher value of the elasticity of demand for region r 's occupation o output to its price, ϵ_{rg} , increases the size of relative output changes and decreases the size of relative price changes. In response to an inflow of immigrants, $n_r^I > 0$, a higher value of ϵ_{rg} therefore generates a larger increase (or smaller decrease if $\epsilon_{rg} < 1$) in labor payments of immigrant-intensive occupations. Because $\epsilon_{rT} > \epsilon_{rN}$, relative labor payments to immigrant-intensive occupations increase relatively more within T than within N in response to an inflow of immigrants.

Infinitesimal changes in immigrant labor supplies, $\{n_{re}^I\}_e$, generate differential changes in labor allocations in occupations that are given by

$$n_{reo}^k - n_{reo'}^k = \frac{(\theta + 1)(\epsilon_{rg} - \rho)}{\theta + \epsilon_{rg}} (S_{ro}^I - S_{ro'}^I) n_r^I \Phi_r^I \tag{16}$$

and changes in occupation wages that are given by

$$w_{ro}^k - w_{ro'}^k = \frac{\epsilon_{rg} - \rho}{\theta + \epsilon_{rg}} (S_{ro}^I - S_{ro'}^I) n_r^I \Phi_r^I \tag{17}$$

for any $o, o' \in g$ and $k \in \{D, I\}$, where n_r^I is given by (14).¹⁴ By (16) and (17), an increase immigrant labor supply, $n_r^I > 0$, decreases relative employment of type k workers and (for finite θ) occupation wages in relatively immigrant-intensive occupations within g if and only if $\epsilon_{rg} < \rho$. If $\epsilon_{rg} < \rho$, we have *crowding out*—an immigrant influx in r reallocates factors away from immigrant-intensive occupations within g ; if $\epsilon_{rg} > \rho$, we have *crowding in*—an immigrant influx reallocates factors toward immigrant-intensive occupations within g .¹⁵

Because $\epsilon_{rT} > \epsilon_{rN}$, we can compare the differential employment response of more to less immigrant-intensive occupations in T and N : within T , immigration causes less crowding out of (or more crowding into) occupations that are more immigrant intensive (compared to the effect within N). Similarly, because $\epsilon_{rT} > \epsilon_{rN}$, we can compare the differential wage response of more to less immigrant-intensive occupations in T and N : within traded occupations T , immigration decreases occupation wages less (or increases occupation wages more) in occupations that are more immigrant intensive (compared to the effect within nontraded occupations N). We next provide intuition for these results.

Labor reallocation between occupations within N or within T is governed by the extent to which immigration is accommodated by expanding production of immigrant-intensive occupations (ϵ_{rg}) or by substituting away from native toward immigrant workers within each occupation (ρ). Consider two special cases. First, in the limit as $\epsilon_{rg} \rightarrow 0$, output ratios across occupations are fixed. Accommodating an increase in immigrant labor supply requires increasing the share of each factor employed in native-labor-intensive occupations (while making each occupation more immigrant intensive). Immigration thus

¹³In Appendix A.4 we prove that $\Phi_r^I \geq 0$ if all occupations have common export and import shares.

¹⁴These results follow similar steps to those outlined in footnote 12.

¹⁵See Appendix A.5 for results where education groups differ in relative productivities across occupations.

crowds out native workers. Second, in the limit as $\rho \rightarrow 0$, factor intensities within each occupation are fixed. To accommodate immigration, the share of each factor employed in immigrant-intensive occupations must rise (while the production of immigrant-intensive occupations increases disproportionately). Now, immigration crowds in native workers. More generally, a lower value of $\epsilon_{rg} - \rho$ generates more crowding out of (or less crowding into) immigrant-labor-intensive occupations in response to an increase in regional immigrant labor supply.

Consider next changes in relative occupation wages within N or within T . If $\theta \rightarrow \infty$, then all workers within each k and e are identical and indifferent between employment in any occupation. In this knife-edge case, labor reallocates across occupations without corresponding changes in relative occupation wages within k and e . The restriction that $\theta \rightarrow \infty$ thus precludes studying the impact of immigration (or any other shock) on the relative wage across occupations of domestic or foreign workers. For any finite value of θ , that is, anything short of pure worker homogeneity, changes in occupation wages vary across occupations. It is these changes in occupation wages that induce labor reallocation: in order to induce workers to switch from occupation o to o' , the occupation wage must increase in o' relative to o , as shown in (17). Hence, factor reallocation translates directly into changes in occupation wages. Specifically, if occupation o' is immigrant intensive relative to occupation o , $S_{ro'}^I > S_{ro}^I$, and $o, o' \in g$, then an increase in the relative supply of immigrant labor in region r , $n_r^I > 0$, decreases the occupation wage for domestic and immigrant labor in occupation o' relative to occupation o if and only if $\epsilon_{rg} < \rho$.

We emphasize that these analytic results apply to *relative* comparisons of occupations within tradables and within nontradables. The quantitative analysis of Sections 5 and 6 allows us to evaluate the absolute impact on real wages and thereby fully characterize the labor-market consequences of immigrant inflows.

3.3. Changes in All Labor Supplies and Occupation Productivities

We now extend the analysis of Section 3.2 to allow native labor supply and occupation productivity to vary along with immigrant labor supply. In the empirical analysis, we must account for the presence of multiple shocks to region–occupation labor-market outcomes. By generalizing equations (15), (16), and (17), the analysis will help guide our empirical specification—in particular, by motivating the fixed-effects structure that we allow for in the estimation and by clarifying the exclusion restrictions required for identification—and will further demonstrate that our insights regarding the differential impacts within more and less traded sectors of an immigration shock apply equally well to other shocks.

PROPOSITION 1: *Infinitesimal changes in immigrant and native labor supplies (n_{re}^k) and region–occupation productivities (a_{ro}) generate differential changes in labor payments (lp_{ro}), factor allocations (n_{reo}^k), and wages per efficiency unit of labor (w_{ro}^k) for any $o, o' \in g$ and $k \in \{D, I\}$ that are given by*

$$lp_{ro} - lp_{ro'} = \frac{(\epsilon_{rg} - 1)(\theta + \rho)}{\epsilon_{rg} + \theta} \tilde{w}_r(S_{ro}^I - S_{ro'}^I) + \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta} (a_{ro} - a_{ro'}), \quad (18)$$

$$n_{reo}^k - n_{reo'}^k = \frac{(\epsilon_{rg} - \rho)(\theta + 1)}{\epsilon_{rg} + \theta} \tilde{w}_r(S_{ro}^I - S_{ro'}^I) + \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta} (a_{ro} - a_{ro'}), \quad (19)$$

$$w_{ro}^k - w_{ro'}^k = \frac{(\epsilon_{rg} - \rho)}{\epsilon_{rg} + \theta} \tilde{w}_r(S_{ro}^I - S_{ro'}^I) + \frac{(\epsilon_{rg} - 1)}{\epsilon_{rg} + \theta} (a_{ro} - a_{ro'}), \quad (20)$$

where

$$\tilde{w}_r \equiv w_{ro}^D - w_{ro}^I = \Phi_r^I n_r^I + \Phi_r^D n_r^D + \sum_o \Phi_{ro}^A a_{ro} \quad (21)$$

is the change in the relative occupation wage for natives relative to immigrants, which is common across occupations, Φ_r^I , Φ_r^D , and Φ_{ro}^A are the elasticities of this relative occupation wage to the three types of shocks, and n_r^k is defined in (14).

Analogous to the previous section, we do not explicitly solve for the change in relative wages per efficiency unit, \tilde{w}_r , and we assume that parameter values satisfy the law of demand: an increase in immigrant labor supply, $n_r^I \geq 0$, or a decrease in native labor supply, $n_r^D \leq 0$, raises the relative occupation wage of natives, $\Phi_r^I \geq 0$ and $\Phi_r^D \leq 0$.¹⁶

While our focus is on the differential impact of immigration on outcomes within more versus less tradable occupational groups, our insights apply equally to the differential impact of native migration and region- and occupation-specific changes in productivity. All else equal, a decrease in the effective supply of native labor in region r , where n_r^D is given by equation (14), has the same qualitative effects on labor payments, factor allocations, and occupation wages as an increase in the effective supply of immigrant labor, since the change in the relative occupation wage of natives to immigrants, \tilde{w}_r , is a sufficient condition for each outcome. Given \tilde{w}_r , an increase in the relative productivity of occupation o within group g increases occupation o labor payments, the share of factor k allocated to occupation o , and the occupation o wage if and only if $\epsilon_{rg} > 1$, and these effects are stronger the higher is ϵ_{rg} if $\epsilon_{rg} > 1$. Changes in productivity may also affect outcomes indirectly through \tilde{w}_r .¹⁷

4. EMPIRICAL ANALYSIS

Guided by our theoretical model, we study the impact of immigration on labor-market outcomes at the occupation level in U.S. regional economies. We begin by using our analytical results on labor-market adjustment to immigration to specify our estimating equation. These results treat changes in productivity and in immigrant and native labor supplies as exogenous. In practice, these changes may be jointly determined. We then turn to an instrumentation strategy for changes in immigrant labor supply, discussion of data used in the analysis, and presentation of our empirical findings. Although our analytical results predict how occupational labor allocations, labor payments, and wages adjust to immigration, measuring changes in occupation-level wages, as discussed in Section 2.2, is not straightforward because changes in observable wages reflect both changes in the occupation wage per efficiency unit of labor and self-selection of workers across occupations according to unobserved worker productivity. Accordingly, we analyze immigration impacts on occupational labor allocations and labor payments in this section and address wage changes in our quantitative exercises.

4.1. Specifications for Labor Allocations and Labor Payments

Combining (19) and (21), in Appendix A.3 we derive the following specification for changes in the allocation of native workers in education cell e to occupation o —given at

¹⁶In Appendix A.4 we prove that $\Phi_r^I = -\Phi_r^D \geq 0$ if all occupations share common export and import shares (i.e., if there is a single g).

¹⁷In Appendix A.4 we show that $\Phi_{ro}^A > 0$ if and only if $(\pi_{ro}^D - \pi_{ro}^I)\epsilon_r > 1$ under the assumption that all occupations share common export and import shares.

least two occupations in each group $g \in \{T, N\}$ —within region r ,

$$n_{reo}^D = s_{rg} a_o + \alpha_{reg}^D + \beta_r^D x_{ro} + \beta_{Nr}^D \mathbb{I}_o(N) x_{ro} + \nu_{ro}^D, \tag{22}$$

where we have decomposed the region–occupation productivity shock as $a_{ro} \equiv a_o + a_{rg} + \tilde{a}_{ro}$, with a_o the national-occupation component of the productivity shock, a_{rg} the region and occupation–group-specific component of the shock, and \tilde{a}_{ro} the region–occupation-specific component of the shock; s_{rg} , β_r^D , and β_{Nr}^D are region- and group-specific treatment effects, which are functions of model parameters; x_{ro} is the model-defined immigration shock; $\mathbb{I}_o(N)$ equals 1 if occupation o is nontradable; α_{reg}^D is a function of model parameters that does not vary across o ; and ν_{ro}^D is a structural residual. Specifically, the immigration shock

$$x_{ro} \equiv \sum_e S_{reo}^I n_{re}^I \tag{23}$$

summarizes how region and education-specific changes in immigration, $\{n_{re}^I\}_e$, are transmitted to occupation o in region r via the initial immigrant intensity of ro in each education cell, S_{reo}^I .¹⁸ The treatment effect of x_{ro} for tradable occupations in (22) is

$$\beta_r^D = \frac{(\epsilon_{rT} - \rho)(\theta + 1)}{\epsilon_{rT} + \theta} \Phi_r^I,$$

which is negative, implying crowding out of natives by immigrants, if the substitutability of immigrant and native labor is large relative to the sensitivity of regional output to price ($\epsilon_{rT} < \rho$).¹⁹ The treatment effect for T differs from that for N by the term

$$\beta_{Nr}^D = \frac{(\theta + \rho)(\theta + 1)}{(\epsilon_{rN} + \theta)(\epsilon_{rT} + \theta)} (\epsilon_{rN} - \epsilon_{rT}) \Phi_r^I,$$

which is negative, implying stronger crowding out in nontradables relative to tradables, since the sensitivity of regional output to price is greater for T than for N ($\epsilon_{rN} < \epsilon_{rT}$). The treatment effect of the national-occupation component of the productivity shock, a_o , is

$$s_{rg} \equiv \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta}.$$

Finally, the structural residual is

$$\nu_{ro}^D \equiv \frac{(\epsilon_{rg} - \rho)(\theta + 1)}{\epsilon_{rg} + \theta} S_{ro}^I (\Phi_r^D n_r^D + a_r) + \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta} \tilde{a}_{ro},$$

where $a_r \equiv \sum_o \Phi_{ro}^A a_{ro}$ is a weighted sum of region–occupation productivity shocks.

