Tradability and the Labor-Market Impact of Immigration: Theory and Evidence from the U.S.*

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November 2019

Abstract

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 explain why this process differs within tradable versus within nontradable activities. Using data for U.S. commuting zones over the period 1980 to 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.

*We thank Daron Acemoglu, Rodrigo Adao, David Atkin, Lorenzo Caliendo, Javier Cravino, Klaus Desmet, Jonathan Dingel, Ben Faber, Cecile Gaubert, Gene Grossman, Joan Monras, Michael Peters, Esteban Rossi-Hansberg, and Fabrizio Zilibotti (the editor) for helpful comments, and Daniel Ober-Reynolds for superb research assistance. We thank the Russell Sage Foundation for financial support under Award 85-17-10. Hanson also acknowledges support from the Center on Global Transformation at UC San Diego.

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 disfavorable to the foreign-born (Peri and Sparber, 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 U.S. 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 occupations within regions and across regions.

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 towards 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.

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 U.S. 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 et al. (2014), and data from Ipums over 1980 to 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 regional wages

[1] This is the classic Rybczynski (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 et al., 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).

and welfare both across occupations within regions and across regions. 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., housekeeping) 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, 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 (non-manufacturing) 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 et al. (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 non-traded 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 non-traded occupations, including manicurist services (Federman et al., 2006), construction (Bratsberg and Raaum, 2012), and nursing (Cortes and Pan, 2014). While these results for nontradables appear to contradict the Ottaviano et al. (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 et al. (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.

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 et al. (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 $\omega \in \Omega^k_{re}$, each of whom inelastically supplies one unit of labor. The measure of Ω^k_{re} is N^k_{re}. Each worker is employed in one of O occupations, indexed by $o \in \mathcal{O}$.[2]

Each region produces a non-traded final good combining the services of all occupations,

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

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,

$$Q_{ro} = A_{ro} \left(\left(A^I_{ro} L^I_{ro}\right)^{\frac{\rho-1}{\rho}} + \left(A^D_{ro} L^D_{ro}\right)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \quad \text{for all } r, o, \tag{1}$$

where L^k_{ro} is the efficiency units of type k workers employed in occupation o in region r; A_{ro} and A^k_{ro} are the systematic components of productivity of all workers and of any type k

[2]While we allow occupational choice to respond to immigration, we take worker education as given. See Llull (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 et al. (2015), and Caliendo et al. (2017) for models of international migration based on cross-country wage differences.

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

$$N^k_{re} = \sum_{o \in \mathcal{O}} N^k_{reo}.$$

A worker $\omega \in \Omega^k_{re}$ supplies $Z^k_{reo}\varepsilon(\omega, o)$ efficiency units of labor if employed in occupation o and region r, where Z^k_{reo} 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

$$L^k_{reo} = Z^k_{reo} \int_{\omega \in \Omega^k_{reo}} \varepsilon(\omega, o)\, d\omega \text{ for all } r, e, o, k.$$

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 $L^k_{ro} = \sum_e L^k_{reo}$.

We assume that each $\varepsilon(\omega, o)$ is drawn independently from a Fréchet distribution with cumulative distribution function $G(\varepsilon) = \exp\left(-\varepsilon^{-(\theta+1)}\right)$, 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,

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

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

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

[4]Because 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.

[5]In marrying Roy with Eaton and Kortum (2002), our work relates to analyses on changes in labor-market outcomes by gender and race (Hsieh et al., 2016), technological change and wage inequality (Burstein et al., 2016), and regional adjustment to trade shocks (Galle et al., 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.

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 Online Appendix A). 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 micro-foundations (see, e.g., Arkolakis et al., 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 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 to 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

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

where

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

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

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

where

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

[6] See Online Appendix B 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.

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

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

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

$$P_{ro} = \frac{1}{A_{ro}} \left(\left(W^I_{ro}/A^I_{ro}\right)^{1-\rho} + \left(W^D_{ro}/A^D_{ro}\right)^{1-\rho} \right)^{\frac{1}{1-\rho}} \tag{8}$$

and

$$L^k_{ro} = \left(A_{ro} A^k_{ro}\right)^{\rho-1} \left(\frac{W^k_{ro}}{P_{ro}}\right)^{-\rho} Q_{ro}, \tag{9}$$

where W^k_{ro} 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^k_{ro} 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^k_{ro} differs from the average wage of type k workers with education e in region r who are employed in occupation o, $Wage^k_{reo}$. In Section 5.3 we use changes in average wages, $Wage^k_{reo}$, across occupations to infer indirectly how immigration affects (unobserved) occupation-level wages.

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

$$\pi^k_{reo} = \frac{\left(Z^k_{reo} W^k_{ro}\right)^{\theta+1}}{\sum_{j \in \mathcal{O}} \left(Z^k_{rej} W^k_{rj}\right)^{\theta+1}}, \tag{10}$$

which is increasing in W^k_{ro}. Total efficiency units supplied by workers in occupation o is

$$L^k_{reo} = \gamma Z^k_{reo} \left(\pi^k_{reo}\right)^{\frac{\theta}{\theta+1}} N^k_{re}, \tag{11}$$

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

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

An equilibrium is a vector of prices $\{P_r, P_{ro}, P^y_{ro}\}$, wages $\left\{W^k_{ro}\right\}$, quantities produced and consumed $\{Y_r, Y_{ro}, Y_{rjo}, Q_{ro}\}$, and labor allocations $\left\{N^k_{reo}, L^k_{reo}\right\}$ for all regions r, occupations o, worker types k, and education cells e that satisfy (3)-(12).

[7] Occupation 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 $\max_o \left\{W^k_{ro} \times \varepsilon(\omega, o)\right\}$. Because this holds for all workers, it also holds for the average wage across workers.

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 × 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. Lower case 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 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 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 $S_{ro}^{x} \equiv 1 - S_{rro}^{x}$ 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 the partial elasticity of demand for region r's occupation o output to its output price and is given by

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

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

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

which the services of occupation o are traded, as measured by the region r share of exports in occupation output (S^x_{ro}) and share of imports in occupation absorption (S^m_{ro}). For occupation o with infinite trade costs, $S^x_{ro} = S^m_{ro} = 0$, so that $\epsilon_{ro} = \eta$. More traded occupations—with higher values of S^x_{ro} and S^m_{ro}—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. 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]

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

$$n^k_r \equiv \sum_e \frac{S^k_{reo}}{S^k_{ro}} n^k_{re}, \tag{14}$$

with weights given by the share of labor income in region r and occupation o accruing to type k labor with education e, $S^k_{reo} \equiv \frac{W^k_{ro} L^k_{reo}}{\sum_{e',k'} W^{k'}_{ro} L^{k'}_{re'o}}$, relative to the share of labor income in region r and occupation o accruing to all type k labor, $S^k_{ro} = \sum_e S^k_{reo}$. The right hand side of (14) does not vary across occupations because $\pi^k_{reo} = \pi^k_{ro}$ implies that S^k_{reo}/S^k_{ro} is common across o. S^I_{ro} 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^I_{ro} and the assumption that $Z^k_{reo} = Z^k_{re}$, we have that $S^I_{ro} \geq S^I_{ro'}$ if and only if $\pi^I_{ro}/\pi^I_{ro'} \geq \pi^D_{ro}/\pi^D_{ro'}$. Along with (10), this implies $S^I_{ro} \geq S^I_{ro'}$ if and only if $\left(\frac{A^I_{ro}}{A^D_{ro}}\right)^{\rho-1} \geq \left(\frac{A^I_{ro'}}{A^D_{ro'}}\right)^{\rho-1}$.

3.2 Changes in immigrant labor supply

We now study the impact of infinitesimal changes in regional immigrant labor supplies, $\left\{n^I_{re}\right\}_e$, on labor payments, factor allocations, and occupation wages across occupations

[9] In 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's rules of derived demand) and, therefore, trade shares, a result related to findings in Rodrik (1997) and Slaughter (2001).

[10] Our results hold with an arbitrary number of sets. In the empirical analysis (see Online Appendix D), 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).

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

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

where $\Phi_r^I = \left(w_{ro}^D - w_{ro}^I\right)/n_r^I$ 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 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, $\left\{n_{re}^I\right\}_e$, generate differential changes in labor allocations in occupations that are given by

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

and changes in occupation wages that are given by

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

[11] Up 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.

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

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

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 towards immigrant workers within each occupation (ρ). Consider two special cases. First, in the limit as $\epsilon_{rg} \to 0$, 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 crowds out native workers. Second, in the limit as $\rho \to 0$, 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 $\theta \to \infty$, 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 $\theta \to \infty$ 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—i.e., 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

[14]These results follow similar steps to those outlined in Footnote 12.

[15]See Appendix A.5 for results where education groups differ in relative productivities across 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^k_{re}) and region-occupation productivities (a_{ro}), generate differential changes in labor payments (lp_{ro}), factor allocations (n^k_{reo}), and wages per efficiency unit of labor (w^k_{ro}) for any $o, o' \in g$ and $k \in \{D, I\}$ that are given by*

$$lp_{ro} - lp_{ro'} = \frac{(\epsilon_{rg} - 1)(\theta + \rho)}{\epsilon_{rg} + \theta} \tilde{w}_r \left(S^I_{ro} - S^I_{ro'}\right) + \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta} (a_{ro} - a_{ro'}) \tag{18}$$

$$n^k_{reo} - n^k_{reo'} = \frac{(\epsilon_{rg} - \rho)(\theta + 1)}{\epsilon_{rg} + \theta} \tilde{w}_r \left(S^I_{ro} - S^I_{ro'}\right) + \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta} (a_{ro} - a_{ro'}) \tag{19}$$

$$w^k_{ro} - w^k_{ro'} = \frac{(\epsilon_{rg} - \rho)}{\epsilon_{rg} + \theta} \tilde{w}_r \left(S^I_{ro} - S^I_{ro'}\right) + \frac{(\epsilon_{rg} - 1)}{\epsilon_{rg} + \theta} (a_{ro} - a_{ro'}), \tag{20}$$

where

$$\tilde{w}_r \equiv w^D_{ro} - w^I_{ro} = \Phi^I_r n^I_r + \Phi^D_r n^D_r + \sum_o \Phi^A_{ro} a_{ro} \tag{21}$$

is the change in the relative occupation wage for natives relative to immigrants, which is common across occupations; Φ^I_r, Φ^D_r, and Φ^A_{ro} are the elasticities of this relative occupation wage to the three types of shocks; and n^k_r 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, $n^I_r \geq 0$, or a decrease in native labor supply, $n^D_r \leq 0$, raises the relative occupation wage of natives, $\Phi^I_r \geq 0$ and $\Phi^D_r \leq 0$.[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^D_r is given by equation (14), has the same qualitative effects—on labor payments, factor allocations, and

[16]In Appendix A.4 we prove that $\Phi^I_r = -\Phi^D_r \geq 0$ if all occupations share common export and import shares (i.e. if there is a single g).

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

$$n^D_{reo} = \varsigma_{rg} a_o + \alpha^D_{reg} + \beta^D_r x_{ro} + \beta^D_{Nr} \mathbb{I}_o(N) x_{ro} + \nu^D_{ro}, \tag{22}$$

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; ς_{rg}, β^D_r, and β^D_{Nr} 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 one if occupation o is nontradable; α^D_{reg} is a function of model parameters that does not vary across o; and ν^D_{ro} is a structural residual. Specifically, the immigration shock

$$x_{ro} \equiv \sum_e S^I_{reo} n^I_{re} \tag{23}$$

summarizes how region and education-specific changes in immigration, $\left\{n^I_{re}\right\}_e$, are transmitted to occupation o in region r via the initial immigrant intensity of ro in each education

[17] In Appendix A.4 we show that $\Phi^A_{ro} > 0$ if and only if $(\pi^D_{ro} - \pi^I_{ro})\epsilon_r > 1$ under the assumption that all occupations share common export and import shares.

cell, S^I_{reo}.[18] The treatment effect of x_{ro} for tradable occupations in (22) is

$$\beta^D_r = \frac{(\epsilon_{rT} - \rho)(\theta + 1)}{\epsilon_{rT} + \theta}\Phi^I_r$$

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,

$$\beta^D_{Nr} = \frac{(\theta + \rho)(\theta + 1)}{(\epsilon_{rN} + \theta)(\epsilon_{rT} + \theta)}(\epsilon_{rN} - \epsilon_{rT})\Phi^I_r$$

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

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

Finally, the structural residual is

$$\nu^D_{ro} \equiv \frac{(\epsilon_{rg} - \rho)(\theta + 1)}{\epsilon_{rg} + \theta}S^I_{ro}\left(\Phi^D_r n^D_r + a_r\right) + \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta}\tilde{a}_{ro},$$

where $a_r \equiv \sum_o \Phi^A_{ro} a_{ro}$ is a weighted sum of region-occupation productivity shocks.

To simplify the estimation, we specify the regression equation,

$$n^D_{reo} = \alpha^D_{reg} + \alpha^D_o + \beta^D x_{ro} + \beta^D_N \mathbb{I}_o(N)x_{ro} + \tilde{\nu}^D_{ro} \tag{24}$$

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 $\tilde{\nu}^D_{ro}$ that adds to ν^D_{ro} specification error generated by these parameter restrictions. By imposing uniformity across regions for these coefficients in (24), β^D and $\beta^D + \beta^D_N$ 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^D_o, and the treatment effects, β^D and $\beta^D + \beta^D_N$, 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 $x_{ro}S^I_{ro}$ does not vary across o. In practice, we construct x_{ro} without imposing this restriction. Our theoretical

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

[19]As in the previous section, we assume that the law of demand holds, such that $\Phi^I_r > 0$.

[20]As we discuss in Online Appendix F, a logic similar to that underlying (24) applies to how an immigrant inflow affects the allocation of foreign-born workers across occupations. In Online Appendix F, we present results on the immigrant-employment allocation regressions that are the counterparts to (24) and Table 1 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.

model implies the sign restriction that $\beta^D > \beta^D + \beta^D_N$, 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^I_r, 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^D_N 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,

$$lp_{ro} = \alpha^D_{rg} + \varsigma_{rg} a_o + \gamma x_{ro} + \gamma_N \mathbb{I}_o (N) x_{ro} + \tilde{\nu}_{ro}, \tag{25}$$

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

[21] See, e.g., 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).

[22] See, e.g., Cadena and Kovak (2016) on the responsiveness of immigration to local labor demand shocks.

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^I_{re}, and the initial intensity of region-occupation ro in the employment of immigrants with education e, S^I_{reo}. 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^D_r. 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^I_{re} 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

$$x^*_{ro} \equiv \sum_e S^I_{reo} \frac{\Delta N^{I*}_{re}}{N^I_{re}}$$

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

$$\Delta N^{I*}_{re} \equiv \sum_c f^{Ic}_{re} \Delta N^{-r}_{ec}.$$

Here, ΔN^{-r}_{ec} 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^{Ic}_{re} 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

$$x^*_{ro} \equiv \sum_e \sum_c \frac{S^I_{reo} f^{Ic}_{re}}{N^I_{re}} \Delta N^{-r}_{ec} \tag{26}$$

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

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

A recent literature—Adao et al. (2018), Borusyak et al. (2018), and Goldsmith-Pinkham et al. (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: (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 pre-existing 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 byproduct 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,

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

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

[24]The 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 et al., 2018).

All data, except for occupation tradability, come from the Integrated Public Use Micro Samples (Ipums; Ruggles et al., 2015). For 1980 and 1990, we use 5% Census samples; for 2012, we use the combined 2011, 2012, and 2013 1% American Community Survey 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 US.

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 U.S. 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]

Our baseline data include 50 occupations (see Table 5 in Appendix B).[28] We measure oc-

[25] Because 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.

[26] Because 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 U.S. as children (and attended U.S. schools) and those who arrived in the U.S. 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 U.S. before the age of 18.

[27] The 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 category 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.

[28] We 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

cupation 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 5 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 6 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- 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 6 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 Online Appendix C. 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 7 in Appendix B, and Figures 10 and 11, and in Online Appendix C. 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.

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 to 2012 time period the unconditional changes in employment shares across occupations within T and across occupations within N. The median absolute log em-

occupations that are similar in education profile and tradability but whose size complicates measurement.

[29] Goos et al. (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 intra-country 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.

ployment 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 1 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 OLS results, column (2a) reports 2SLS results, and column (3a) reports reduced-form 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 1, 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 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-

[30] If 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.

[31] This 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.

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1a)	(2a)	(3a)	(4a)	(5a)	(6a)
Panel A						
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	-.088	-.150**	-.097**	-.130***	-.225***	-.205***
	(.065)	(.069)	(.040)	(.040)	(.048)	(.037)
Obs	33723	33723	33723	26644	26644	26644
R-sq	.822	.822	.822	.68	.679	.68
AP F-stats (first stage)		136.10			105.67	
Panel B						
	(1b)	(2b)	(3b)	(4b)	(5b)	(6b)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.089*	.002	.004	.022	-.030	-.018
	(.049)	(.089)	(.060)	(.036)	(.066)	(.059)
$\mathbb{I}_o(N)\, x_{ro}$	-.303***	-.296***	-.234***	-.309***	-.374***	-.328***
	(.062)	(.102)	(.090)	(.097)	(.126)	(.112)
Obs	33723	33723	33723	26644	26644	26644
R-sq	.836	.836	.836	.699	.699	.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	

Notes: 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. Significance levels: * 10%, ** 5%, ***1%.

Table 1: Allocation for domestic workers across occupations

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 1 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 $0.20 = 0.65 \times 0.30$ differential log point employment reduction for low-education natives and a $0.24 = 0.65 \times 0.37$ 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 2, 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 one ($\epsilon_{rT} > 1$). 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 1 and 2 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.

[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.

Consequently, labor payments of immigrant-intensive occupations increase by more within tradable than within nontradable jobs, as shown in Table 2. Consistent with this mechanism, Table 1 shows that an immigration shock generates null effects on native employment within T and negative effects on native employment within N.

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.392***	.380**	.320**
	(.115)	(.166)	(.131)
$\mathbb{I}_o(N)\, x_{ro}$	-.351***	-.398***	-.324***
	(.116)	(.137)	(.092)
Obs	34892	34892	34892
R-sq	.897	.897	.897
Wald Test: P-values	0.38	0.85	0.96
A-P F-stats (first stage)			
x_{ro}		55.54	
$\mathbb{I}_o(N)\, x_{ro}$		105.82	

Notes: 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. Significance levels: * 10%, ** 5%, ***1%.

Table 2: Labor payments across occupations

Robustness. In Online Appendix D, 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 Online Appendix D.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 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 Online Appendix D.2. Our results would be similarly compromised if the negative impact of the immigration shock on native allocations and total labor payments was the byproduct of persistent region-occupation employment trends, as in the Borjas et al. (1997) critique of the Card instrument. To examine the relevance of this critique for our analysis, we re-estimate (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 Online Appendix D.1, reveal no evidence that current impacts of immigration on native-born employment are simply the byproduct of continuing patterns of regional employment growth.[33] The results in Tables 1 and 2 also embody assumptions about which activities are nontradable and which are tradable. In Table 1, we divide occupations into equal-sized groups of tradables and nontradables. In Online Appendix D.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 1. Results are also similar, as reported in Online Appendix D.6, when we redo the analysis for region-industries, rather than for region-occupations, and identify the 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 Online Appendix D.1.2.[35] Finally, in Online Appendix D.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

[33]The results in Online Appendix D.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.

[34]Immigration 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).

[35]Variation 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.

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, non-negligible 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^{I}_{reo}, does not depend on the immigrant's source country c. Hence, given the measure of immigrants in education cell e from each source country in each region, denoted N^{Ic}_{re}, the equations in our baseline model continue to hold, where $N^{I}_{re} \equiv \sum_c N^{Ic}_{re}$. 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^{D}_{re} for natives with education e and U^{Ic}_{re} 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

[36]The 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.

country c for immigrants) with education e in region r is given by

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

where N_e^D and N_e^{Ic} denote the exogenous measure of education e workers of 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, $\frac{N_{re}^{k}\times Wage_{re}^{k}}{\sum_{e'k'} N_{re'}^{k'}\times Wage_{re'}^{k'}}$, 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

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

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

[37] Specifically, 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.

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

Table 3: Parameter values in quantitative analysis

graduates and some college, and college graduates). The values of π^k_{reo}, $\frac{N^k_{re} \times Wage^k_{re}}{\sum_{e'k'} N^{k'}_{re'} \times Wage^{k'}_{re'}}$ and N^{kc}_{re} 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), $\tau_{rjo} = \tau_{rjo'}$ 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 U.S. 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 et al. (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 Online Appendix E.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 Mayer (2014) and in line with the estimates using regional data within the U.S. estimated in Donaldson (Forthcoming) 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, $\nu = \frac{n^k_{re} - n^k_{r'e}}{w^k_r - w^k_{r'} - p_r + p_{r'}}$. We set $\nu = 1.5$, which falls in the middle of the range of estimates in the geographic labor mobility literature reviewed by Fajgelbaum et al. (2015). The parameter $\theta + 1$ is the elasticity of occupation allocations with respect to occupation wages within a region, $\theta + 1 = \frac{n^k_{ro} - n^k_{ro'}}{w^k_{ro} - w^k_{ro'}}$. We set $\theta = 1$ following analyses on worker sorting across occupations in the U.S. in Burstein et al. (2016) and Hsieh et al. (2016).[39]

[38] We also consider a parameterization with 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.

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

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 1: 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 3 reports calibrated parameter values and Table 4 reports the employment-allocation regressions using data generated by the model.[41] Comparing empirical estimates in Table 1 with estimates using model-generated data in Table 4, 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

[40] In 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 $\hat{N}_{re}^I$, are sufficient statistics for all calibrated moments.

[41] The R^2 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 $\hat{A}_{ro}^k$.

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).

	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-sq	0.99	0.98	0.98	0.95

Table 4: Regression results using model-generated data

Notes: Calibration targets: average low & high education for native workers: $\beta^D = -0.01$ and $\beta^D_N = -0.34$.