To simplify the estimation, we specify the regression equation

$$n_{reo}^D = \alpha_{reg}^D + \alpha_o^D + \beta^D x_{ro} + \beta_N^D \mathbb{I}_o(N) x_{ro} + \tilde{\nu}_{ro}^D \tag{24}$$

in which we impose regional homogeneity for the treatment effects in (22), which in turn changes the interpretation of the coefficients and generates a modified residual $\tilde{\nu}_{ro}^D$ that

¹⁸In practice, in constructing x_{ro} in our empirics and calibration, we use percentage changes rather than log changes in N_{re}^I .

¹⁹As in the previous section, we assume that the law of demand holds, such that $\Phi_r^I > 0$.

adds to ν_{ro}^D specification error generated by these parameter restrictions. By imposing uniformity across regions for these coefficients in (24), β^D and $\beta^D + \beta_N^D$ represent average treatment effects for the immigration shock on native allocations. Because we estimate (24) separately for low- and high-education labor allocations, we effectively allow the occupation fixed effect, α_o^D , and the treatment effects, β^D and $\beta^D + \beta_N^D$, to differ by education level.²⁰

Our empirical exercise does not directly recover a combination of structural parameters for two reasons. First, we transform (22) to (24) by estimating an average treatment effect across regions. Second, (22) was derived under the assumption that education groups within each k differ only in their absolute productivities, which implies that $x_{ro}S_{ro}^I$ does not vary across o . In practice, we construct x_{ro} without imposing this restriction. Our theoretical model implies the sign restriction that $\beta^D > \beta^D + \beta_N^D$, which we test for explicitly. In the quantitative analysis, we use the estimated coefficients from (24) to discipline the calibration of the structural parameters of an extended model.

Because regional shocks to occupation productivity and native labor supply are in the residual in (24) and do not enter the specification directly as regressors, the coefficients that we estimate on x_{ro} will capture not just the direct effect of immigration on native labor allocations, but also any indirect effects of this immigration shock through its effect on the supply of native workers or the productivity of specific occupations at the regional level.²¹ If, for instance, immigration induces regional migration of natives—a possibility that our quantitative model in Section 5 accommodates explicitly—then the total effect of the immigration shock on native allocations that we estimate in (24) may differ from the theoretically defined partial effect in Proposition 1. Nevertheless, as long as a version of the law of demand holds (i.e., accounting for the responses of productivity and native labor supplies, an increase in immigrant supply raises the relative occupation wage of natives), our results that there is crowding out in g if and only if $\epsilon_{rg} < \rho$ and that there is more crowding out within N occupations than within T occupations still hold.

More pertinent to identifying the labor-market impacts of immigration, immigrant inflows for region r , n_r^I , may result from the endogenous location response of immigrants to regional productivity or amenity shocks or to native labor supply. If this was the case, our estimates of β^D and β_N^D would reflect not just our theoretically specified impact of immigration on native allocations, but also the direct effect of these regional shocks on native allocations.²² Estimating (24) therefore requires an instrumentation strategy to isolate variation in x_{ro} that is orthogonal to the components of regional changes in native labor supply and occupation productivities that are not themselves caused by immigrant inflows.

Based on a similar motivation to that underlying equation (24), we specify an expression for changes in occupation labor payments,

$$lp_{ro} = \alpha_{rg}^D + s_{rg}a_o + \gamma x_{ro} + \gamma_N \mathbb{I}_o(N)x_{ro} + \tilde{\nu}_{ro}, \quad (25)$$

²⁰As we discuss in Appendix J, a logic similar to that underlying (24) applies to how an immigrant inflow affects the allocation of foreign-born workers across occupations. In Appendix J, we present results on the immigrant-employment allocation regressions that are the counterparts to (24) and Table I below. As with our findings on the allocation of native-born workers, the results on how immigration affects the allocation of foreign-born workers across occupations are qualitatively consistent with our framework.

²¹See, for example, Borjas (2006) on the response of native outmigration to immigrant inflows. Other work suggests that inflows of foreign labor lead to higher land rents (Saiz (2007)), local agglomeration externalities (Kerr and Lincoln (2010)), and weaker incentives for firms to adopt labor-saving technologies (Lewis (2011)). Such adjustments in costs and productivity appear to disproportionately affect manufacturing (Peters (2017)).

²²See, for example, Cadena and Kovak (2016) on the responsiveness of immigration to local labor demand shocks.

in which we again estimate average treatment effects, γ and γ_N , for the immigration shock x_{ro} . Following Proposition 1, the treatment effect for tradables γ will be positive if the sensitivity of regional output to price exceeds unity ($\epsilon_{rT} > 1$) and the differential treatment effect for nontradables γ_N will be negative since the sensitivity of regional output to price is greater for tradables than for nontradables ($\epsilon_{rN} < \epsilon_{rT}$). Analogous to the above discussion, identifying the impact of x_{ro} on labor payments requires an instrumentation strategy.

In the regression in (24), we estimate whether immigrant flows into a region induce on average crowding out (or crowding in) of domestic workers in relatively immigrant-intensive occupations separately within tradable and within nontradable occupations, thereby allowing us to test whether crowding out is weaker (or crowding in is stronger) in tradable relative to nontradable jobs. In the regression in (25), we estimate whether immigrant flows into a region induce on average an increase or decrease in labor payments in relatively immigrant-intensive occupations separately within tradables and within nontradables. This allows us to assess the mechanism in our model that generates differential crowding out within N and T occupations, which is that quantities are more responsive and prices less responsive to local factor supply shocks in tradable than nontradable activities.

4.2. An Instrumental Variables Approach

The immigration shock in (23) is a function of the inflows of immigrants in region r within each education cell e , n_{re}^I , and the initial intensity of region–occupation ro in the employment of immigrants with education e , S_{reo}^I . The residuals in turn contain the region–occupation-specific productivity shock, \tilde{a}_{ro} , and the interaction of region–occupation immigrant employment intensities with the average regional productivity shock, a_r , and the regional native labor supply shock, n_r^D . Endogeneity could arise from two sources: a correlation between regional productivity or native labor supply shocks playing a role in determining the contemporaneous inflow of immigrants to a region, and (or) region–occupation productivity shocks being a function of initial region–occupation immigrant employment intensities.

To construct an instrument for x_{ro} , we exploit the fact that n_{re}^I is the result of inflows of immigrants from multiple source countries c . We leave unmodelled the cause of migrant outflows from these countries. Inspired by literature on migration networks (e.g., Munshi (2003)), we allocate these aggregate inflows across regions according to historical settlement patterns, as summarized in the identifying restrictions that we discuss below.

Following Altonji and Card (1991) and Card (2001), we instrument for x_{ro} using

$$x_{ro}^* \equiv \sum_e S_{reo}^I \frac{\Delta N_{re}^{I*}}{N_{re}^I},$$

where ΔN_{re}^{I*} is a variant of the standard Card instrument that accounts for education-group- and region-specific immigration shocks,

$$\Delta N_{re}^{I*} \equiv \sum_c f_{re}^{Ic} \Delta N_{ec}^{-r}.$$

Here, ΔN_{ec}^{-r} is defined as the change in the number of immigrants from source c with education e at the national level excluding region r , and f_{re}^{Ic} is the share of immigrants from

source c with education e who lived in region r in the initial (or some earlier) period.²³ Combining the two previous expressions, we obtain

$$x_{ro}^* \equiv \sum_e \sum_c \frac{S_{reo}^I f_{re}^{Ic}}{N_{re}^I} \Delta N_{ec}^{-r}, \tag{26}$$

where x_{ro}^* is a valid instrument in regressions (24) and (25) if it is uncorrelated with $\tilde{\nu}_{ro}^D$ and $\tilde{\nu}_{ro}$, respectively.

A recent literature (Adao, Kolesár, and Morales (2018), Borusyak, Hull, and Jaravel (2018), and Goldsmith-Pinkham, Sorkin, and Swift (2018)) explores identification and inference using shift–share instruments taking the form of (26). This literature formally specifies the data generating process that is responsible either for the “shifters” or the “shares,” and argues that identification is obtained if either the shifters or the shares are as good as randomly assigned. In our case, the shifters are given by ΔN_{ec}^{-r} and the shares are given by $S_{reo}^I f_{re}^{Ic} / N_{re}^I$. For example, a sufficient set of restrictions under which our instrument is valid is that (i) the predicted inflow of immigrants, ΔN_{re}^{I*} , is uncorrelated with the change in the supply of natives in r not induced by immigration, (ii) the predicted inflow of immigrants, ΔN_{re}^{I*} , is also uncorrelated with the weighted region productivity shock not induced by immigration, and (iii) the initial region–occupation immigrant employment intensity for each education cell e , S_{reo}^I , is uncorrelated with the region–occupation-specific productivity shock, \tilde{a}_{ro} . Restrictions (i) and (ii), which rule out correlation between the components of x_{ro}^* and of the structural residual ν_{ro}^D that vary in the r dimension (and are interacted with S_{reo}^I) and are not themselves functions of x_{ro}^* , are likely to hold if each region r is small in the sense that its specific shocks do not affect aggregate immigration inflows across other regions and if the historical attraction of immigrants to particular regions is due to preexisting migration networks (i.e., f_{re}^{Ic} is not a function of recent shocks to native migration or regional productivity that persist into the current period). Restriction (iii), which rules out correlation between the components of x_{ro}^* and ν_{ro}^D that vary in the ro dimension, holds if deviations in region–occupation productivity—from the national average within the occupation and the regional average within the occupation group—are not a function of past immigrant employment intensities across occupations, S_{reo}^I .²⁴

In extended results, we examine the robustness of our results to dropping the largest immigrant-receiving regions from the sample (which account for a substantial fraction of immigrant inflows and whose shocks could plausibly affect immigration in the aggregate). We also check whether current immigration shocks are correlated with past changes in labor-market outcomes to evaluate whether our results may be a by-product of persistent regional employment trends. Given the possibility that current immigration shocks are correlated with persistent regional employment trends, we also consider a modified Card instrument in which we replace initial immigrant employment intensities for education cell e in region–occupation ro with occupation–education immigrant employment intensities averaged over a set of regions other than r and outside of r ’s state, which creates the value

$$x_{ro}^* \equiv \sum_e S_{-reo}^I \frac{\Delta N_{re}^{I*}}{N_{re}^I}. \tag{27}$$

²³In our extended model in Section 5, we introduce immigrant source countries so as to construct the same instrument and run the same two-stage least squares (2SLS) regression on model-generated data to calibrate the model. This extension does not impact our analytic results, yet does burden the notation.

²⁴The three-decade period of our analysis helps address concerns that results based on the Card instrument may conflate short-run and long-run impacts of immigration (Jaeger, Ruist, and Stuhler (2018)).

The alternative instrument in (27) helps address a well known critique of the Card instrument regarding the persistence of regional labor-demand shocks (Borjas, Freeman, and Katz (1997)).