The intuition for the value of $\eta = 1.65$ is similar. Targeting $\beta^D_N < 0$ 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 Online Appendix G plots model-implied values of β^D and β^D_N 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^D_N. Therefore, the estimated value of β^D_N 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 nontraded dummy in model-generated data (as in the upper panel of Table 1), 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 4. 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 2. 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:

$$w^D_{ro} = \tilde{\alpha}^D_{rg} + \tilde{\alpha}^D_o + \chi^D x_{ro} + \chi^D_N \mathbb{I}_o(N)\, x_{ro} + \tilde{\nu}^D_{ro}. \tag{29}$$

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 8 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 $Wage_{reo}^D \equiv W_{ro}^D L_{reo}^D / N_{reo}^D$ the average wage paid to native workers in region r, education e, and occupation o, we have

$$Wage_{reo}^k = \gamma W_{ro}^k Z_{reo}^k \left(\pi_{reo}^k\right)^{\frac{-1}{\theta+1}}$$

which implies

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

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 9 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 4. 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 et al., 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 parametrization, 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 byproduct 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 in the U.S. 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 U.S. (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

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

[42]Unlike 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 Online Appendix E.2.

where $\psi^I_{re} \equiv N^I_{re} \times Wage^I_{re} / \sum_{e'k'} N^{k'}_{re'} \times Wage^{k'}_{re'}$ is the share of immigrant workers with education e in region r in total labor payments in region r and where ΔN^I_{re} is the change between the initial and final periods in education e labor supply of immigrants in region r. The measure x^I_r 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 50% Reduction of Latin American Immigrants

In this scenario, we halve the number of Latin American immigrants at the national level. We set $\hat{N}^{Ic}_e = 1 - \frac{0.5 \times N^{Ic}_e}{N^{Ic}_e}$ for c = South and Central America and c = Mexico for all education cells and we set $\hat{N}^{Ic}_e = 1$ for all other c's and all education cells, where N^{Ic}_e is the total number of region c immigrants with education e in the U.S. 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^I_r 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^I_r.[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 the counterfactual change in immigrant labor supply) for low-education natives.[44] We next examine the consequences 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^I_r. 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.

[43]With 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.

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

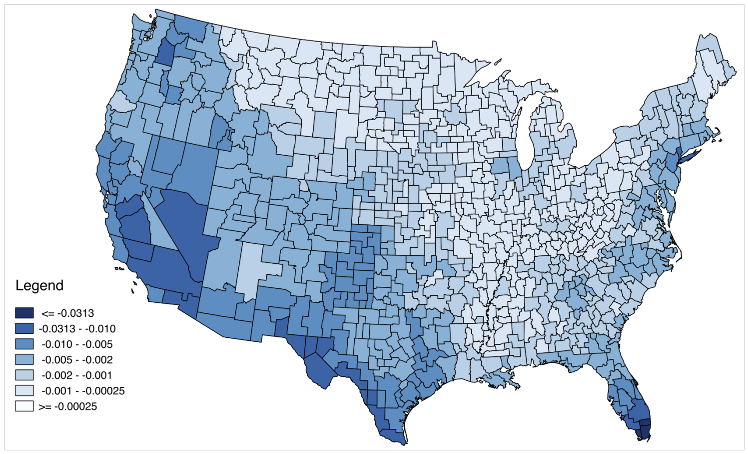

Figure 1: 50% reduction in Latin American Immigrants: change in the real wage of low-education native-born workers across CZs

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_{ro} tends to be lower than ρ (which implies that native and foreign-born workers are more substitutable 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 nor migrate between CZs in response to the shock) deflated by the change in

[45] We also consider a specification in which immigration affects productivity via agglomeration effects. Productivity is given by $Z^k_{reo} = \bar{Z}^k_{reo} N_r^{\lambda}$, where $N_r = \sum_{k,e} N^k_{re}$ 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.

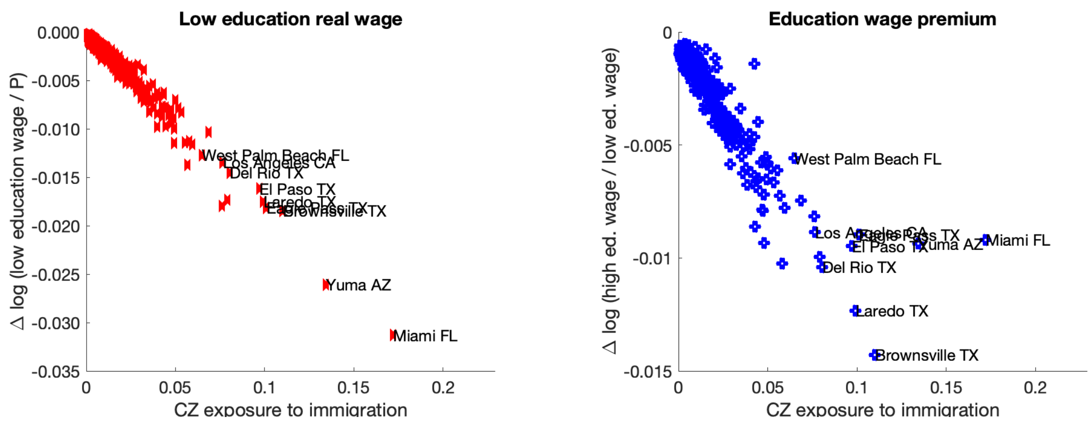

Figure 2: 50% reduction in Latin American Immigrants: change across CZs in real wage of low-education (left) and in education wage premium (right) of native workers

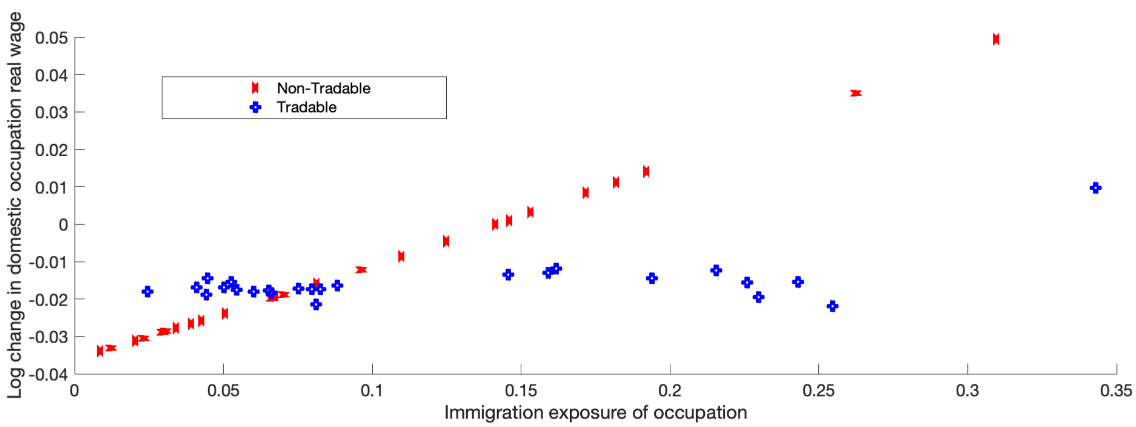

Figure 3: 50% reduction in Latin American immigrants: change in domestic occupation wage (deflated by the price index) by occupation in Los Angeles, CA

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 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

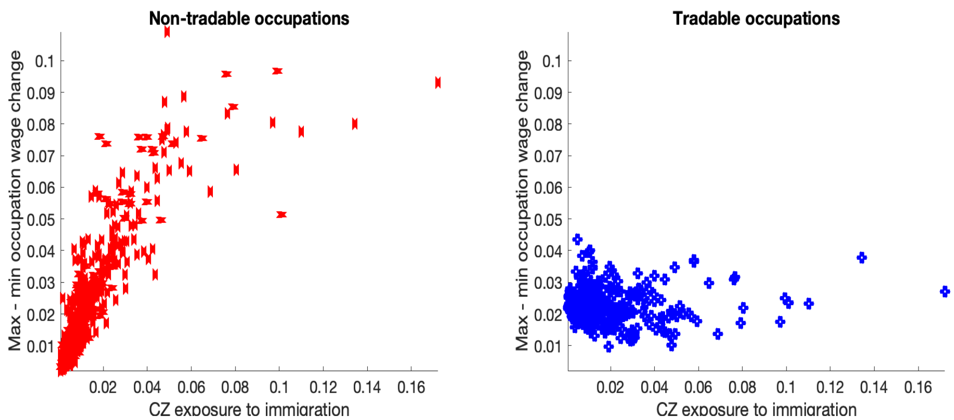

Figure 4: 50% reduction in Latin American Immigrants: highest minus lowest occupation wage increase across CZs in nontradable (left) and tradable (right) occupations

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 Online Appendix H 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 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

[46]For 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.

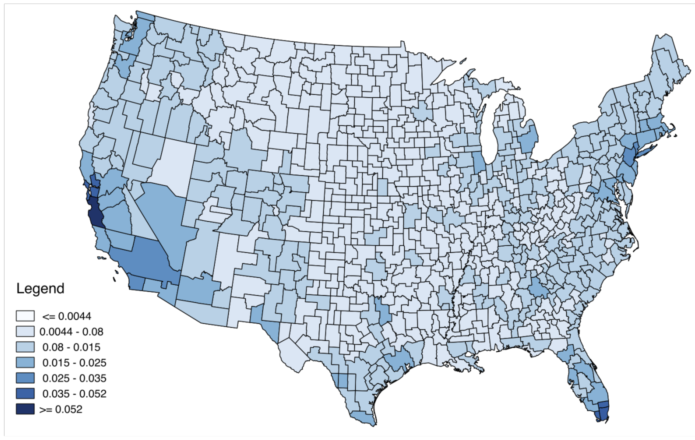

Figure 5: Doubling of high education immigrants: change in the real wage of low-education native-born workers across CZs

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 modeled 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.

[47]Even if all regions within the U.S. 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.

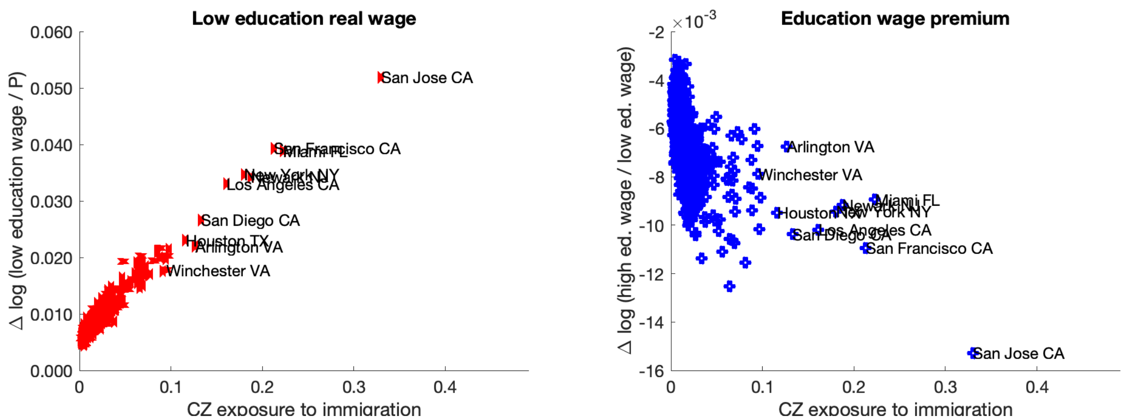

Figure 6: Doubling of high education immigrants: change across CZs in real wage of low-education (left) and in education wage premium (right) of native workers

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.

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

[48] When 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 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 when solving for all prices in full general equilibrium. The differences between general and partial equilibrium are much smaller in our first counterfactual.

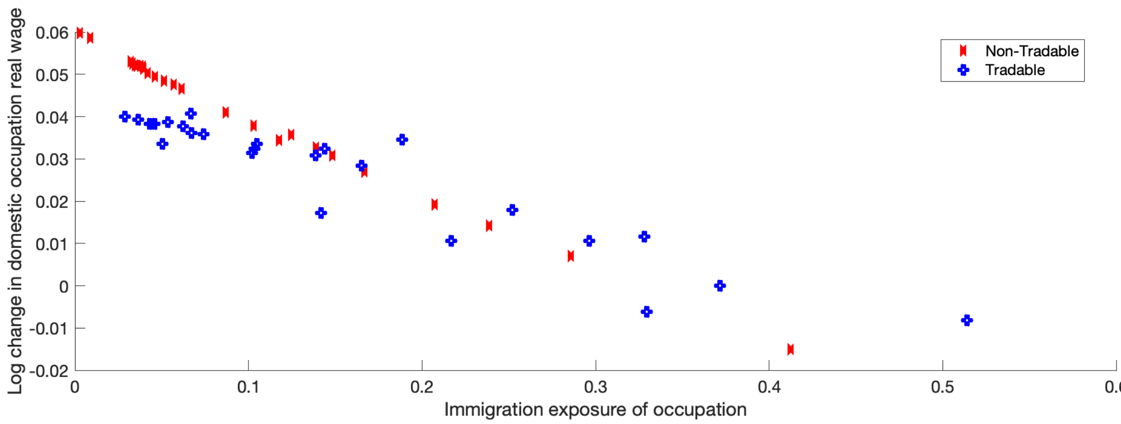

Figure 7: Doubling of high education immigrants: change in domestic occupation wage (deflated by the price index) by occupation in Los Angeles, CA

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, agriculture and labor-intensive 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

[49]In 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.

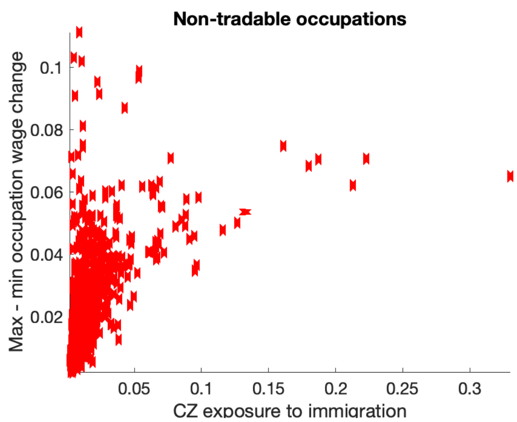

Figure 8: Doubling of high education immigrants: highest minus lowest occupation wage increase across CZs in nontradable (left) and tradable (right) occupations

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 technology 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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Appendix

A Derivation of analytic results

In this sectionwe derive the system of equations that allows us to solve for all endogenous variables as a function of small changes in immigrant and natives supplies in every region and education group and productivities in every region and occupation; we then derive the analytic results formally presented in Sections 3.2 and 3.3 as well as a range of other results described throughout the paper. In Section A.1, we begin by deriving the system in changes for small changes in $\{n_{re}^k\}_{r,e,k}$ and $\{a_{ro}\}_{r,o}$ for our baseline model of Section 2. We then impose the restrictions of Section 3.1 and simplify this system in changes in Section A.2. In Section A.3 we derive the analytic results presented in Sections 3.2 and 3.3. In Section A.4 we solve explicitly for all endogenous variables of interest in a special case of the model in Section A.2. Finally, in Section A.5 we deviate from the model of Section A.2 in the other direction and provide additional results in a version of the model that imposes fewer rather than more restrictions.

A.1 System in changes

Here we derive a system of equations that we use to solve for changes in endogenous variables in response to infinitesimal changes in N_{re}^I, N_{re}^D, and A_{ro} in every region r, education cell e, and occupation o. We use lower case characters, x, to denote the log change of any variable X relative to its initial equilibrium level: $x = d \ln X$.

Log-differentiating equation (8) we obtain

$$p_{ro} = -a_{ro} + \sum_k S_{ro}^k w_{ro}^k, \tag{32}$$

where $S_{ro}^k \equiv \sum_e \frac{W_{reo}^k L_{reo}^k}{P_{ro} Q_{ro}}$ is the cost share of factor k (across all education cells) in occupation o output in region r. Log differentiating equation (9), we obtain

$$l_{ro}^D - l_{ro}^I = -\rho \left(w_{ro}^D - w_{ro}^I \right). \tag{33}$$

Combining equations (10) and (11) and log differentiating yields

$$l_{reo}^k = \theta w_{ro}^k - \theta \left(\sum_{j \in \mathcal{O}} \pi_{rej}^k w_{rj}^k \right) + n_{re}^k. \tag{34}$$

Log differentiating $L_{ro}^k = \sum_e L_{reo}^k$, we obtain

$$l_{ro}^k = \sum_e \frac{L_{reo}^k}{L_{ro}^k} l_{reo}^k. \tag{35}$$

Log differentiating equation (10), we obtain

$$n_{reo}^k = (\theta + 1) w_{ro}^k - (\theta + 1) \sum_o \pi_{ro}^k w_{ro}^k + n_{re}^k. \tag{36}$$

Log differentiating equation (6), we obtain

$$p_{ro}^y = (1 - S_{ro}^m) p_{ro} + \sum_{j \neq r} S_{jro}^m p_{jo}. \tag{37}$$

where $S_{jro}^m \equiv \frac{P_{jo} \tau_{jro} Y_{jro}}{P_{ro}^y Y_{ro}}$ is the share of the value of region r's absorption in occupation o that originates in region j and $S_{ro}^m \equiv \sum_{j \neq r} S_{jro}^m$ is regions r's import share of absorption in occupation o. Log differentiating equation (4) and using equation (37) yields

$$p_r = \sum_{o \in \mathcal{O}} S^A_{ro} \left(\left(1 - S^m_{ro}\right) p_{ro} + \sum_{j \neq r} S^m_{jro} p_{jo} \right), \tag{38}$$

where $S^A_{ro} = \frac{P^y_{ro} Y_{ro}}{P_r Y_r}$ denotes the share of occupation o in total absorption in region r.

Log differentiating equation (7), we obtain

$$q_{ro} = -\alpha p_{ro} + \sum_{j \in \mathcal{R}} S^x_{rjo} \left[(\alpha - \eta) p^y_{jo} + \eta p_j + y_j \right], \tag{39}$$

where $S^x_{rjo} \equiv \frac{P_{ro} \tau_{rjo} Y_{rjo}}{P_{ro} Q_{ro}}$ is the share of the value of region r's output in occupation o that is destined for region j. Equations 39 and (37) yield

$$q_{ro} = -\alpha p_{ro} + \sum_{j \in \mathcal{R}} S^x_{rjo} \left[(\alpha - \eta) \left(\left(1 - S^m_{jo}\right) p_{jo} + \sum_{j' \neq j} S^m_{j'jo} p_{j'o} \right) + \eta p_j + y_j \right].$$

Log differentiating equation (1) and using equation (9) we obtain

$$q_{ro} = a_{ro} + \sum_k S^k_{ro} l^k_{ro}.$$

Combining the two previous expressions, we obtain

$$q_{ro} = a_{ro} + \sum_k S^k_{ro} l^k_{ro} = -\alpha p_{ro} + \sum_{j \in \mathcal{R}} S^x_{rjo} \left[(\alpha - \eta) \left(\left(1 - S^m_{jo}\right) p_{jo} + \sum_{j' \neq j} S^m_{j'jo} p_{j'o} \right) + \eta p_j + y_j \right]. \tag{40}$$

Log differentiating equation (12) yields

$$\sum_o S^P_{ro} \sum_k S^k_{ro} \left(w^k_{ro} + l^k_{ro} \right) = p_r + y_r \tag{41}$$

where S^P_{ro} denotes the share of occupation o in total absorption in region r, $S^P_{ro} = \frac{P_{ro} Q_{ro}}{P_r Y_r}$.

We can use equations (32), (33), (34), (35), (36), (38), (40), and (41) to solve for changes in employment allocations in efficiency units l^k_{reo} and l^k_{ro} and bodies n^k_{reo}, occupation wages w^k_{ro}, occupation prices p_{ro} and quantities q_{ro}, aggregate absorption price p_r and quantity y_r, for all r, o and k.

A.2 Imposing the restrictions of Section 3.1

In Section 3.1, we impose three restrictions. First, we assume that region r is a small open economy in the sense that it constitutes a negligible share of exports and absorption in each occupation for each region $j \neq r$. Specifically, we assume that $S^m_{rjo} \to 0$ and $S^x_{jro} \to 0$ for all o and $j \neq r$. The small-open-economy assumption implies that, in response to a shock in region r only, prices and output elsewhere are unaffected in all occupations: $p^y_{jo} = p_{jo} = p_j = y_j = 0$ for $j \neq r$. Therefore, given a shock to region r alone, equation (40) simplifies to

$$q_{ro} = a_{ro} + \sum_k S^k_{ro} l^k_{ro} = -\epsilon_{ro} p_{ro} + \left(1 - S^x_{ro}\right) \left(\eta p_r + y_r\right), \tag{42}$$

where

$$\epsilon_{ro} \equiv \left(1 - \left(1 - S^x_{ro}\right)\left(1 - S^m_{ro}\right)\right) \alpha + \left(1 - S^x_{ro}\right)\left(1 - S^m_{ro}\right) \eta \tag{43}$$

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 an occupation are traded, as measured by S^x_{ro} and S^m_{ro}. The parameter ϵ_{ro} is the partial demand elasticity of region r's occupation o output to its output price. It is a partial elasticity because it holds fixed region r's aggregate output and price index (but lets it's absorption price of occupation o change). Equation (38) simplifies to

$$p_r = \sum_{o \in \mathcal{O}} S^A_{ro} \left(1 - S^m_{ro}\right) p_{ro} \tag{44}$$

Second, we assume that occupations are grouped into two sets, g for $g = \{T, N\}$, where $S^x_{ro} = S^x_{ro'}$ and $S^m_{ro} = S^m_{ro'}$ for all $o, o' \in g$. According to (43), the assumption that $S^x_{ro} = S^x_{ro'}$ and $S^m_{ro} = S^m_{ro'}$ for all $o, o' \in g$ implies that the elasticity of local output to the local producer price, ϵ_{ro}, is common across all occupations in g. We refer to ϵ_{rg} as the common elasticity for all $o \in g$ within region r. The assumption that that $S^x_{ro} = S^x_{ro'}$ for all $o, o' \in g$ also implies that the term $\left(1 - S^x_{ro}\right)(\eta p_r + y_r)$ in (42) is common across all occupations in g.[50]

Third, we restrict comparative advantage by assuming that education groups within each k differ only in their absolute productivities, $Z^k_{reo} = Z^k_{re}$. This assumption and equation (10) imply that education groups within k are allocated identically across occupations: $\pi^k_{reo} = \pi^k_{ro}$ for all e. Hence, equation (34) becomes

$$l^k_{reo} = \theta w^k_{ro} - \theta \left(\sum_{j \in \mathcal{O}} \pi^k_{rj} w^k_{rj} \right) + n^k_{re}.$$

The previous expression and equation (35) yield[51]

$$l^k_{ro} = \theta w^k_{ro} - \theta \left(\sum_{j \in \mathcal{O}} \pi^k_{rj} w^k_{rj} \right) + \sum_e \frac{S^k_{reo}}{S^k_{ro}} n^k_{re}.$$

Under the assumption that $Z^k_{reo} = Z^k_{re}$, the ratio S^k_{reo}/S^k_{ro} is common across o, so

$$l^k_{ro} = \theta w^k_{ro} - \theta \left(\sum_{j \in \mathcal{O}} \pi^k_{rj} w^k_{rj} \right) + n^k_r, \tag{45}$$

where the vector of changes in labor supplies by education level in region r, $\left\{n^k_{re}\right\}_e$, is summarized by a single sufficient statistic,

$$n^k_r \equiv \sum_e \frac{S^k_{re}}{S^k_r} n^k_{re},$$

with weights given by the share of labor income in region r accruing to type k labor with education e, $S^k_{re} \equiv \frac{W^k_{ro} L^k_{re}}{\sum_{e',k'} W^{k'}_{ro} L^{k'}_{re'}}$, relative to the share of labor income in region r accruing to all type k labor, $S^k_r = \sum_{e'} S^k_{re'}$.