4.3. Data

In our baseline analysis, we study changes in labor-market outcomes between 1980 and 2012. In sensitivity analysis, we use 1990 and 2007 as alternative start and end years, respectively. All data, except for occupation tradability, come from the Integrated Public Use Micro Samples (IPUMS; Ruggles, Genadek, Goeken, Grover, and Sobek (2015)). For 1980 and 1990, we use 5% Census samples; for 2012, we use the combined 2011, 2012, and 2013 1% American Community Survey (ACS) samples. Our sample includes individuals who were between ages 16 and 64 in the year preceding the survey. Residents of group quarters are dropped. Our concept of local labor markets is commuting zones (CZs), as developed by Tolbert and Sizer (1996). Each CZ is a cluster of counties characterized by strong commuting ties within and weak commuting ties across zones. There are 722 CZs in the mainland United States.

For our first dependent variable, the log change in native-born employment for an occupation in a CZ shown in (24), we consider two education groups: high-education workers are those with a college degree (or four years of college) or more, whereas low-education workers are those without a college degree. Although these education groups may seem rather aggregate, note that in (24) the unit of observation is the region and occupation, where our 50 occupational groups already entail considerable skill-level specificity (e.g., computer scientists versus textile-machine operators).²⁵ We measure domestic employment as total hours worked by native-born individuals in full-time-equivalent units (for an education group in an occupation in a CZ) and use the log change in this value as our first regressand. We measure our second dependent variable, the change in total labor payments, as the log change in total wages and salaries in an occupation in a commuting zone.

We define immigrants as those born outside of the United States and not born to U.S. citizens. The aggregate share of immigrants in hours worked in our sample rises from 6.6% in 1980 to 16.8% in 2012.²⁶ We construct the occupation- and CZ-specific immigration shock in (24) and (25), x_{ro} , defined in (23), as the percentage growth in the number of working-age immigrants for an education group in CZ r times the initial-period share of foreign-born workers in that education group in total earnings for occupation o in CZ r , where this product is then summed over education groups. In constructing x_{ro} and its instrument, x_{ro}^* , shown in (26), we use three education groups; for the instrument we use 12 source regions for immigrants.²⁷

²⁵Because the divide in occupational sorting is sharpest between college-educated and all other workers, we include the some-college group with lower-education workers. Whereas workers with a high-school education or less tend to work in similar occupations, the some-college group may seem overly skilled for this category. Results are similar if we shift some-college workers from the low-education to the high-education group.

²⁶Because we use data from the Census and ACS (which seek to be representative of the *entire* resident population), undocumented immigrants will be included to the extent that are captured by these surveys. An additional concern is that the matching of immigrants to occupations may differ for individuals who arrived in the United States as children (and attended U.S. schools) and those who arrived in the United States as adults. Our results (in unreported analysis) are substantially unchanged using an alternative definition of immigrant status in which we exclude foreign-born individuals who moved to the United States before the age of 18.

²⁷The education groups are less than a high-school education, high-school graduates and those with some college education, and college graduates. Relative to native-born workers, we create a third education cate-

Our baseline data include 50 occupations (see Table V in Appendix B).²⁸ We measure occupation tradability using the [Blinder and Krueger \(2013\)](#) measure of “offshorability,” which is based on professional coders’ assessments of the ease with which each occupation could be offshored.²⁹ We group occupations into more and less tradable categories using the median so that there are 25 tradable and 25 nontradable entries (see Table V in Appendix B). The most tradable occupations include fabricators, financial-record processors, mathematicians and computer scientists, and textile-machine operators; the least tradable include firefighters, health assessors, therapists, and vehicle mechanics.

In Table VI in Appendix B, we compare the characteristics of workers employed in tradable and nontradable occupations. Whereas the two groups are similar in terms of the shares of employment of workers with a college education, by age and racial group, and in communication-intensive occupations (see, e.g., [Peri and Sparber \(2009\)](#)), tradable occupations do have relatively high shares of employment of male workers and workers in routine-task-intensive and abstract-reasoning-intensive jobs. High male and routine-task intensity arise because tradable occupations are overrepresented in manufacturing. In robustness checks, we use alternative cutoffs for which occupations are tradable and which are nontradable: drop workers in routine-task-intensive jobs, in which pressures for labor-saving technological change has been particularly strong ([Lewis \(2011\)](#), [Autor and Dorn \(2013\)](#)); and drop workers in communication-task-intensive jobs, in which native workers may be less exposed to immigration shocks ([Peri and Sparber \(2009\)](#)). In further checks, we use industries in place of occupations, categorizing tradable industries to include agriculture, manufacturing, and mining, and nontradable industries to include services.

In Table VI in Appendix B, we show that the national shares of immigrants in employment for nontradable and tradable occupations are similar, both in 1980 and in 2012. These aggregates mask heterogeneity in two dimensions. First, the share of immigrants in total employment varies widely across regions; see Figure 9 in Appendix G. For example, in 2012 the share of immigrants in total employment is highest in Miami, San Jose, and Yuma. Second, within regions there is heterogeneity in immigrant cost shares across occupations, both within tradable and within nontradable jobs; see Table VII in Appendix B, and Figures 10 and 11 in Appendix G. For example, in Los Angeles in 2012, immigrant intensity among tradable occupations is highest for textile machine operators, printing machine operators, and other machine operators. Among nontradable occupations, immigrant intensity in 2012 is highest among housekeeping, agricultural workers, cleaning and building services, and food preparation services. This variation in exposure to immigration across regions and occupations is at the core of our empirical and quantitative analysis.

gory of less-than-high-school completed for foreign-born workers, given the preponderance of undocumented immigrants in this group (and the much larger proportional size of the less-than-high-school educated among immigrants relative to natives). The source regions for immigrants are Africa, Canada, Central and South America, China, Eastern Europe and Russia, India, Mexico, East Asia (excluding China), Middle East and South and Southeast Asia (excluding India), Oceania, Western Europe, and all other countries.

²⁸We begin with the 69 occupations from the 1990 Census occupational classification system and aggregate up to 50 to concord to David Dorn’s categorization (<http://www.ddorn.net/>) and to combine small occupations that are similar in education profile and tradability but whose size complicates measurement.

²⁹[Goos, Manning, and Salomons \(2014\)](#) provide evidence supporting this measure. Their index of actual offshoring by occupation based on the European Restructuring Monitor is strongly and positively correlated with the Blinder–Krueger measure. Given limited data on intracountry trade flows in occupation services, we use measures of offshorability at the national level to capture tradability at the regional level, a correspondence which is imperfect. Our results are robust to using alternative cutoffs regarding which occupations are assigned to T versus assigned to N and to defining tradability at the industry rather than occupation level.

Finally, to provide context for our analysis of adjustment to immigration across occupations within tradables versus within nontradables in the estimation of (24) and (25), we compare over our 1980–2012 time period the unconditional changes in employment shares across occupations within T and across occupations within N . The median absolute log employment change for occupations is 0.59 in nontradables, as compared to 0.65 in tradables.³⁰ Although these unconditional changes do not account for differences in the magnitude of shocks affecting occupations in the two groups, the higher variability of employment changes within T when compared to within N suggests that overall adjustment is no less sluggish among tradable jobs than among nontradable jobs.³¹

4.4. Empirical Results on Labor Allocations and Labor Payments

In the specification for the allocation of native-born workers across occupations within CZs in (24), the dependent variable is the log change in CZ employment of native-born workers for an education cell in an occupation and the independent variables are the CZ immigration shock to the occupation, shown in (23), this value interacted with a dummy for the occupation being nontraded, and dummies for the occupation and CZ-occupation group. The regressions, which we run separately for low-education and high-education workers, are weighted by the initial number of native-born workers in the education cell employed in the occupation in the CZ; standard errors are clustered by state. We instrument for the immigration shock using the value in (26), where we disaggregate the sum in specifying the instrument, such that we have three instruments per endogenous variable; we report Angrist and Pischke (2008) F -statistics for first-stage regressions with multiple endogenous variables.

Table I presents results for equation (24). In the upper panel, we exclude the interaction term for the immigration shock and the nontraded dummy, such that we estimate a common impact coefficient across all occupations; in the lower panel we incorporate this interaction and allow x_{ro} to have differential effects across occupations within T and within N . For low-education workers, column 1a reports ordinary least squares (OLS) results, column 2a reports 2SLS results, and column 3a reports reduced-form (RF) results in which we replace the immigration shock with the instrument in (26), a pattern we repeat for high-education workers. In the upper panel, all coefficients are negative: on average the arrival of immigrant workers in a CZ crowds out native-born workers at the education–occupation level. The impact coefficient on x_{ro} is larger in absolute value for high-education workers than for low-education workers, suggesting that crowding-out is stronger for the more skilled. Referring to our analytic model, these results are consistent with immigrant–native substitutability ρ being large relative to occupation–output sensitivity to price ϵ_{rg} (averaged across r and g).

In the lower panel of Table I, we add the interaction between the immigration shock and the nontradable indicator, as in (24), to allow for differences in crowding out within T and within N . The two groups are clearly delineated. In tradables, the 2SLS impact coefficient is close to zero (0.002 for low-education workers, -0.03 for high-education workers) with narrow confidence intervals. The arrival of immigrant workers crowds native-born

³⁰If we instead examine the mean absolute log employment change (weighted by initial occupation employment shares), the corresponding values are 0.45 for nontradables and 0.48 for tradables.

³¹This observation poses a challenge to an alternative explanation for the greater immigrant displacement of natives within N versus within T : that the occupation supply elasticity is lower in T than in N . If this were the case, one would expect, all else equal, employment changes across occupations within T to be smaller than those across occupations within N . Yet, in the data we observe the opposite.

TABLE I
ALLOCATION FOR DOMESTIC WORKERS ACROSS OCCUPATIONS^a

Panel A						
	(1a)	(2a)	(3a)	(4a)	(5a)	(6a)
	OLS	Low Ed. 2SLS	RF	OLS	High Ed. 2SLS	RF
x_{ro}	-0.088 (0.065)	-0.150 (0.069)	-0.097 (0.040)	-0.130 (0.040)	-0.225 (0.048)	-0.205 (0.037)
Obs.	33,723	33,723	33,723	26,644	26,644	26,644
R^2	0.822	0.822	0.822	0.68	0.679	0.68
AP F -stats (first stage)		136.10			105.67	
Panel B						
	(1b)	(2b)	(3b)	(4b)	(5b)	(6b)
	OLS	Low Ed. 2SLS	RF	OLS	High Ed. 2SLS	RF
x_{ro}	0.089 (0.049)	0.002 (0.089)	0.004 (0.060)	0.022 (0.036)	-0.030 (0.066)	-0.018 (0.059)
$\mathbb{I}_o(N)x_{ro}$	-0.303 (0.062)	-0.296 (0.102)	-0.234 (0.090)	-0.309 (0.097)	-0.374 (0.126)	-0.328 (0.112)
Obs.	33,723	33,723	33,723	26,644	26,644	26,644
R^2	0.836	0.836	0.836	0.699	0.699	0.699
Wald test: P -values	0.00	0.00	0.00	0.00	0.00	0.00
AP F -stats (first stage)						
x_{ro}		102.77			65.90	
$\mathbb{I}_o(N)x_{ro}$		75.21			48.48	

^aThe dependent variable is the log change in the employment of domestic workers in a region–occupation, 1980–2012. The estimating equation is (24). Observations are for CZ–occupation pairs (722 CZs×50 occupations). The dependent variable is the log change in hours worked by native-born workers in a CZ–occupation; the immigration shock, x_{ro} , is defined in (23); $\mathbb{I}_o(N)$ is a dummy variable for the occupation being nontradable. All regressions include dummy variables for the occupation and the CZ group (tradable, nontradable). Columns 1 and 4 report OLS results, columns 2 and 5 report 2SLS results using (26) to instrument for x_{ro} , and columns 3 and 6 replace the immigration shock(s) with the instrument(s). Low-education workers are those with some college or less; high-education workers are those with at least a bachelor’s degree. Robust standard errors (in parentheses) are clustered on state. Models are weighted by start of period CZ–occupation–education group native-born population. For the Wald test, the null hypothesis is that the sum of the coefficients on x_{ro} and $\mathbb{I}_o(N)x_{ro}$ is zero. We report Angrist–Pischke (AP) F -statistics for the first-stage regressions.

workers neither out of nor into tradable jobs. In nontradables, by contrast, the impact coefficient—the sum of the coefficients on x_{ro} and the $x_{ro}\mathbb{I}_o(N)$ interaction—is strongly negative. For both low- and high-education workers, in either the 2SLS or the reduced-form regression, the coefficient sum is significant at the 1% level. In nontradables, an influx of immigrant workers crowds out native-born workers, consistent with our theoretical model in which the crowding-out effects of immigration are stronger within N than within T .