Hence, under the first and third restrictions of Section 3.1, we can use equations (32), (33), (36), (41), (42), (44), and (45) to solve for changes in employment allocations l^k_{ro} and n^k_{ro}, occupation wages w^k_{ro}, occupation prices p_{ro} and quantities q_{ro}, and aggregate absorption price p_r and quantity y_r, for all r, o and k. With shocks to region r alone, log changes in all endogenous variables are linear functions of shocks in region r: $\left\{n^I_{re}\right\}_e$, $\left\{n^D_{re}\right\}_e$, and $\left\{a_{ro}\right\}_o$.

[50]Under the assumption that α is infinite, as in the Rybczynski theorem, ϵ_{ro} is infinite and the assumption that r is a small open economy implies that $p_{ro} = 0$. In this case, we obtain our analytic results in Section 3.2 without requiring common trade shares across goods. Of course, in this case crowding in obtains.

[51]In this derivation, we use the following

$$\sum_e \frac{L^k_{reo}}{L^k_{ro}} n^k_{re} = \frac{1}{W^k_{ro} \sum_{e'} L^k_{re'o}} \sum_e W^k_{ro} L^k_{reo} n^k_{re} = \frac{\sum_{e',k'} W^{k'}_{ro} L^{k'}_{re'o}}{W^k_{ro} \sum_{e'} L^k_{re'o}} \sum_e S^k_{reo} n^k_{re}$$

and the definitions in the main text $S^k_{reo} \equiv \frac{W^k_{ro} L^k_{reo}}{\sum_{e',k'} W^{k'}_{ro} L^{k'}_{re'o}}$ and $S^k_{ro} \equiv \sum_e S^k_{reo}$.

A.3 Proofs for Sections 3.2 and 3.3

Deriving equations (18)-(21): Combining equations (33) and (45), we obtain

$$(\theta+\rho)\left(w_{ro}^{D}-w_{ro}^{I}\right)=\theta\left(\sum_{j\in\mathcal{O}}\pi_{rj}^{D}w_{rj}^{D}-\sum_{j\in\mathcal{O}}\pi_{rj}^{I}w_{rj}^{I}\right)+n_{r}^{I}-n_{r}^{D} \tag{46}$$

so that $\tilde{w}_r\equiv w_{ro}^{D}-w_{ro}^{I}$ is common across occupations o. With shocks to region r alone, it follows from the system of equation in changes that $\tilde{w}_r$ is a linear combination of region r shocks, as in equation (21). We do not explicitly solve for the change in relative wages per efficiency unit, $\tilde{w}_r$, in general; we do so under the assumption of a single g in Section A.4.

Equation (42) is equivalent to

$$p_{ro}=\frac{1}{\epsilon_{ro}}\left(1-S_{ro}^{x}\right)\left(\eta p_{r}+y_{r}\right)-\frac{1}{\epsilon_{ro}}a_{ro}-\frac{1}{\epsilon_{ro}}S_{ro}^{I}\left(l_{ro}^{I}-l_{ro}^{D}\right)-\frac{1}{\epsilon_{ro}}l_{ro}^{D}.$$

The previous expression and equation (33) yield

$$p_{ro}=\frac{1}{\epsilon_{ro}}\left(1-S_{ro}^{x}\right)\left(\eta p_{r}+y_{r}\right)-\frac{1}{\epsilon_{ro}}a_{ro}-\frac{\rho}{\epsilon_{ro}}S_{ro}^{I}\tilde{w}_{r}-\frac{1}{\epsilon_{ro}}l_{ro}^{D},$$

which, together with equation (32) yields

$$w_{ro}^{D}=\frac{1}{\epsilon_{ro}}\left(1-S_{ro}^{x}\right)\left(\eta p_{r}+y_{r}\right)+\left(\frac{\epsilon_{ro}-1}{\epsilon_{ro}}\right)a_{ro}+\left(\frac{\epsilon_{ro}-\rho}{\epsilon_{ro}}\right)S_{ro}^{I}\tilde{w}_{r}-\frac{1}{\epsilon_{ro}}l_{ro}^{D}.$$

The previous expression and equation (45) yield

$$\begin{aligned}w_{ro}^{D}=&\left(\frac{\epsilon_{ro}-\rho}{\epsilon_{ro}+\theta}\right)\tilde{w}_{r}S_{ro}^{I}+\left(\frac{\epsilon_{ro}-1}{\epsilon_{ro}+\theta}\right)a_{ro}\\&+\frac{1}{\epsilon_{ro}+\theta}\left[\left(1-S_{ro}^{x}\right)\left(\eta p_{r}+y_{r}\right)+\theta\sum_{j\in\mathcal{O}}\pi_{rj}^{D}w_{rj}^{D}-n_{r}^{D}\right].\end{aligned} \tag{47}$$

We similarly obtain

$$\begin{aligned}w_{ro}^{I}=&\left(\frac{\epsilon_{ro}-\rho}{\epsilon_{ro}+\theta}\right)\tilde{w}_{r}\left(S_{ro}^{I}-1\right)+\left(\frac{\epsilon_{ro}-1}{\epsilon_{ro}+\theta}\right)a_{ro}\\&+\frac{1}{\epsilon_{ro}+\theta}\left[\left(1-S_{ro}^{x}\right)\left(\eta p_{r}+y_{r}\right)+\theta\sum_{j}\pi_{rj}^{I}w_{rj}^{I}-n_{r}^{I}\right].\end{aligned} \tag{48}$$

Imposing the second restriction from Section (3.1), equations (36), (47), and (48) yield equation (20), where $\epsilon_{rg}=\epsilon_{ro}$ for all $o\in g$. Under the same restriction, equations (36) and (20) yield equation (19). Equations 19 and (20) simplify to equations (16) and (17) if $a_{ro}=a_{ro'}$ for all $o,o'\in g$ and $n_{re}^{D}=0$ for all e.

Using equations (32) and (20), we obtain

$$p_{ro}-p_{ro'}=-\frac{\theta+\rho}{\theta+\epsilon_{rg}}\tilde{w}_{r}\left(S_{ro}^{I}-S_{ro'}^{I}\right)-\frac{\theta+1}{\theta+\epsilon_{rg}}\left(a_{ro}-a_{ro'}\right)$$

for any $o,o'\in g$. Combining the previous expression and equation (42), we obtain

$$q_{ro}-q_{ro'}=\frac{\epsilon_{rg}\left(\theta+\rho\right)}{\theta+\epsilon_{rg}}\tilde{w}_{r}\left(S_{ro}^{I}-S_{ro'}^{I}\right)+\frac{\epsilon_{rg}\left(\theta+1\right)}{\theta+\epsilon_{rg}}\left(a_{ro}-a_{ro'}\right)$$

for any $o,o'\in g$. The two previous expressions yield equation (18). Equation (18) simplifies to equation (15) if $a_{ro}=a_{ro'}$ for all $o,o'\in g$ and $n_{re}^{D}=0$ for all e.

Deriving equation (22): Consider $o, o' \in g$. Equation (19) implies

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

The previous expression is equivalent to

$$\frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} n_{reo}^{k} = \frac{(\epsilon_{rg} - \rho)(\theta + 1)}{\epsilon_{rg} + \theta} \tilde{w}_r \left(\frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} S_{ro}^{I} - \frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} S_{ro'}^{I}\right) + \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta} \left(\frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} a_{ro} - \frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} a_{ro'}\right) + \frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} n_{reo'}^{k}$$

Letting $n_{reg}^{k} \equiv \sum_{o' \in g} \frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} n_{reo'}^{k}$ denote the log change in labor allocated to g, and summing the previous expression over all $o' \in g$, we obtain

$$n_{reo}^{k} = \frac{(\epsilon_{rg} - \rho)(\theta + 1)}{\epsilon_{rg} + \theta} \tilde{w}_r \left(S_{ro}^{I} - \sum_{o' \in g} \frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} S_{ro'}^{I}\right) + \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta} \left(a_{ro} - \sum_{o' \in g} \frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} a_{ro'}\right) + n_{reg}^{k}$$

The previous expression, equation (21), and $a_{ro} \equiv a_o + a_{rg} + \tilde{a}_{ro}$ yield equation (22), where

$$\alpha_{reg}^{k} \equiv -\frac{(\epsilon_{rg} - \rho)(\theta + 1)}{\epsilon_{rg} + \theta} \tilde{w}_r \sum_{o' \in g} \frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} S_{ro'}^{I} - \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta} \sum_{o' \in g} \frac{\pi_{reo'}^{k}}{\pi_{reg}^{k}} a_{ro'} + \frac{(\epsilon_{rg} - 1)(\theta + 1)}{\epsilon_{rg} + \theta} a_{rg} + n_{reg}^{k}.$$

The partial own labor demand elasticity: We can solve for the partial own labor demand elasticity at the level of the region-occupation, l_{ro}^{D}/w_{ro}^{D}, in which we allow for native and immigrant labor to reallocate across occupations and occupation prices to change, but hold immigrant wages, aggregate output, and aggregate prices fixed. Combining equations (32), (33), and 42, we obtain

$$\left|l_{ro}^{D}/w_{ro}^{D}\right| = \epsilon_{ro}\left(1 - S_{ro}^{I}\right) + \rho S_{ro}^{I}.$$

This partial elasticity is increasing in ρ (as is standard) and also ϵ_{ro} (consistent with Hicks-Marshall's rules of derived demand). Moreover, it is increasing in S_{ro}^{I} if and only if $\rho > \epsilon_{ro}$.

A.4 Explicit solutions if all o have common trade shares

Here we consider a version of our baseline model in which we assume that there is a single grouping of occupations so that all occupations o have a common export share of output, $S_r^x = S_{ro}^x$, and import share of absorption, $S_{ro}^m = S_r^m$. This formulation nests the case in which bilateral trade costs are infinite, in which case $S_{ro}^x = S_{ro}^m = 0$ for all o.

We begin by solving explicitly for $\tilde{w}_r$ and n_{reo}^{D}. We then sign Ψ_{ro}^{I}, Ψ_{ro}^{D}, and Ψ_{ro}^{A}.