Because the immigration exposure measure, x_{ro} , is the interaction between the immigrant inflow into a CZ and the initial immigrant intensity of an occupation and because we allow this term to matter differentially for tradable and nontradable occupations, interpreting coefficient magnitudes in Table I requires guidance. Consider the impact of an immigrant inflow between 1980 and 2012 into high-immigration Los Angeles on two occupations within N , high-immigrant intensity housekeeping ($x_{ro} = 0.71$), and low immigrant-intensity firefighting ($x_{ro} = 0.06$), where the difference in their occupation exposure is 0.65. Our results indicate that for housekeeping relative to firefighting, we would see a

0.20 = 0.65 × 0.30 differential log point employment reduction for low-education natives and a 0.24 = 0.65 × 0.37 differential log point employment reduction for high-education natives. By contrast, because the 2SLS coefficient on x_{ro} in column 2b within T is a reasonably precisely estimated zero, we would detect no differential domestic employment changes between any pair of tradable occupations, either in Los Angeles or elsewhere.³² These results do not address how immigration affects tradables or nontradables *in the aggregate*, which is the focus of previous literature.

Our results highlight a new source of labor-market exposure to immigration. Living in a high immigration region (e.g., Los Angeles) *and* preferring to work in immigrant-intensive nontradable jobs (e.g., housekeeping) leaves one relatively exposed to foreign labor inflows, whereas living in the same CZ but having a proclivity to work either in tradable jobs or in nontradable jobs that attract few immigrants leaves one comparatively less exposed. In Section 6, we use our quantitative framework to interpret these coefficients, without imposing the restrictions we make in Section 3.1, to determine the welfare consequences of differential exposure to immigration and to solve for wage effects across CZs.

The specification for the log change in total labor payments in (25) provides evidence on the theoretical mechanism underlying differential immigrant crowding out of native-born workers in T versus N . In Table II, we report estimates of γ , which is the coefficient on the immigration shock, x_{ro} , and γ_N , which is the coefficient on the immigration shock interacted with the nontradable-occupation dummy, $\mathbb{I}_o(N)x_{ro}$. In all specifications, the coefficient on x_{ro} is positive and precisely estimated, consistent with the elasticity of local output to local prices in tradables being larger than 1 ($\epsilon_{rT} > 1$). Similarly, in all specifications the coefficient on $\mathbb{I}_o(N)x_{ro}$ is negative and highly significant, consistent with $\epsilon_{rT} > \epsilon_{rN}$.

Together, the results in Tables I and II verify both differential crowding out within T versus within N and the mechanism in our model through which this difference is achieved. The arrival of immigrant labor results in an expansion in output and a decline in prices of immigrant-intensive tasks both within tradables and within nontradables. Compared to N , however, adjustment in T occurs more through output changes than through price changes. Consequently, labor payments of immigrant-intensive occupations increase by more within tradable than within nontradable jobs, as shown in Table II. Consistent with this mechanism, Table I shows that an immigration shock generates null effects on native employment within T and negative effects on native employment within N .

Robustness. In Appendix H, we present alternative specifications in which we check for violations of the identifying restrictions (i)–(iii) discussed in Section 4.2. Assumptions (i) and (ii) require that employment shocks to a region do not affect immigration inflows to other regions. When we drop the largest CZs, for which concerns about reverse causality from local labor-market shocks to immigrant inflows may be strongest, our results are materially unchanged; see Appendix H.1.3. Assumption (iii) would be violated if current regional productivity shocks are correlated with past shocks that affected initial region–occupation immigrant employment intensities. Reassuringly, our results are

³² Given a value of $\theta + 1$, which is the elasticity of occupation wages to factor allocation as shown in equation (20) and which we set at 2 in our quantitative model in Section 5, our theory allows us to use these results to interpret wage implications. Specifically, our results indicate that we would detect a 0.10 = 0.20/2 and a 0.12 = 0.24/2 log point reduction in domestic low-education and high-education wages in housekeeping relative to firefighters in Los Angeles but no differential domestic wage changes between any two tradable occupations in Los Angeles or elsewhere.

TABLE II
LABOR PAYMENTS ACROSS OCCUPATIONS^a

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	0.392 (0.115)	0.380 (0.166)	0.320 (0.131)
$\mathbb{I}_o(N)x_{ro}$	-0.351 (0.116)	-0.398 (0.137)	-0.324 (0.092)
Obs.	34,892	34,892	34,892
R^2	0.897	0.897	0.897
Wald test: P -values	0.38	0.85	0.96
AP F -stats (first stage)			
x_{ro}		55.54	
$\mathbb{I}_o(N)x_{ro}$		105.82	

^aThe dependent variable is log change in labor payments in a region–occupation, 1980–2012. The estimating equation is (25). Observations are for CZ–occupation pairs. The dependent variable is the log change in total labor payments in a CZ–occupation; the immigration shock, x_{ro} , is in (23); $\mathbb{I}_o(N)$ is a dummy variable for the occupation being nontradable. All regressions include dummy variables for the occupation and the CZ group (tradable, nontradable). Column 1 reports OLS results, column 2 reports 2SLS results using (26) to instrument for x_{ro} , and column 3 replaces the immigration shocks with the instruments. Robust standard errors (in parentheses) are clustered on state. Models are weighted by start of period CZ–occupation population. For the Wald test, the null hypothesis is that the sum of the coefficients on x_{ro} and $\mathbb{I}_o(N)x_{ro}$ is zero. We report Angrist–Pischke (AP) F -statistics for the first-stage regressions.

qualitatively unaltered when we construct the instrument replacing initial immigrant employment intensities for a given region with the corresponding intensities averaged over a set of regions other than this region and outside of the region’s state, as in (27); see Appendix H.2. Our results would be similarly compromised if the negative impact of the immigration shock on native allocations and total labor payments was the by-product of persistent region–occupation employment trends, as in the Borjas, Freeman, and Katz (1997) critique of the Card instrument. To examine the relevance of this critique for our analysis, we reestimate (24) with a dependent variable that is the change in the occupational employment of native workers over the 1950–1980 period, while keeping the immigration shock defined over the 1980–2012 period, thus assessing whether confounding long-run region–occupation employment trends are present in the data. These exercises, presented in Appendix H.1, reveal no evidence that current impacts of immigration on native-born employment are simply the by-product of continuing patterns of regional employment growth.³³ The results in Tables I and II also embody assumptions about which activities are nontradable and which are tradable. In Table I, we divide occupations into equal-sized groups of tradables and nontradables. In Appendix H.3, we explore alternative assumptions about which occupations are tradable and which are not (and alternative occupation aggregation schemes). The corresponding regression results are very similar to those in Table I. Results are also similar, as reported in Appendix H.6, when we redo the analysis for region–industries, rather than for region–occupations, and identify the

³³The results in Appendix H.1 indicate that the 1980–2012 immigration shock has “impacts” on outcomes for 1950–1980 with the opposite sign of impacts on outcomes for 1980–2012. One potential explanation for this pattern, which data limitations prevent us from evaluating, is that the immigration shocks for the 1950–1980 and 1980–2012 time periods are negatively correlated. A major change in U.S. immigration law in 1965, which in later decades helped redirect source countries for U.S. labor inflows from Europe to Asia and Latin America, could be one cause of this negative correlation. Whereas immigrants as a share of the population and labor force declined modestly from 1950 to 1980, these shares increased sharply in the following three decades, consistent with a negative correlation between shocks in the 1950–1980 and 1980–2012 periods.

tradability of industries as discussed in Section 4.3.³⁴ We also experiment with changing the end year for the analysis from 2012 to 2007, which falls before the onset of the Great Recession. Using this earlier end year yields results similar to our baseline sample period of strong immigrant crowding out of native-born workers in nontradable occupations and no crowding out in tradable occupations. When we alternatively change the start year from 1980 to 1990, the differential crowding-out effect for low-education workers in nontradables weakens, but remains strong for high-education workers in nontradables; see Appendix H.1.2.³⁵ Finally, in Appendix H.4 we verify that our results are qualitatively unaffected by imposing alternative occupation aggregations (to establish the robustness of our results to either expanding or contracting the number of occupational groups) or by dropping routine- or communication-intensive occupations (to address concerns over the confounding effects of skill-biased technical change and the language-based adjustment mechanisms discussed in Peri and Sparber (2009)).

Summary. The empirical results show that, in line with our theoretical model, there are differences in adjustment to labor supply shocks across occupations within tradables and within nontradables. The allocation regressions are consistent with immigrant crowding out of native-born workers within nontradables ($\epsilon_{rN} < \rho$) and with neither crowding in nor crowding out within tradables ($\epsilon_{rT} \approx \rho$).

5. A QUANTITATIVE FRAMEWORK

We next present a quantitative model in which we impose less restrictive assumptions than in our baseline model of Section 2 (geographic mobility of native and immigrant workers, many source countries for immigrants) and in our comparative static exercises in Section 3 (allowing for flexible occupational comparative advantage of education groups, large shocks, nonnegligible shares of regions in the national economy, variation in trade shares across tradable occupations). This extended model allows us to show numerically that our theoretical results of Section 3 hold under less restrictive assumptions; to calibrate model parameters and assess quantitatively other model implications using the same two-stage least squares approach on model-generated data as in the actual data, to conduct counterfactual exercises in which we change immigrant stocks by source country, and to calculate absolute changes in real wages by CZ (in addition to relative outcomes across occupations within regions, which are the focus of our empirical and theoretical analyses). In this section, we describe our quantitative model, parameterize it, and evaluate additional quantitative implications. In the following section, we conduct counterfactual exercises regarding U.S. immigration.

5.1. An Extended Model

We extend our model of Section 2 as follows. First, we introduce many source countries, c , from which immigrants originate. We assume that the systematic component of productivity, Z_{reo}^l , does not depend on the immigrant's source country c . Hence, given the

³⁴Immigration crowds out native-born employment in nontradables but not in tradables (although β_N in (24) is always negative, it is significant in 2SLS and reduced-form regressions for high-education but not low-education natives), while leading to a greater expansion of labor payments in immigrant-intensive occupations in tradable than in nontradable industries (γ_N in (25) is significantly negative in all specifications).

³⁵Variation in parameter estimates across time periods should not be surprising. In (24), these parameters are functions of output price elasticities and embodied native labor-supply and productivity elasticities; they will vary across time periods to the extent that trade shares or the component elasticities vary.

measure of immigrants in education cell e from each source country in each region, denoted N_{re}^{Ic} , the equations in our baseline model continue to hold, where $N_{re}^I \equiv \sum_c N_{re}^{Ic}$. We incorporate source countries in order to calibrate the model to our two-stage least squares regressions and to perform source-country-specific counterfactuals. Nevertheless, we do not model trade between regions in our model—U.S. commuting zones—and the rest of the world.

A second extension is that native and immigrant workers choose in which region r to live. We follow Redding (2016) and assume that the utility of a worker ω living in region r depends on amenities and the expected real wage from living there. Preferences for amenities from residing in region r are given by the product of a systematic component, U_{re}^D for natives with education e and U_{re}^{Ic} for immigrants with education e from source country c , and an idiosyncratic preference shock, $\varepsilon_r(\omega, r)$, which is distributed Fréchet with shape parameter $\nu > 1$.³⁶ We assume that each worker first draws her preference shocks across regions and chooses her region, and then draws her productivity shocks across occupations and chooses her occupation. Under these assumptions, the measure of workers of type k (and source country c for immigrants) with education e in region r is given by

$$N_{re}^D = \frac{\left(U_{re}^D \frac{\text{Wage}_{re}^D}{P_r} \right)^\nu}{\sum_{j \in \mathcal{R}} \left(U_{je}^D \frac{\text{Wage}_{je}^D}{P_j} \right)^\nu} N_e^D \quad \text{and} \quad N_{re}^{Ic} = \frac{\left(U_{re}^{Ic} \frac{\text{Wage}_{re}^{Ic}}{P_r} \right)^\nu}{\sum_{j \in \mathcal{R}} \left(U_{je}^{Ic} \frac{\text{Wage}_{je}^{Ic}}{P_j} \right)^\nu} N_e^{Ic},$$

where N_e^D and N_e^{Ic} denote the exogenous measure of education e workers who are native and who are immigrant from source country c , respectively, across all regions ($N_e^D = \sum_{r \in \mathcal{R}} N_{re}^D$ and $N_e^{Ic} = \sum_{r \in \mathcal{R}} N_{re}^{Ic}$). We take the aggregate measure of migrants from source country c and education group e , N_e^{Ic} , as given, leaving unmodelled the cause of migrant outflows from the set of source countries.

In Appendix D.1 we specify a system of equations to solve for changes between two time periods in prices and quantities in response to changes in exogenously specified national supplies of immigrant workers by education and source country.³⁷ These changes are not restricted to be infinitesimal as in Section 3. Three sets of inputs are required to solve this system. First, we require initial period of allocations across occupations for each worker type and education cell in each region, π_{reo}^k ; wage income of each worker type and education cell as a share of total income by region, $\frac{N_{re}^k \times \text{Wage}_{re}^k}{\sum_{e',k'} N_{re'}^{k'} \times \text{Wage}_{re'}^{k'}}$, where the average wage of type k workers with education e in region r (i.e., the total income of these workers divided by their mass) is (independently of country of origin c and occupation o) given by

$$\text{Wage}_{re}^k = \gamma \left[\sum_{j \in \mathcal{O}} (Z_{rej}^k W_{rj}^k)^{\theta+1} \right]^{\frac{1}{\theta+1}}; \tag{28}$$

³⁶The assumption that immigrants with a given education level differ in their preferences across U.S. regions (based on their source country) but not in their pattern of comparative advantage across occupations provides a model-based motivation of our Card-type instrument.

³⁷Specifically, we must solve for 72,200 ($2 \times 50 \times 722$) occupation wage changes and 27,436 ($(2 + (3 \times 12)) \times 722$) population changes.

labor allocations across regions for each worker type and education cell (and source country for immigrants), N_{re}^D and N_{re}^{Ic} ; absorption shares by occupation in each region, $\frac{Y_{ro} \times P_{ro}^y}{\sum_{o'} Y_{ro'} \times P_{ro'}^y}$; and occupation bilateral exports relative to production and relative to absorption in each region. Second, we require values of parameters η (the substitution elasticity between occupations in production of the final good), α (the substitution elasticity between occupation services from different regions in the production of a given service), ρ (the substitution elasticity between domestic and immigrant workers in production within an occupation), θ (the dispersion of worker productivity), and ν (the dispersion of worker preferences for regions). Third, we require aggregate changes in the national number of natives and immigrants by source country and education, \hat{N}_e^D and \hat{N}_e^{Ic} , as well as changes in preferences for amenities by region r , nativity, and education, \hat{U}_{re}^D and \hat{U}_{re}^{Ic} .

5.2. Calibration

We calibrate the model based on the U.S. data used in Section 4. We consider 722 regions (each of which corresponds to a CZ) within a closed national economy, 50 occupations (half tradable, half nontradable), two domestic education groups (some college or less, college completed or more), and three immigrant education groups (less than high school, high school graduates and some college, and college graduates). The values of π_{reo}^k , $\frac{N_{re}^k \times Wage_{re}^k}{\sum_{e'k'} N_{re'}^{k'} \times Wage_{re'}^{k'}}$, and N_{re}^{kc} in the initial equilibrium are obtained from Census and ACS data. We use the same 12 source regions for immigrants as in our empirical exercises.

In order to construct bilateral exports by occupation in each region, we assume that occupation demand shifters are common across regions for tradable occupations, $\mu_{ro} = \mu_o$ for $o \in T$, and choose trade costs as follows. First, we assume that nontradable occupations are subject to prohibitive trade costs across CZs ($\tau_{rjo} = \infty$ for all $j \neq r$). Second, we assume that bilateral trade costs for a given tradable occupation between a given origin–destination pair are common across tradable occupations (given the absence of bilateral cross-CZ trade data by occupation), $\tau_{rjo} = \tau_{rj'o'}$ for all $o, o' \in T$, and parameterize them using a standard gravity trade cost function, $\tau_{rjo} = \bar{\tau} \times \ln(\text{distance}_{rj})^\delta$ for $j \neq r$. Given this assumption, the elasticity of trade with respect to distance across CZs within the United States in our model is given by $(1 - \alpha)\delta$, where $1 - \alpha$ is the trade elasticity introduced in equation (5). We set $(1 - \alpha)\delta = -1.29$, as estimated in [Monte, Redding, and Rossi-Hansberg \(2016\)](#) using data on intra-U.S. manufacturing trade from the Commodity Flow Survey (CFS). We calibrate $\bar{\tau}$ to match the average export share within tradables in our model (in the year 2012) to that in the 23 CFS regions (in the year 2007) that closely align with our CZs, where we weight each CZ according to total labor payments in tradables in the model and according to total shipments in manufactures in the data. Further details are provided in Appendix D.2 and Appendix I.1. Even though bilateral trade costs are common across tradable occupations, bilateral trade shares differ across occupations due to variation in size and marginal costs across occupations and regions.³⁸

We assign values to the parameters α , ν , θ , η , and ρ as follows. The parameter $\alpha - 1$ is the partial elasticity of trade flows to trade costs. We set $\alpha = 7$, yielding a trade elasticity of 6, in the mid-range of estimates in the trade literature surveyed by Head and

³⁸We also consider a parameterization in which trade is free trade within tradables. We match our moments—excluding trade shares—by setting $\alpha = 7$, $\rho = 6.8$, and $\eta = 1.85$ (compared to our baseline parameterization $\alpha = 7$, $\rho = 4.6$, and $\eta = 1.65$). In unreported results, we obtain similar results to our baseline parameterization.

TABLE III
PARAMETER VALUES IN QUANTITATIVE ANALYSIS

	θ	α	ρ	η	ν
Parameter values	1	7	4.6	1.65	1.5

Mayer (2014) and in line with the estimates using regional data within the United States estimated in Donaldson (2020) and Donaldson and Hornbeck (2016). The parameter ν is the elasticity of native and immigrant spatial allocations with respect to native real wages across regions, $\nu = \frac{n_{re}^k - n_{re}^k}{w_r^k - w_{r'}^k - p_r + p_{r'}}$. We set $\nu = 1.5$, which falls in the middle of the range of estimates in the geographic labor mobility literature reviewed by Fajgelbaum, Morales, Carlos Suárez Serrato, and Zidar (2015). The parameter $\theta + 1$ is the elasticity of occupation allocations with respect to occupation wages within a region, $\theta + 1 = \frac{n_{ro}^k - n_{ro}^k}{w_{ro}^k - w_{ro'}^k}$. We set $\theta = 1$ following analyses on worker sorting across occupations in the United States in Burstein, Morales, and Vogel (2016) and Hsieh et al. (2016).³⁹

Since estimates of the elasticity of substitution between occupations, η , and the elasticity of substitution between native and immigrant workers within occupations, ρ , are not available from existing research, we calibrate them. To do so, we feed into our model national changes in natives and immigrants by source country and education, \hat{N}_e^D and \hat{N}_e^{Ic} , as well as changes in preferences for amenities in region r by nativity and education, \hat{U}_{re}^D and \hat{U}_{re}^{Ic} , and solve for the full general equilibrium, allowing for endogenous movements of natives and immigrants between regions and occupations. We choose \hat{N}_e^D and \hat{N}_e^{Ic} to match observed changes between 1990 and 2012. We choose \hat{U}_{re}^D and \hat{U}_{re}^{Ic} to match changes in regional populations of each nativity and education cell observed between 1980 and 2012, \hat{N}_{re}^D and \hat{N}_{re}^I .⁴⁰ We then run the 2SLS employment-allocation regression in (24) on model-generated data. While (24) no longer holds in the extended model, it provides useful “identified moments,” which we can match in our full model. In particular, the signs and relative magnitudes of the regression coefficients contain information about the underlying structural parameters.

We choose η and ρ to target the extent to which immigration crowds in (out) native employment within tradables and within nontradables, reported in the lower panel of Table I: we target the coefficient on x_{ro} , $\beta^D = -0.01$ (neither crowding in nor crowding out of natives by immigrants in tradables), and the coefficient on $\mathbb{I}_o(N)x_{ro}$, $\beta_N^D = -0.34$ (crowding out of natives by immigrants in nontradables), where each is the average of the 2SLS estimates across high- and low-education native workers. This procedure results in values of $\rho = 4.6$ and $\eta = 1.65$. Table III reports calibrated parameter values and Table IV reports the employment-allocation regressions using data generated by the model.⁴¹ Comparing empirical estimates in Table I with estimates using model-generated

³⁹Our parameter θ corresponds to $\theta + 1$ in Burstein, Morales, and Vogel (2016) and Hsieh et al. (2016).

⁴⁰In practice, we do not need to back out the realization of these amenity shocks because the total number of natives and immigrants by education and region, \hat{N}_{re}^D and \hat{N}_{re}^I , provides sufficient statistics for all calibrated moments.

⁴¹The R^2 s in the 2SLS regressions are high, suggesting that our reduced-form regressions have a good fit. In order to match the lower R^2 in the data, we would have to introduce random changes in productivities by occupation and regions, \hat{A}_{ro} and \hat{A}_{ro}^k .

TABLE IV
REGRESSION RESULTS USING MODEL-GENERATED DATA^a

	Allocations		Labor Payments	Occupation Wages
	Low Education	High Education		
x_{ro}	-0.007	-0.006	0.482	-0.008
$\mathbb{I}_o(N)x_{ro}$	-0.372	-0.309	-0.270	-0.203
R^2	0.99	0.98	0.98	0.95

^aCalibration targets are averages of the regression coefficients for low and high education native workers: $\beta^D = -0.01$ and $\beta_N^D = -0.34$.

data in Table IV, we see that estimates of β^D are similar for the two education groups in both exercises (0.002 for low-education natives and -0.03 for high-education natives in the empirical estimates; -0.007 for low-education natives and -0.006 for high-education natives in the model-generated estimates). In mild contrast, estimates for β_N^D are modestly smaller in absolute value for low- relative to high-education natives in the empirical estimates (-0.30 versus -0.37) and modestly larger in absolute value for low- relative to high-education natives in model-generated estimates (-0.37 versus -0.31).

The intuition for the realized values of the parameters η and ρ can be understood using the analytics in Section 3, although the restrictions under which these results are obtained are partially relaxed here. Our assumption that trade shares are zero within N implies that the elasticity of regional output to the regional producer price for nontradables, ϵ_{rN} , equals η . The elasticity of regional output to the regional producer price for tradables, ϵ_{rT} , is a weighted average of α and η , with the weight on α increasing in trade shares of tradable occupations, where trade shares are implied by the calibration procedure described above. Since tradable occupations have high trade shares, ϵ_{rT} is closer to α than to η . From Section 3, targeting $\beta^D \approx 0$ in the employment-allocation regression (no crowding in or out within tradables for natives) requires that the elasticity of regional output to the regional producer price within tradables, ϵ_{rT} , equals the elasticity of substitution between native- and foreign-born workers within each occupation, ρ . Thus, ρ must be closer to α than to η , yielding $\rho = 4.6$. A higher value of ρ would imply crowding out within tradables, which is inconsistent with our reduced-form estimates (see the alternative parameterization below).