Solving explicitly for $\tilde{w}_r$ and n_r^k. Equation (43) simplifies to

$$\epsilon_r \equiv \epsilon_{ro} = \left(1 - \left(1 - S_r^x\right)\left(1 - S_r^m\right)\right)\alpha + \left(1 - S_r^x\right)\left(1 - S_r^m\right)\eta \text{ for all } o. \tag{49}$$

Equations (47) and (49) imply

$$\sum_o \pi_{ro}^{D} w_{ro}^{D} = \left(\frac{\epsilon_r - \rho}{\epsilon_r}\right) \tilde{w}_r \sum_o \pi_{ro}^{D} S_{ro}^{I} + \left(\frac{\epsilon_r - 1}{\epsilon_r}\right) \sum_o \pi_{ro}^{D} a_{ro} + \frac{1}{\epsilon_r}\left(\eta p_r + y_r\right)\left(1 - S_r^x\right) - \frac{1}{\epsilon_r} n_r^{D}$$

We similarly obtain from equations (48) and (49)

$$\sum_o \pi_{ro}^I w_{ro}^I = \left(\frac{\rho-\epsilon_r}{\epsilon_r}\right)\tilde{w}_r \sum_o \pi_{ro}^I \left(1-S_{ro}^I\right) + \left(\frac{\epsilon_r-1}{\epsilon_r}\right)\sum_o \pi_{ro}^I a_{ro} + \frac{1}{\epsilon_r}\left(\eta p_r + y_r\right)\left(1-S_r^x\right) - \frac{1}{\epsilon_r} n_r^I.$$

The previous two expressions and equation (46) yield an explicit solution for $\tilde{w}_r$,

$$\tilde{w}_r = \frac{\left(\theta+\epsilon_r\right)\left(n_r^I - n_r^D\right) + \theta\left(\epsilon_r - 1\right)\sum_o \left(\pi_{ro}^D - \pi_{ro}^I\right) a_{ro}}{\epsilon_r\left(\theta+\rho\right) + \theta\left(\rho-\epsilon_r\right)\left[1+\sum_o \left(\pi_{ro}^D - \pi_{ro}^I\right) S_{ro}^I\right]}$$

This can be re-expressed as

$$\tilde{w}_r = \Phi_r^I\left(n_r^I - n_r^D\right) + \sum_o \Phi_{ro}^A a_{ro}, \tag{50}$$

where

$$\Phi_r^I = \frac{\theta+\epsilon_r}{\epsilon_r\left(\theta+\rho\right) + \theta\left(\rho-\epsilon_r\right)\left[1+\sum_o \left(\pi_{ro}^D - \pi_{ro}^I\right) S_{ro}^I\right]}$$

and

$$\Phi_{ro}^A = \frac{\theta\left(\epsilon_r-1\right)}{\epsilon_r\left(\theta+\rho\right) + \theta\left(\rho-\epsilon_r\right)\left[1+\sum_o \left(\pi_{ro}^D - \pi_{ro}^I\right) S_{ro}^I\right]}\left(\pi_{ro}^D - \pi_{ro}^I\right)$$

Equation (50) provides an explicit solution for the log change in the relative occupation wage of natives to immigrants, $\tilde{w}_r$, as a function of the relative log change in the supply of immigrant to native workers, $n_r^I - n_r^D$, and the log change in the change in occupation productivities, $\sum_o \left(\pi_{ro}^D - \pi_{ro}^I\right) a_{ro}$, where Φ_r^I and Φ_r^A represent the corresponding elasticities. Finally, we can also solve explicitly for log changes in labor allocations as

$$n_{reo}^D = \frac{\theta+1}{\epsilon_r+\theta}\left[\left(\epsilon_r-\rho\right)\tilde{w}_r\left(S_{ro}^I - \sum_o \pi_{ro}^D S_{ro}^I\right) + \left(\epsilon_r-1\right)\left(a_{ro} - \sum_o \pi_{ro}^D a_{ro}\right)\right] + n_{re}^D$$

Signing Φ_r^I. Here, we prove that $\Phi_r^I \geq 0$. Let

$$z_r \equiv \sum_j \left(\pi_{rj}^I - \pi_{rj}^D\right) S_{rj}^I. \tag{51}$$

The numerator of Φ_r^I is weakly positive. We consider two cases: (i) $\rho \geq \epsilon_r$ and (ii) $\rho < \epsilon_r$. In the first case $(\rho \geq \epsilon_r)$, we clearly have $\Phi_r^I \geq 0$, since $z_r \leq 1$. In the second case $(\rho \geq \epsilon_r)$, $z_r \geq 0$ is a sufficient condition for $\Phi_r^I \geq 0$ since $\Phi_r^I \geq 0 \iff \frac{\epsilon_r \rho}{\rho-\epsilon_r}\left(\frac{1}{\epsilon_r}+\frac{1}{\theta}\right) \leq z_r$. Order occupations such that

$$o \leq o' \Rightarrow S_{ro}^I \leq S_{ro'}^I.$$

By definition, $S_{ro}^I = W_{ro}^I L_{ro}^I / \left(W_{ro}^I L_{ro}^I + W_{ro}^D L_{ro}^D\right)$. Equations (10) and (11) imply

$$W_{ro}^k L_{reo}^k = \gamma N_{re}^k \pi_{reo}^k \left(\sum_{j\in\mathcal{O}}\left(Z_{rej}^k W_{rj}^k\right)^{\theta+1}\right)^{\frac{1}{\theta+1}},$$

which, together with our restriction that $Z_{reo}^k = Z_{ro}^k$, yields

$$W_{ro}^k L_{ro}^k = \gamma \pi_{ro}^k \left(\sum_{j\in\mathcal{O}}\left(Z_{rj}^k W_{rj}^k\right)^{\theta+1}\right)^{\frac{1}{\theta+1}} N_r^k,$$

where $N_r^k \equiv \sum_e N_{re}^k$. Hence, we have

$$o \leq o' \Rightarrow \frac{\pi_{ro}^D}{\pi_{ro}^I} \geq \frac{\pi_{ro'}^D}{\pi_{ro'}^I}. \tag{52}$$

Let $\Pi_r^k(o) \equiv \sum_{o'=1}^{o} \pi_{ro}^k$. Condition (52) is equivalent to stating that $\Pi_r^I(o)$ dominates $\Pi_r^D(o)$ in terms of the likelihood ratio. This implies that $\Pi_r^I(o)$ (first-order) stochastically dominates $\Pi_r^D(o)$. Since S_{ro}^I is increasing in o, equation (51) therefore implies $z_r \geq 0$, which implies $\Phi_r^I \geq 0$ if $\rho < \epsilon_r$. Combining the two cases ($\rho \geq \epsilon_r$ and $\rho < \epsilon_r$), we obtain the result that $\Phi_r^I \geq 0$.

Signing Φ_{ro}^A. Here, we prove that $\Phi_{ro}^A > 0 \iff (\pi_{ro}^D - \pi_{ro}^I)\epsilon_r > 1$. The denominator of Φ_r^A is strictly positive, since $z_r \leq 1$ and $\rho, \theta, \epsilon_r > 0$. The numerator of Φ_r^A is positive if and only if $(\pi_{ro}^D - \pi_{ro}^I)\epsilon_r > 1$.

A.5 Relaxing restriction three: education-specific occupation comparative advantage

In our baseline analytic results we assumed that education cells did not differ in their relative productivities across occupations: $Z_{reo}^k / Z_{reo'}^k = Z_{re'o}^k / Z_{re'o'}^k$ (restriction 3). Here we discuss the conditions for crowding in or out when we relax this assumption (as is the case in the data we use in our quantitative analysis). We impose that $a_{ro} = 0$.

By equation (34) and (35),

$$l_{ro}^k = \theta w_{ro}^k + \sum_e \frac{L_{reo}^k}{L_{ro}^k} \left(-\theta wage_{re}^k + n_{re}^k \right), \tag{53}$$

where

$$wage_{re}^k = \sum_{o \in \mathcal{O}} \pi_{reo}^k w_{ro}^k$$

Equations (32), (33), and (42) (which do not use restriction 3) imply that

$$l_{ro}^D + (\rho - \epsilon_{ro}) S_{ro}^I \tilde{w}_{ro} = -\epsilon_{ro} w_{ro}^D + (1 - S_{ro}^x)(\eta p_r + y_r)$$

where $\tilde{w}_{ro} \equiv w_{ro}^D - w_{ro}^I$. For two occupations $o, o' \in g$,

$$l_{ro}^D - l_{ro'}^D + \epsilon_{rg} \left(w_{ro}^D - w_{ro'}^D \right) = (\epsilon_{rg} - \rho) \left[S_{ro}^I \tilde{w}_{ro} - S_{ro'}^I \tilde{w}_{ro'} \right]. \tag{54}$$

Consider first the case in which $Z_{reo}^k / Z_{reo'}^k = Z_{re'o}^k / Z_{re'o'}^k$ for $k = D$ (satisfying restriction 3) but not for $k = I$. In this case, $\frac{L_{reo}^D}{L_{ro}^D} = \frac{L_{reo'}^D}{L_{ro'}^D}$ and equation (53) implies that $l_{ro}^D - l_{ro'}^D = \theta \left(w_{ro}^D - w_{ro'}^D \right)$. Using (33), (54) can be re-written as

$$w_{ro}^D - w_{ro'}^D = \frac{(\epsilon_{rg} - \rho)}{(\epsilon_{rg} + \theta)} \left(S_{ro}^I \tilde{w}_{ro} - S_{ro'}^I \tilde{w}_{ro'} \right)$$

If $\epsilon_{rg} = \rho$, then $w_{ro}^D = w_{ro'}^D$ so by equation (34), $l_{reo}^D - l_{reo'}^D = 0$ for $o, o' \in g$; that is there is neither crowding in or out for native workers in g. If $\epsilon_{rg} \neq \rho$, then the sign and magnitude of $l_{reo}^D - l_{reo'}^D$ depends on S_{ro}^I, $S_{ro'}^I$, $\tilde{w}_{ro}$ and $\tilde{w}_{ro'}$.

Consider now the more general case in which we do not impose restriction 3 for either $k = D$ or $k = I$. We aim to understand under what conditions $\rho = \epsilon_{rg}$ implies neither crowding in nor out in g, as under the assumption that restriction 3 holds. If $\rho = \epsilon_{rg}$, then equation (54) (and the analogous equation for immigrant labor) implies that for $o, o' \in g$,

$$l_{ro}^k - l_{ro'}^k + \epsilon_{rg} \left(w_{ro}^k - w_{ro'}^k \right) = 0$$

which combined with equation (53) implies

$$w_{ro}^k - w_{ro'}^k = \frac{1}{\epsilon_{rg} + \theta} \sum_e \left(\frac{L_{reo}^k}{L_{ro}^k} - \frac{L_{reo'}^k}{L_{ro'}^k} \right) \left(\theta wage_{re}^k - n_{re}^k \right) \tag{55}$$

for $k = D, I$ and $o, o' \in g$. If $\theta wage_{re}^k - n_{re}^k$ is common across education levels e, then $w_{ro}^k - w_{ro'}^k = l_{reo}^k - l_{reo'}^k = 0$ for all $o, o' \in g$; that is, there is neither crowding in nor out across occupations in g for worker k type.

We can use this result to understand why, in the calibrated model of Section 5 (in which we do not impose restriction 3) setting $\epsilon_{rT} \approx \rho$ results roughly in neither crowding in nor crowding out for natives workers within the set of tradable occupations, as in the model with a single education group. This is because immigration induces only small differential changes across education groups in native population across space (via endogenous mobility of native workers) and in average wages within a region: that is, $n^D_{re} \approx n^D_{re'}$ and $wage^D_{re} \approx wage^D_{re'}$ for all e, e'. In contrast, in Section F of the Appendix we show that setting $\epsilon_{rT} \approx \rho$ implies that immigrant workers reallocate systematically across tradable occupations in response to an inflow of immigrants. As shown in Section F, this is also the case in the data when we consider the allocation regressions for immigrant workers.