The intuition for the value of $\eta = 1.65$ is similar. Targeting $\beta_N^D < 0$ in the employment-allocation regression (crowding out for natives in N) requires that $\eta = \epsilon_{rN} < \rho$. To demonstrate how the allocation regression shapes our choice of η beyond requiring that $\eta < \rho$, Figure 12 in Appendix K plots model-implied values of β^D and β_N^D against the value of η if we fix all other parameters at their baseline levels. As described above, β^D is less responsive to changes in η than is β_N^D . Therefore, the estimated value of β_N^D guides our choice of η .

5.3. Additional Quantitative Implications

To explore further the validity of our extended model, we perform a series of regressions using model-generated data, where the implied moments are not targeted in the calibration, and compare the estimated parameters to those we obtain when using actual data.

Labor allocations. In our baseline calibration, we target separately the lack of crowding in of natives by immigrants in tradables and the extent of crowding out of natives by

immigrants in nontradables. When we estimate a common impact coefficient across all occupations by excluding the interaction term for the immigration shock and the non-traded dummy in model-generated data (as in the upper panel of Table I), we obtain an average estimate, across low- and high-education natives, of -0.17 (versus -0.19 in the data).

Labor Payments. Estimating the 2SLS labor-payments regression on model-generated data yields a coefficient on x_{ro} of 0.48 and a coefficient on $\mathbb{I}_o(N)x_{ro}$, of -0.27 , as shown in Table IV. These results are roughly in line with the coefficient on x_{ro} of 0.38 and the coefficient on $\mathbb{I}_o(N)x_{ro}$ of -0.40 estimated in the data and shown in column 3 of Table II. Both in the model and in the data, labor payments expand in immigrant-intensive occupations more in tradable than in nontradable occupations.

Occupation Wages. Our analytic results in (20) predict how occupation wages per efficiency unit of native-born workers adjust to an inflow of foreign workers. Following the same steps that led to specification (24) for the impact of foreign labor inflows on native labor allocations in Section 4.1, this equation yields the following regression for native occupation wages:

$$w_{ro}^D = \tilde{\alpha}_{rg}^D + \tilde{\alpha}_o^D + \chi^D x_{ro} + \chi_N^D \mathbb{I}_o(N)x_{ro} + \tilde{\nu}_{ro}^D. \tag{29}$$

Unfortunately, in actual data we do not observe w_{ro}^D , wages per efficiency unit at the region–occupation level. All we observe empirically is the change in the average wage for workers in a region–education–occupation cell, wage_{reo}^D , which conflates changes in wages per efficiency unit of labor with changes in wages driven by changes in the composition of workers in the region–education–occupation cell, as workers select into or out of occupations and (or) regions in response to changing labor-market conditions. Our assumption that each $\varepsilon(\omega, o)$ is drawn independently from a Fréchet distribution yields the prediction that wage_{reo}^D is not systematically related to the immigration shock, since changes in selection exactly offset changes in occupation wages under this distributional assumption.

We examine this prediction in Table VIII in Appendix C, which presents results from estimating a version of equation (29) in which we replace the dependent variable, w_{ro}^D , with the observed change in the average wage for a region–occupation, wage_{reo}^D . For high-education native workers, the 2SLS regression strongly supports the implications of the Fréchet distribution: immigration has no differential effects on the average wages of high-education natives in more immigrant-intensive occupations either within tradable or nontradable occupations. The results for low-education natives are mixed. Within nontradables, the 2SLS regression supports the implications of the Fréchet distribution. However, within tradable occupations, the average wages of low-education natives rise in more immigrant-intensive occupations (but point estimates are small), inconsistent with our assumption of a Fréchet-distribution of idiosyncratic productivity draws.

Alternatively, rather than test for an implication of Fréchet, we can leverage the assumption of a Fréchet distribution to recover unobserved occupation wage changes from changes in observed native allocations and average occupation wages. Specifically, denoting by $\text{Wage}_{reo}^D \equiv W_{ro}^D L_{reo}^D / N_{reo}^D$ the average wage paid to native workers in region r , education e , and occupation o , we have

$$\text{Wage}_{reo}^k = \gamma W_{ro}^k Z_{reo}^k (\pi_{reo}^k)^{\frac{-1}{\theta+1}},$$

which implies

$$w_{ro}^k = \text{wage}_{reo}^k + \frac{1}{\theta + 1} d \ln \pi_{reo}^k, \tag{30}$$

where $d \ln \pi_{reo}^k$ denotes the log change in π_{reo}^k between two equilibria. Using the previous expression, we construct changes in native occupation wages using our calibrated value of $\theta = 1$ and observed values of wage_{reo}^D and $d \ln \pi_{reo}^D$. Table IX in Appendix C presents results from estimating a version of equation (29) in which we use this constructed value of occupation wage changes. The results are strongly consistent with our calibrated model’s predictions, displayed in Table IV. We observe no differential change in occupation wages in more relative to less immigrant-intensive tradable occupations for low- or high-education natives and we observe a greater decline in occupation wages in more relative to less immigrant-intensive nontradable occupations for low- and high-education natives, where both results are consistent with our empirical results on native labor allocations.

Alternative parameterizations of ρ . We consider two alternative parameterizations for the value of ρ . In the first, we triple its value to $\rho = 13.8$ and hold fixed other parameters. This alternative is motivated by the concern that our chosen value of the within-occupation elasticity of substitution between native and immigrant labor, ρ , is lower than the aggregate version of this elasticity estimated by the empirical literature (e.g., Borjas, Grogger, and Hanson (2012), Ottaviano and Peri (2012)).⁴² When raising ρ , the model still implies stronger crowding out within nontradables compared to tradables ($\beta_N^D = -0.34$), but it now generates the counterfactual result of crowding out within tradable occupations ($\beta^D = -0.14$). In a second parameterization, we assume that ρ differs exogenously and systematically between tradable, ρ_T , and nontradable, ρ_N , occupations. In this parameterization, we assume autarky in all occupations (so that $\epsilon_T = \epsilon_N$), fix η at our baseline level, and choose $\rho_T = 1.3 < 3.7 = \rho_N$ targeting the native labor allocation regression estimates. This alternative is motivated by the concern that our finding of stronger crowding out within nontradables relative to within tradables could be a by-product of higher immigrant–native substitution elasticities in nontradables relative to tradables. In this case, however, the model has counterfactual predictions for how labor payments respond to immigration. In particular, relative labor payments to immigrant-intensive occupations increase relatively more within nontradable than within tradable occupations in response to an inflow of immigrants ($\gamma_N = 0.068$). Similarly, prices of immigrant-intensive occupations do not fall relatively more within nontradable than within tradable occupations, which is inconsistent with evidence in Cortes (2008).

6. COUNTERFACTUAL CHANGES IN IMMIGRATION

Using data for 2012 as the initial period, we consider two counterfactual changes in the supply of immigrant workers, \hat{N}_e^{Ic} , which we motivate using proposed reforms in U.S. immigration policy. One potential change is to tighten U.S. border security and to intensify U.S. interior enforcement, which would effectively reduce immigration from Latin America, the source region that accounts for the vast majority of undocumented migration flows across the U.S.–Mexico border. For illustrative purposes, we operationalize this change by reducing the immigrant population from Mexico, Central America, and South America

⁴²Unlike the elasticity of substitution between immigrant and domestic workers within occupations ρ , the aggregate substitution elasticity is not a structural parameter in our model. When we estimate it using model-generated data, it is roughly twice as high as our assumed value of ρ ; see Appendix I.2.

in the United States by one-half. Following the logic of the Card instrument, this labor-supply shock differentially affects CZs that historically have attracted more immigration from Latin America. Labor-market adjustment to the shock takes the form of changes in occupational output prices and occupational wages, a resorting of workers across occupations within CZs, and movements of native- and foreign-born workers between CZs. The second shock we consider is expanded immigration of high-skilled workers. The U.S. business community has advocated for expanding the supply of H1-B visas, the majority of which go to more-educated foreign-born workers (Kerr and Lincoln (2010)). We operationalize this shock via a doubling of immigrants in the United States (from all 12 source countries) with a college education.

In order to describe the results of our counterfactual exercises, it is useful to define a measure of the aggregate exposure of region r to a change in immigration as

$$x_r^I = \left| \sum_e \psi_{re}^I \frac{\Delta N_{re}^I}{N_{re}^I} \right|, \quad (31)$$

where $\psi_{re}^I \equiv N_{re}^I \times \text{Wage}_{re}^I / \sum_{e',k'} N_{re'}^{k'} \times \text{Wage}_{re'}^{k'}$ is the share of immigrant workers with education e in region r in total labor payments in region r and where ΔN_{re}^I is the change between the initial and final periods in education e labor supply of immigrants in region r . The measure x_r^I captures the change in effective labor supply in CZ r caused by changes in the local supply of immigrants, accounting for endogenous regional labor movements.

6.1. A 50% Reduction of Latin American Immigrants

In this scenario, we halve the number of Latin American immigrants at the national level. We set $\hat{N}_e^{Ic} = 1 - \frac{0.5 \times N_e^{Ic}}{N_e^{Ic}}$ for $c = \text{South and Central America}$ and $c = \text{Mexico}$ for all education cells, and we set $\hat{N}_e^{Ic} = 1$ for all other c s and all education cells, where N_e^{Ic} is the total number of region c immigrants with education e in the United States in 2012. Because Latin American immigrants tend to have relatively low schooling, reducing immigration from the region reduces the relative supply of less-educated labor. In 2012, 70.4% of working-age immigrants from the region had a high-school education or less, as compared to 29.4% of non-Latin American immigrants and 38.3% of native-born workers.

There is large variation in aggregate exposure across regions in response to this shock: x_r^I ranges from near 0 in several CZs to 0.17 in Miami and takes a value of 0.08 in Los Angeles, a case we discuss below. This variation arises from differences across CZs in 2012 in the share of immigrants by education in total income and in the share of Latin Americans in the total number of immigrants by education. Although natives and immigrants reallocate across space in response to this shock, this spatial re-sorting plays little role in shaping x_r^I .⁴³

We first examine the consequences of a reduction in immigrants from Latin America on changes in average real wages (i.e., the change in average consumption for workers who begin in the region before and remain in the region after the counterfactual change in immigrant labor supply) for low-education natives.⁴⁴ We next examine the consequences

⁴³With changes in real wages across regions that are relatively small in comparison to the size of the shocks that we feed in, labor reallocation across regions is minor relative to the large initial shock. Hence, all of our results in what follows are very similar to what we would obtain without geographic labor mobility.

⁴⁴To a first-order approximation, this change in real wages equals the change in utility of low-education natives initially located in that region.

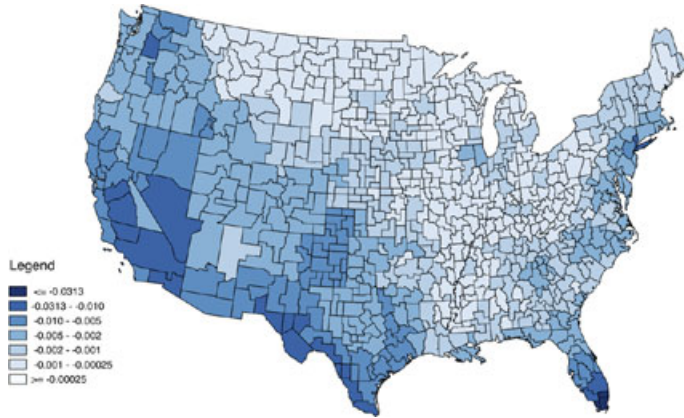


FIGURE 1.—A 50% reduction in Latin American immigrants: change in the real wage of low-education native-born workers across CZs.

on the native education wage premium. These outcomes, which are the focus of much previous literature, capture differences across CZs in immigration impacts. They do not reveal within-CZ variation in exposure to factor supply shocks, which is the emphasis of our paper. Figure 1, which depicts the spatial variation in the log change in average real wages for less-educated native-born workers across commuting zones, reveals the expected larger impacts in CZs that are located in Florida, close to the U.S. border with Mexico, or gateway regions for immigration, such as Atlanta, Chicago, and New York. Figure 2 plots, on the *y*-axis, the log change in average real wages for less-educated native-born workers in the left panel and the log change in the education wage premium for native-born workers (college-educated workers versus workers with less than college) in the right panel, where in each graph the *x*-axis is CZ exposure to the immigration shock, x_r^l . In response to an outflow of Latin American immigrants, average native low-education real wages fall in all locations, from close to zero in the least-exposed CZs, to 1.3% in Los Angeles and to 3.1% in Miami. These wage impacts arise because native and immigrant workers are imperfect substitutes, such that reducing immigration from Latin America reduces native real wages.⁴⁵

Moving to the right panel of Figure 2, we see that because the immigration shock reduces the relative supply of less-educated immigrant labor and because less-educated immigrants are relatively substitutable with less-educated natives, the education wage premium falls (and more so in CZs that are exposed to larger reductions in immigration from Latin America). For example, in Miami and Los Angeles the education premium falls by roughly 1%. Less-educated foreign-born workers substitute more easily for less-educated natives than for more-educated natives both because less-educated native- and foreign-born workers tend to specialize in similar occupations and because ϵ_{r_o} tends to be lower than ρ (which implies that native- and foreign-born workers are more substitutable

⁴⁵We also consider a specification in which immigration affects productivity via agglomeration effects. Productivity is given by $Z_{reo}^k = \bar{Z}_{reo}^k N_r^\lambda$, where $N_r = \sum_{k,e} N_{re}^k$ is the population in region *r* and λ governs the extent of regional agglomeration or congestion. We set $\lambda = 0.05$, in line with estimates in the literature (Combes and Gobillon (2015)). Whereas differences in employment and wage changes across occupations within regions are largely insensitive to λ , the immigration-induced decline in average real wages is higher in most CZs in the presence of agglomeration effects. For example, the real wage of low-education workers falls by 2.0 (4.4) percentage point in Los Angeles (Miami), instead of 1.3 (3.1) percentage points in our baseline.

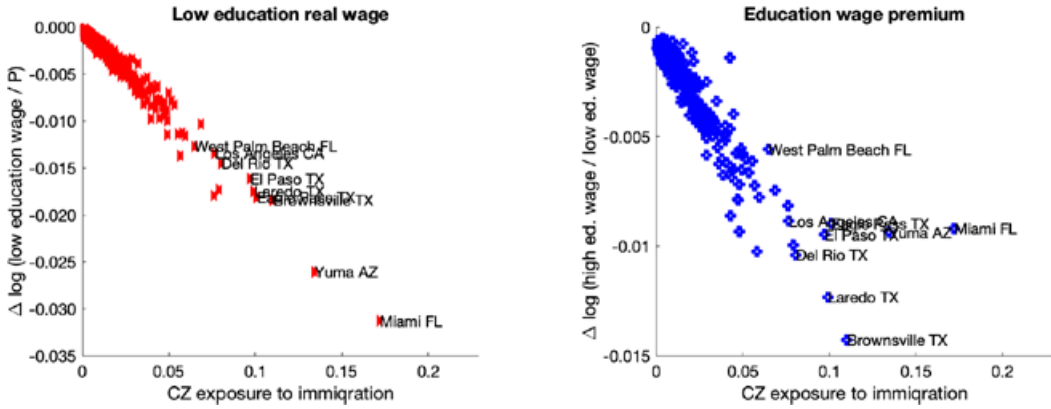


FIGURE 2.—A 50% reduction in Latin American immigrants: change across CZs in real wage of low-education (left) and in education wage premium (right) of native workers.

within than across occupations). Our Roy model, in which education groups are perfect substitutes *within* occupations, endogenously generates *aggregate* patterns of imperfect substitutability between education groups.

Our more novel results are for changes in wages at the occupation level, which capture variation in exposure to immigration across jobs within a CZ. Figure 3 describes differences across occupations in adjustment to the immigration shock in nontradable and tradable tasks for the CZ of Los Angeles. The horizontal axis reports occupation-level exposure to immigration, as measured by the absolute value of x_{ro} in (23). The vertical axis reports the change in wage by occupation for stayers (native-born workers who do not switch between occupations or migrate between CZs in response to the shock) deflated by the change in the absorption price index in Los Angeles. Even though real wages fall on average across occupations for natives in Los Angeles, reducing immigration from Latin America helps natives in the eight most-exposed nontradable occupations. The difference between average and extreme real wage changes reflects large differences in real wage changes according to occupation-level exposure to immigration across nontradable occupations. The most-exposed nontradable occupation (housekeeping) sees wages rise by

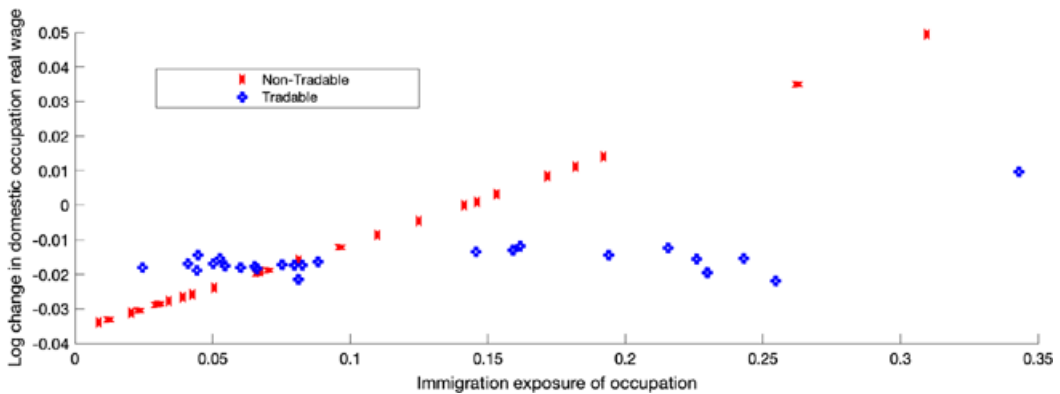


FIGURE 3.—A 50% reduction in Latin American immigrants: change in domestic occupation wage (deflated by the price index) by occupation in Los Angeles, CA.

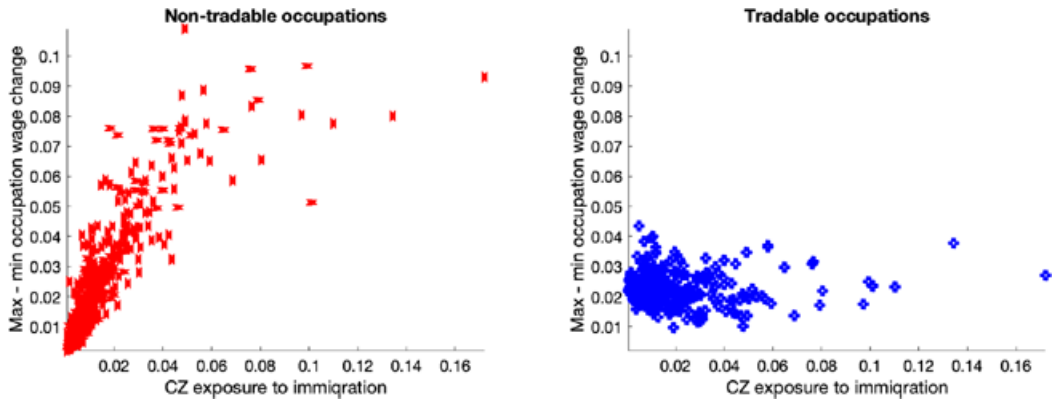


FIGURE 4.—A 50% reduction in Latin American immigrants: highest minus lowest occupation wage increase across CZs in nontradable (left) and tradable (right) occupations.

8.3 percentage points more than the least-exposed nontradable occupation (firefighting). This difference in wage changes across nontradable jobs dwarfs variation in immigration impacts between CZs, which are aggregations of occupation–wage changes. In particular, our across-job, within-CZ wage change is large relative to the difference in real wage changes across CZs for low-education natives and relative to the difference in changes in the education wage premium between the most-exposed CZ and the least-exposed CZ, seen in the left and right panels of Figure 2.

The adjustment process across tradable occupations differs markedly from that across nontradables. In Figure 3, the most-exposed tradable occupation (textile-machine operators) sees real wages rise by just 3.2 percentage points more than the least-exposed tradable occupations (social scientists). The most–least difference for occupations in wage adjustment is thus 5.2 percentage points larger in nontradables than in tradables. While the real wage for natives in Los Angeles rises in 8 out of 25 nontradable occupations, it only rises in one out of 25 tradable occupations.

The patterns of wage adjustment by occupation that we describe are not specific to Los Angeles. To characterize changes in wages across occupations in all CZs, Figure 4 plots the difference in wage changes between the occupation that has the largest wage increase (or smallest wage decrease) and the occupation that has the smallest wage increase (or largest wage decrease), on the vertical axis, against overall CZ exposure to the immigration shock, on the horizontal axis. The left panel of Figure 4 reports comparisons among nontradable occupations, while the right panel reports comparisons for tradable occupations. Consistent with the case of Los Angeles in Figure 3, across CZs we see much more variation in wage adjustment across jobs within nontradables than across jobs within tradables.⁴⁶ Moreover, variation in wage adjustment across occupations in most CZs tends to be much larger than variation in real wages across CZs (displayed in Figure 2). Finally, Figure 13 in Appendix L depicts the spatial variation in the difference in wage changes between the occupation that has the largest wage increase and the occupation that has the smallest wage increase (or largest wage decrease) in nontradables across commuting zones. It shows a similar regional concentration of impacts as for real wage changes

⁴⁶For given aggregate exposure to Latin American immigration (*x*-axis in Figure 4), regions vary in the highest–lowest occupation wage change (*y*-axis) because occupation exposure varies across CZs.

in Figure 1, though with an attenuated distance gradient as one moves away from the Southwest border and the coasts.

6.2. Doubling of High-Education Immigrants

The intuition we have developed for differences in adjustment across occupations within nontradables versus within tradables rests on labor supply shocks varying across regions or on factor allocations across occupations varying across regions. If, on the other hand, all regions within a national or global economy are subject to similar aggregate labor supply shocks and if labor is allocated similarly across occupations in all regions, there is no functional difference between nontradable and tradable activities. Specifically, if within each tradable occupation, shocks are highly correlated across regions, then local producer prices will move together with absorption prices, as is the case for nontraded occupations. Because immigrants from Latin America concentrate in specific U.S. commuting zones and specialize in different occupations across these commuting zones, the immigration shock we modelled in the previous section represents a non-uniform change in labor supply across regions within an occupation. Hence, the logic of asymmetric adjustment across occupations within tradables versus within nontradables to a local labor supply shock, which is the focus of our small open economy analytic results in Section 3, applies in our first counterfactual. The experiment we consider in this section, an increase in high-skilled immigration, is closer to a uniform increase in labor supplies across regions within an occupation. The consequence will be less differentiation in adjustment across occupations within nontradables versus within tradables. Characterizing such differentiation would have been difficult with the reduced form empirical results alone. Assessing how adjustment across occupations within nontradables versus within tradables will differ across given realizations of immigration shocks is made possible by filtering these shocks through our structural model.⁴⁷

In this scenario, we double the number of immigrants with a college degree at the national level, setting $\hat{N}_e^{Ic} = 2$ for $e = 3$ (immigrants with a college education) from all sources c . As in the previous section, there is large variation in aggregate exposure across regions in response to this shock, with x_r^I ranging from roughly 0 to a high of 0.33 in San Jose and taking a value of 0.16 in Los Angeles. However, unlike in the previous section, high-education immigrants tend to work in similar occupations across commuting zones.