B Summary statistics and occupation details

We list the 50 occupations used in our baseline analysis, as well as their tradability ranking from Blinder and Krueger (2013), in Table 5. We provide balance tables across tradable and nontradable occupations using 1980 occupation characteristics and 2012 occupation characteristics, in Table 6. We provide summary statistics for immigrant intensity, S^I_{ro}, for the most and least tradable occupations both at the national level and in Los Angeles, CA in Table 7.

Most and least tradable occupations		
Rank*	Twenty-five most tradable occupations	Twenty-five least tradable occupations
1	Fabricators$^+$	Social, Recreation and Religious Workers$^+$
2	Printing Machine Operators$^+$	Cleaning and Building Service$^+$
3	Metal and Plastic Processing Operator$^+$	Electronic Repairer$^+$
4	Woodworking Machine Operators$^+$	Lawyers and Judges$^+$
5	Textile Machine Operator	Vehicle Mechanic$^+$
6	Math and Computer Science	Police$^+$
7	Precision Production, Food and Textile	Housekeeping$^+$
8	Records Processing	Teachers, Postsecondary$^+$
9	Machine Operator, Other	Health Assessment$^+$
10	Computer, Communication Equipment Operator	Food Preparation and Service$^+$
11	Office Machine Operator	Personal Service$^+$
12	Precision Production, Other	Firefighting$^+$
13	Metal and Plastic Machine Operator	Related Agriculture$^+$
14	Technical Support Staff	Extractive$^+$
15	Science Technicians	Production, Other$^+$
16	Engineering Technicians	Guards$^+$
17	Natural Science	Construction Trade$^+$
18	Arts and Athletes	Therapists$^+$
19	Misc. Administrative Support	Supervisors, Protective Services$^+$
20	Engineers	Teachers, Non-postsecondary
21	Social Scientists, Urban Planners and Architects	Transportation and Material Moving
22	Managerial Related	Librarians and Curators
23	Secretaries and Office Clerks	Health Service
24	Sales, All	Misc. Repairer
25	Health Technologists and Diagnosing	Executive, Administrative and Managerial

Table 5: The most and least tradable occupations, in order

Notes: To construct the 50 occupations used in our baseline anlaysis, we start with the 69 occupations based on the sub-headings of the 1990 Census Occupational Classification System and aggregate up to 50 to concord to David Dorn's occupation categorization (http://www.ddorn.net/) and to combine occupations that are similar in education profile and tradability but whose small size creates measurement problems (given the larger number of CZs in our data). *: for most (least) traded occupations, rank is in decreasing (increasing) order of tradability score; $^+$: occupations that achieve either the maximum or minimum tradability score.

	Characteristics of Workers		1980 Natives	1980 Immigrants	1980 **Total**	2012 Natives	2012 Immigrants	2012 **Total**
Tradable	Share of female		0.49	0.47	0.49	0.51	0.46	0.51
	Share of college and above		0.17	0.23	0.17	0.34	0.43	0.34
	Share of non-white		0.10	0.25	0.11	0.17	0.57	0.24
	Age distribution	16-32	0.44	0.37	0.44	0.30	0.25	0.29
		33-49	0.33	0.40	0.33	0.37	0.48	0.39
		50-65	0.23	0.23	0.23	0.33	0.28	0.32
	Share in routine-intensive		0.45	0.39	0.44	0.40	0.35	0.39
	Share in abstract-intensive		0.30	0.22	0.29	0.34	0.27	0.33
	Share in communication-intensive		0.27	0.22	0.27	0.34	0.27	0.33
	Total		**0.46**	**0.03**	**0.50**	**0.37**	**0.07**	**0.44**
Nontradable	Share of female		0.31	0.33	0.31	0.42	0.38	0.41
	Share of college and above		0.20	0.18	0.20	0.34	0.24	0.32
	Share of non-white		0.11	0.22	0.12	0.18	0.50	0.24
	Age distribution	16-32	0.41	0.35	0.41	0.28	0.24	0.28
		33-49	0.35	0.40	0.35	0.39	0.49	0.40
		50-65	0.24	0.24	0.24	0.33	0.27	0.32
	Share in routine-intensive		0.07	0.10	0.07	0.07	0.11	0.08
	Share in abstract-intensive		0.24	0.22	0.24	0.28	0.19	0.26
	Share in communication-intensive		0.33	0.28	0.32	0.41	0.25	0.39
	Total		**0.47**	**0.03**	**0.50**	**0.46**	**0.10**	**0.56**

Table 6: Characteristics of workers, 1980 in left panel and 2012 in right panel

Notes: Source for data is 1980 Census for the left panel and 2011-2013 ACS in the right panel. Values are weighted by annual hours worked times the sampling weight.

Occupation Immigrant Intensity within CZ, S^I_{ro}							
		1980			2012		
		LA	All CZs		LA	All CZs	
	Occupations		Mean	Std. Dev.		Mean	Std. Dev.
10 Most Tradable*	Fabricators+	.324	.027	.054	.628	.068	.095
	Printing Machine Operators+	.153	.019	.051	.433	.042	.093
	Metal and Plastic Processing Operators+	.352	.038	.133	.646	.053	.158
	Woodworking Machine Operators+	.457	.023	.09	.72	.073	.163
	Textile Machine Operators	.714	.053	.103	.899	.14	.178
	Math and Computer Science	.125	.026	.086	.364	.053	.065
	Precision Production, Food and Textile	.218	.024	.034	.464	.085	.096
	Records Processing	.136	.016	.024	.301	.03	.044
	Machine Operators, Other	.262	.027	.058	.589	.11	.11
	Computer, Communication Equipment Operators	.104	.012	.024	.274	.034	.088
19 Least Tradable**	Social, Recreation and Religious Workers	.093	.023	.037	.284	.032	.042
	Cleaning and Building Service	.242	.025	.042	.527	.076	.093
	Electronic Repairer	.1	.01	.022	.267	.025	.047
	Lawyers and Judges	.055	.006	.031	.124	.019	.051
	Vehicle Mechanic	.207	.018	.033	.441	.039	.063
	Police	.054	.014	.048	.119	.016	.029
	Housekeeping	.537	.04	.068	.823	.165	.174
	Teachers, Postsecondary	.148	.046	.056	.283	.109	.078
	Health Assessment	.215	.03	.046	.484	.042	.065
	Food Preparation and Service	.337	.034	.044	.527	.092	.085
	Personal Service	.175	.023	.031	.325	.05	.053
	Firefighting	.027	.008	.026	.03	.01	.023
	Related Agriculture	.442	.041	.077	.679	.142	.134
	Extractive	.11	.02	.06	.164	.042	.092
	Production, Other	.186	.019	.033	.374	.043	.057
	Guards	.08	.014	.031	.225	.026	.042
	Construction Trade	.144	.019	.031	.396	.054	.067
	Therapists	.11	.027	.087	.287	.037	.051
	Supervisors, Protective Services	.03	.008	.066	.117	.016	.056

Table 7: Summary Statistics of S^I_{ro} for the most and least tradable occupations in Los Angeles and across all CZs

Notes: *: the most tradable occupations ordered by decreasing tradability score; +: occupations that achieve the maximum tradability score; **: the least tradable occupations that achieve the minimum tradability score.

C Wage analysis

To estimate regression 29 replacing unobserved occupation wages with observed average wages and to estimate regression 30, we require measures of average wages by education group, occupation, and CZ (reo) cell. To obtain these, we first regress log hourly earnings of native-born workers in each year on a gender dummy, a race dummy, a categorical variable for 10 levels of educational attainment, a quartic in years of potential experience, and all pair-wise interactions of these values (where regressions are weighted by annual hours worked times the sampling weight). We take the residuals from this Mincerian regression and calculate the sampling weight and hours-weighted average value for native-born workers for an education group, occupation, and CZ. Finally, we use these values to calculate changes in average wages in each reo cell.

Dependent variable: change in the average wage of domestic workers in a region-occupation, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.038***	.046**	.038**	.003	-.008	.001
	(.014)	(.023)	(.017)	(.021)	(.031)	(.030)
$\mathbb{I}_o(N)\,x_{ro}$	-.057**	-.083	-.076**	.007	-.022	-.0189
	(.028)	(.052)	(.037)	(.028)	(.037)	(.0311)
Obs	33723	33723	33723	26644	26644	26644
R-sq	.639	.639	.639	.613	.613	.613
Wald Test: P-values	0.34	0.38	0.18	0.64	0.36	0.52
AP F-stats (first stage)						
x_{ro}		102.77			65.90	
$\mathbb{I}_o(N)\,x_{ro}$		75.21			48.48	

Notes: Observations are for CZ-occupation pairs. The dependent variable is the log change in the average CZ-occupation wage for native-born workers; 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-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. Significance levels: * 10%, ** 5%, ***1%.

Table 8: Average occupation wage for domestic workers

Dependent variable: log change in the constructed occupation wage of domestic workers in a region-occupation, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.075***	.039	.033	.019	-.021	-.006
	(.023)	(.045)	(.031)	(.032)	(.057)	(.052)
$\mathbb{I}_o(N)\,x_{ro}$	-.189***	-.204***	-.171***	-.167***	-.234***	-.203***
	(.038)	(.070)	(.050)	(.061)	(.087)	(.077)
Obs	33723	33723	33723	26644	26644	26644
R-sq	.798	.797	.797	.712	.711	.712
Wald Test: P-values	0.01	0.01	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	

Notes: Observations are for CZ-occupation pairs. The dependent variable is the constructed changes in native occupation wages in (30); 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-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. Significance levels: * 10%, ** 5%, ***1%.

Table 9: Constructed occupation wage for domestic workers

D Additional details of the extended model

D.1 System of equilibrium equations in changes

We describe a system of equations to solve for changes in prices and quantities in the extended model. We consider the specification of the model that incorporates agglomeration externalities governed by the parameter λ; see footnote 45. We use the "exact hat algebra" approach that is widely used in international trade (Dekle et al., 2008). We denote with a "hat" the ratio of any variable between two time periods. The two driving forces are changes in the national supply of foreign workers (denoted by $\hat{N}_e^I$) and domestic workers (denoted by $\hat{N}_e^D$).