In response to an inflow of college-educated immigrants, average native low-education real wages rise in all locations, as seen in Figure 5 and the left panel of Figure 6, from as little as 0.5 percentage points in the least-exposed CZs, to 3.3 percentage points in Los Angeles and to as much as 5.2 percentage points in San Jose. As in the previous exercise, this real wage impact arises because native and immigrant workers are imperfect substitutes, so that increasing high-education immigrants raises native real wages. In the right panel of Figure 6, we see that in response to the increase in relative supply of more-educated immigrant labor, the education wage premium falls (and more so in CZs that are exposed to larger increases in skilled foreign labor). Consistent with the logic operating in the previous shock, this effect arises because more-educated immigrants and less-educated natives tend to work in dissimilar occupations and not because they are weakly substitutable within occupations.

⁴⁷Even if all regions within the United States are identical, as long as there is trade between countries there will be a functional difference in adjustment to shocks between tradable and nontradable occupations. By abstracting away from trade with the rest of the world, we may understate differences between T and N .

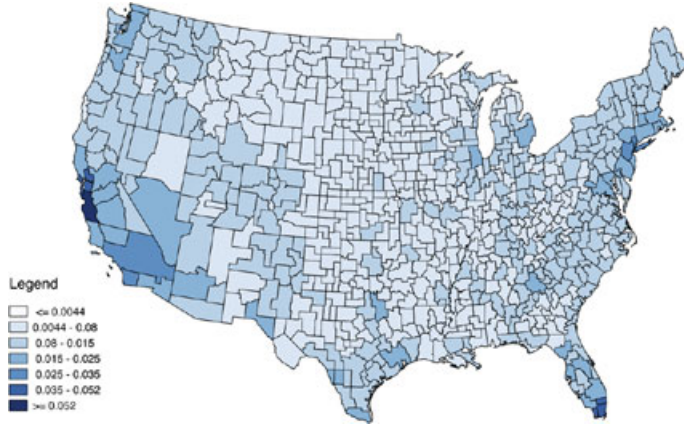


FIGURE 5.—Doubling of high education immigrants: change in the real wage of low-education native-born workers across CZs.

Figure 7 describes differences across occupations in the adjustment of occupation wages to the immigration shock separately for nontradable and tradable tasks in Los Angeles. Since there is a positive inflow of immigrants, most occupations experience an increase in real earnings. However, for the occupations that are most exposed to the labor inflow, real wages decline in both nontradable and tradable occupations, in contrast to the previous section. In sharp contrast with Figure 3, the difference in real wage adjustment between the two sets of occupations is now rather modest. Regarding relative earnings within the two groups, wages for the most-exposed nontradable occupation (health assessment) fall by 7.5 percentage points more than for the least-exposed nontradable occupation (extractive mining). In tradables, the difference in wage changes between the most- and least-exposed occupation (natural sciences and fabricators, respectively) is 4.9 percentage points. Whereas in the case of the previous counterfactual exercise the difference in wage changes between the most and least immigration-exposed occupations was

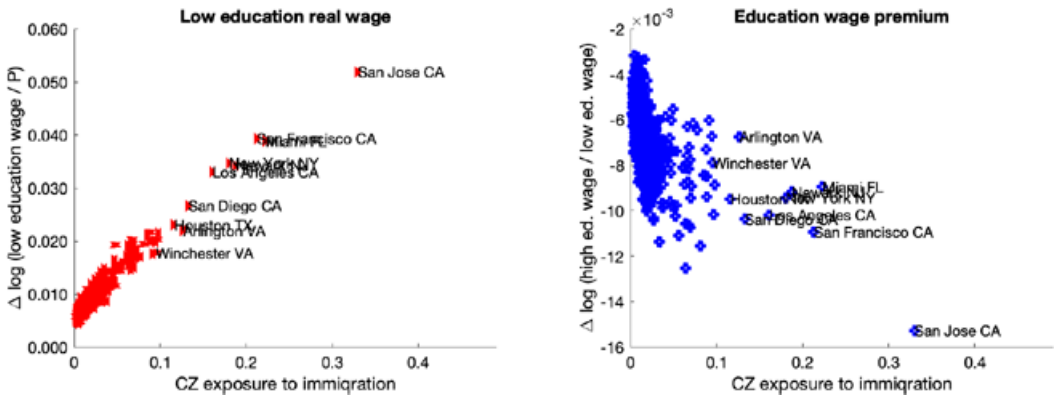


FIGURE 6.—Doubling of high education immigrants: change across CZs in real wage of low-education (left) and in education wage premium (right) of native workers.

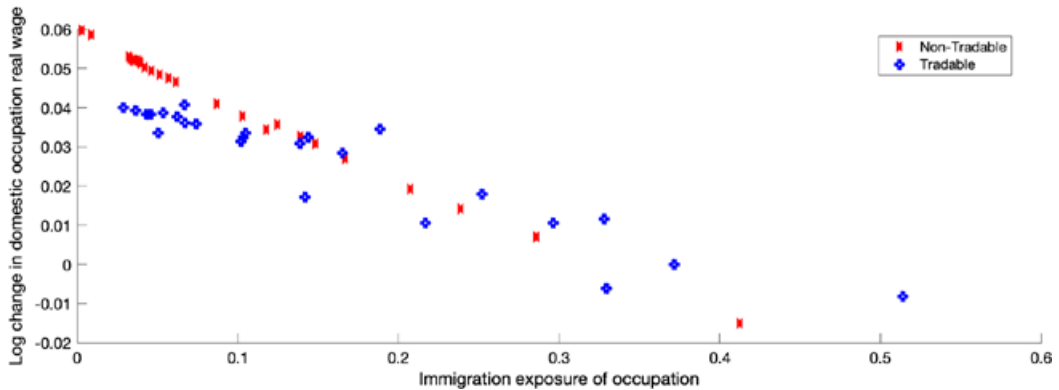


FIGURE 7.—Doubling of high education immigrants: change in domestic occupation wage (deflated by the price index) by occupation in Los Angeles, CA.

5.2 percentage points larger in nontradables than in tradables, the difference in Figure 7 is 2.6 percentage points.⁴⁸

The patterns of wage adjustment by occupation that we describe is by no means specific to Los Angeles. Figure 8—which plots the difference in wage changes between the occupation that has the largest wage increase (or smallest wage decrease) and the occupation that has the smallest wage increase (or largest wage decrease), on the vertical axis, against overall CZ exposure to the immigration shock, on the horizontal axis—provides further evidence of reduced differences in occupation–wage adjustment between nontradables and tradables in the high-skilled immigration experiment as compared to the Latin American immigration experiment. In nontradable jobs, differences in wage changes range from 0 to 11 percentage points, whereas in tradable jobs they range from 4 to 9 percentage points. In the regions that are more exposed to high-skilled immigration, differences in wage changes are roughly only 2 percentage points higher within nontradable occupations than within tradable occupations, much smaller than in our first counterfactual.⁴⁹

7. CONCLUSION

Empirical analysis of the labor-market impacts of immigration has focused overwhelmingly on how inflows of foreign-born workers affect average wages at the regional or education-group level. When working with a single-sector model of the economy, such emphases are natural. Once one allows for multiple sectors or occupations and trade between labor markets, however, comparative advantage at the worker level immediately comes into play. Because foreign-born workers tend to concentrate in specific groups of jobs—computer-related tasks for the high skilled, and agriculture and labor-intensive

⁴⁸When we consider a partial equilibrium specification in which we solve for occupation wages in each CZ, assuming constant producer prices in all other locations, the difference in wage changes between the most and the least immigration-exposed occupations is 7.5 percentage points larger in nontradables than in tradables in Los Angeles, which is much larger than 2.6 percentage points when solving for all prices in full general equilibrium. The differences between general and partial equilibrium are much smaller in our first counterfactual.

⁴⁹In Figure 8, there are CZs that have large changes in wages between occupations even though their aggregate exposure to immigration is low. These CZs tend to have a small number of highly exposed occupations, whereas their other occupations have little exposure. For these CZs, aggregate exposure to immigration is not necessarily predictive of the difference in wage changes between occupations.

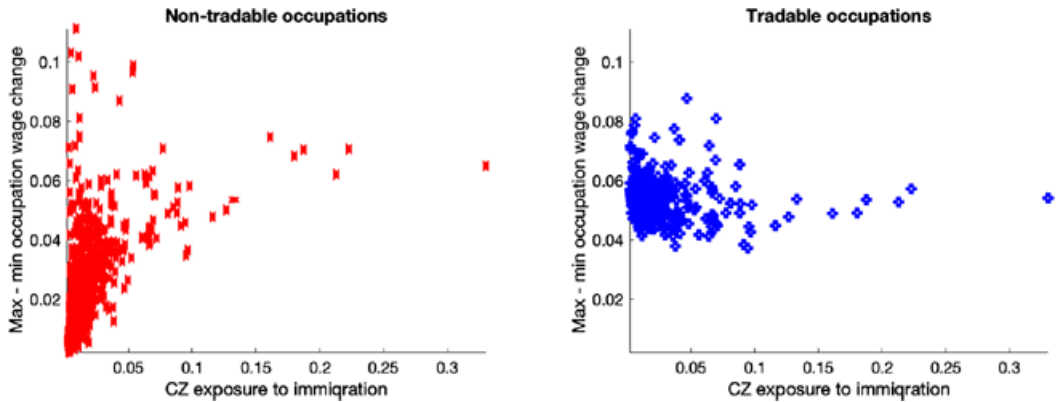


FIGURE 8.—Doubling of high education immigrants: highest minus lowest occupation–wage increase across CZs in nontradable (left) and tradable (right) occupations.

manufacturing for the low skilled—exposure to immigration will vary across native-born workers according to their favored occupation. That worker heterogeneity in occupational productivity creates variation in how workers are affected by immigration is hardly a surprise. What is more surprising is that the impact on native workers of occupation exposure to immigration varies within the sets of tradable and nontradable jobs. The contribution of our paper is to show theoretically how this tradable–nontradable distinction arises, to identify empirically its relevance for local-labor-market adjustment to immigration, and to quantify its implications for labor-market outcomes including changes in real wages in general equilibrium.

While our empirical analysis validates the differential labor-market adjustment patterns within tradables and within nontradables predicted by our theoretical model, it is only in the quantitative analysis that we see the consequences of this mechanism for wage levels and welfare. Individuals who choose occupations that attract larger numbers of immigrants may experience very different consequences for their real incomes, depending on whether they work in tradable or nontradable activities. Workers drawn to less-tradable jobs are likely to experience larger changes in wages in response to a given immigration shock, owing to adjustment occurring more through changes in occupational prices and less through changes in occupational output. In contrast to recent literature, a worker's region and education level may be insufficient to predict labor-market impacts to changes in inflows of foreign labor. Occupational abilities and preferences of workers may be of paramount importance, too.

Regarding immigration policy, the U.S. Congress has repeatedly considered comprehensive immigration reform, which would seek to legalize undocumented immigrants, prevent future undocumented immigration, and reallocate visas from family members of U.S. residents to high-tech workers. Our analysis suggests that it would be shortsighted to see these changes simply in terms of aggregate labor-supply shocks, as is the tendency in the policy domain. They must instead be recognized as shocks whose occupational and regional patterns of variation will determine which mechanisms of adjustment they induce.

We choose to study immigration because it is a measurable shock whose magnitude varies across occupations, skill groups, regions, and time, thus providing sufficient dimensions of variation to understand where the distinction between tradable and nontradable jobs is relevant. The logic at the core of our analytical approach is applicable to a wide range of shocks, as shown in Proposition 1. Sector- or region-specific changes in technol-

ogy or labor-market institutions would potentially have distinct impacts within tradable versus within nontradable activities, as well. For these distinct impacts to materialize, there must be variation in exposure to shocks within tradable and within nontradable jobs and across local labor markets, such that individual regions do not simply replicate the aggregate economy.

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