We proceed in two steps. First, for a given guess of changes in occupation wages for domestic and immigrant workers in each region, $\{\hat{W}_{ro}^D\}$ and $\{\hat{W}_{ro}^I\}$, changes in the supply of domestic workers by education in each region, $\left\{\hat{N}_{re}^D\right\}$, and changes in the supply of immigrant workers by education and source country in each region, $\left\{\hat{N}_{re}^{Ic}\right\}$, we calculate in each region r changes in the supply of immigrant workers by education e

$$\hat{N}_{re}^I = \sum_c \frac{N_{re}^{Ic}}{N_{re}^I} \hat{N}_{re}^{Ic},$$

changes in the total population in each region

$$\hat{N}_r = \sum_{k,e} \frac{N_{re}^k}{N_r} \hat{N}_{re}^k,$$

changes in average group wages

$$W\hat{age}_{re}^k = \hat{N}_r^\lambda \left(\sum_o \pi_{reo}^k \left(\hat{W}_{ro}^k \right)^{\theta+1} \right)^{\frac{1}{\theta+1}},$$

changes in occupation output prices

$$\hat{P}_{ro} = \left(S_{ro}^I \left(\hat{W}_{ro}^I \right)^{1-\rho} + \left(1 - S_{ro}^I\right) \left(\hat{W}_{ro}^D \right)^{1-\rho} \right)^{\frac{1}{1-\rho}},$$

changes in allocations of workers across occupations

$$\hat{\pi}_{reo}^k = \frac{\left(\hat{N}_r^\lambda \hat{W}_{ro}^k \right)^{\theta+1}}{\left(W\hat{age}_{re}^k \right)^{\theta+1}},$$

changes in occupation output

$$\hat{Q}_{ro} = \frac{1}{\hat{P}_{ro}} \sum_{k,e} S_{reo}^k \hat{\pi}_{reo}^k W\hat{age}_{re}^k \hat{N}_{re}^k,$$

and change in aggregate expenditures (and income)

$$\hat{E}_r = \sum_{k,e} S_{re}^k W\hat{age}_{re}^k \hat{N}_{re}^k.$$

Here, S_{re}^k is defined as the total income share within region r of workers of group k, e (such that $\sum_{k,e} S_{re}^k = 1$), S_{reo}^k is defined as the cost (or income) share within region r of workers of group k, e in occupation o (such that $\sum_{k,e} S_{reo}^k = 1$), and S_{ro}^I denotes the cost (or income) share of immigrants in occupation o in region r (i.e. $S_{ro}^I = \sum_e S_{reo}^I$). If $S_{ro}^I = 0$ ($S_{ro}^I = 1$), then we set $\hat{W}_{ro}^I = 1$ ($\hat{W}_{ro}^D = 1$).

Second, we update our guess of changes in occupation wages and changes in the supply within each region r of domestic and immigrant workers by education (and, for immigrants, also by source country) until the following equations are satisfied

$$\hat{Q}_{ro} = \left(\hat{P}_{ro}\right)^{-\alpha} \sum_{j\in\mathcal{R}} S^{x}_{rjo} \left(\hat{P}^{y}_{jo}\right)^{\alpha-\eta} \left(\hat{P}_{j}\right)^{\eta-1} \hat{E}_{j}$$

$$\frac{\left(1-S^{I}_{ro}\right)}{S^{I}_{ro}} \frac{\sum_{e} S^{I}_{reo}\hat{\pi}^{I}_{reo}\hat{Wage}^{I}_{re}\hat{N}^{I}_{re}}{\sum_{e} S^{D}_{reo}\hat{\pi}^{D}_{reo}\hat{Wage}^{D}_{re}\hat{N}^{D}_{re}} = \left(\frac{\hat{W}^{I}_{ro}}{\hat{W}^{D}_{ro}}\right)^{1-\rho}$$

$$\hat{N}^{D}_{re} = \frac{\left(\frac{\hat{Wage}^{D}_{re}}{\hat{P}_{r}}\right)^{\nu}}{\sum_{j\in\mathcal{R}} \frac{N^{D}_{je}}{N^{D}_{e}} \left(\frac{\hat{Wage}^{D}_{re}}{\hat{P}_{j}}\right)^{\nu}} \hat{N}^{D}_{e}$$

$$\hat{N}^{Ic}_{re} = \frac{\left(\frac{\hat{Wage}^{I}_{re}}{\hat{P}_{r}}\right)^{\nu}}{\sum_{j\in\mathcal{R}} \frac{N^{Ic}_{je}}{N^{Ic}_{e}} \left(\frac{\hat{Wage}^{I}_{re}}{\hat{P}_{j}}\right)^{\nu}} \hat{N}^{Ic}_{e}$$

where changes in absorption prices are given by

$$\hat{P}^{y}_{ro} = \left(\sum_{j\in\mathcal{R}} S^{m}_{jro} \left(\hat{P}_{jo}\right)^{1-\alpha}\right)^{\frac{1}{1-\alpha}}$$

$$\hat{P}_{r} = \left(\sum_{o\in\mathcal{O}} S^{A}_{ro} \left(\hat{P}^{y}_{ro}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}$$

Here, S^{A}_{ro} is defined as the total absorption share in region r of occupation o, $S^{A}_{ro} \equiv \frac{P^{y}_{ro}Y_{ro}}{E_{r}}$, S^{x}_{rjo} is the share of the value of region r's output in occupation o that is destined for region j, $S^{x}_{rjo} \equiv \frac{P_{ro}\tau_{rjo}Y_{rjo}}{P_{ro}Q_{ro}}$, and S^{m}_{jro} is the share of the value of region r's absorption within occupation o that originates in region j, $S^{m}_{jro} \equiv \frac{P_{jo}\tau_{jro}Y_{jro}}{P^{y}_{ro}Y_{ro}}$.[52] If $N^{Ic}_{re} = 0$, then we set $\hat{N}^{Ic}_{re} = 1$.

In this second step, we solve for $|\mathcal{O}| \times |\mathcal{R}|$ unknown occupation wage changes for domestic workers and the same for foreign workers. We also solve for $\left|\mathcal{E}^{D}\right| \times |\mathcal{R}|$ unknown changes in population of domestic workers by region $\left\{\hat{N}^{D}_{re}\right\}$, and $\left|\mathcal{E}^{IC}\right| \times |\mathcal{R}|$ unknown changes in population of immigrant workers by region $\left\{\hat{N}^{Ic}_{re}\right\}$, using the same number of equations.

The inputs required to solve this system are: (i) values of initial equilibrium shares π^{D}_{reo}, π^{I}_{reo}, S^{D}_{re}, S^{I}_{re}, S^{A}_{ro}, S^{m}_{jro}, S^{x}_{rjo} and population levels for natives, immigrants by education and source country N^{D}_{re}, N^{Ic}_{re}; (ii) values of parameters θ, η, α, ν and λ; and (iii) values of changes in aggregate domestic supply by education $\hat{N}^{D}_{e}$, and changes in aggregate immigrant supply by education and source country $\hat{N}^{Ic}_{e}$. We have omitted S^{k}_{reo} and S^{I}_{ro} from the list of required inputs because they can be immediately calculated given π^{k}_{reo} and S^{k}_{re} as

$$S^{k}_{reo} = \frac{\pi^{k}_{reo}S^{k}_{re}}{\sum_{k',e'} S^{k'}_{re'}\pi^{k'}_{re'o}}$$

and $S^{I}_{ro} = \sum_{e} S^{I}_{reo}$. In the model, π^{k}_{reo} equals both the share of labor income earned and the share of employment in occupation o by nativity k in region r (because average wages are equal across occupations). In practice, we measure π^{k}_{reo} as the share of labor income.

[52] In terms of our model's primitive parameters, regions vary in their occupational output composition due to variation in labor productivities, A^{k}_{ro} and T^{k}_{reo} (for $k = D, I$ and by education e); amenities, U^{D}_{re} and U^{Is}_{re} (by source country and education group); and bilateral trade costs, τ_{rj}.

D.2 Bilateral trade and absorption shares

Given the difficulty of obtaining bilateral regional trade data by occupation that is required to construct initial equilibrium trade shares S^m_{jro} and S^x_{rjo}, we construct them given assumptions on trade costs, as described in Section 5.2. For nontradable occupations, we assume that trade costs are prohibitive across CZs ($\tau_{rjo} = \infty$ for all $j \neq r$). This implies that $S^x_{rro} = S^m_{rro} = 1$ and $S^x_{rjo} = S^m_{rjo} = 0$ for all $j \neq r$. Absorption shares for each nontradable occupation, S^A_{ro}, are given by

$$S^A_{ro} = \frac{P_{ro}Q_{ro}}{E_r},$$

where occupation revenues, $P_{ro}Q_{ro}$, are measured by labor payments of this occupation in the data, and E_r is equal to total expenditures in region r (which, by the assumption of balanced trade, is equal to the sum of revenues—labor payments—across all occupations). For tradable occupations, we assume instead that trade costs between a given origin-destination pair are common across occupations, $\tau_{rjo} = \tau_{rjo'}$ for all $o, o' \in T$, and are parameterized as $\tau_{rjo} = \bar{\tau} \times \ln(\text{distance}_{rj})^{\varepsilon}$ for $j \neq r$. We also assume that occupation demand shifters are common across regions for tradable occupations, $\mu_{ro} = \mu_o$ for $o \in T$. Equations (3) and (5) imply that region r's sales to region j in occupation o are given by

$$\begin{aligned} E_{rjo} &= (\tau_{rjo}P_{ro})^{1-\alpha} \left(P^y_{jo}\right)^{\alpha-1} P^y_{jo}Y_{jo} \\ &= \mu_o (\tau_{rjo}P_{ro})^{1-\alpha} \left(P^y_{jo}\right)^{\alpha-\eta} \left(P^y_{jT}\right)^{\eta-1} E_{jT}, \end{aligned} \tag{56}$$

where E_{rT} denotes total expenditures on tradable occupations in region r, which by trade balance equals the sum of revenues across tradable occupations and is related to aggregate expenditures and prices by $E_{rT} = E_r (P_r/P_{rT})^{\eta-1}$. We now describe how we solve for E_{rjo} given measures of E_{rT}, τ_{rjo}, and $P_{ro}Q_{ro}$ and parameter values α, η.

Defining $\tilde{P}_{ro} = \left(\mu_o^{\frac{1}{1-\eta}} P_{ro}\right)^{1-\alpha}$ and $\tilde{P}^y_{jo} = \left(\mu_o^{\frac{1}{1-\eta}} P^y_{jo}\right)^{1-\alpha}$, E_{rjo} in equation (56) can be re-written as a function of $\left\{\tilde{P}_{ro}\right\}$,

$$E_{rjo} = (\tau_{rjo})^{1-\alpha} \tilde{P}_{ro} \left(\tilde{P}^y_{jo}\right)^{\frac{\alpha-\eta}{1-\alpha}} \left(P^y_{jT}\right)^{\eta-1} E_{jT}, \tag{57}$$

where, by equations (4) and (6),

$$\tilde{P}^y_{jo} = \sum_{j' \in \mathcal{R}} (\tau_{j'jo})^{1-\alpha} \tilde{P}_{j'o}$$

$$\left(P^y_{jT}\right)^{1-\eta} = \sum_{o \in \mathcal{O}^T} \left(\tilde{P}^y_{jo}\right)^{\frac{1-\eta}{1-\alpha}}$$

Given measures of E_{rT}, τ_{rjo}, and $P_{ro}Q_{ro}$ and parameter values α, η, we solve for $\left|\mathcal{O}^T\right| \times |\mathcal{R}|$ values of $\tilde{P}_{ro}$ using an equal number of equations

$$P_{ro}Q_{ro} = \sum_{j \in \mathcal{R}} E_{rjo} \tag{58}$$

where E_{rjo} is given by equation (57). Once we solve for tradable occupation prices $\tilde{P}_{ro}$, we calculate E_{rjo}, which allows us to construct import, export and absorption shares as

$$S^m_{rjo} = \frac{E_{rjo}}{\sum_{r'} E_{r'jo}}$$

$$S^x_{rjo} = \frac{E_{rjo}}{P_{ro}Q_{ro}}$$

and

$$S^A_{ro} = \frac{\sum_j E_{jro}}{E_r}.$$

The own export share of region r across all tradable occupations is defined as

$$S_r^{own} = \frac{\sum_{o \in \mathcal{O}^T} E_{rro}}{E_{rT}}$$

In our model calibration, we assume $(1-\alpha)\delta = -1.29$ and set $\bar{\tau}$ to target a weighted average of own export shares S_r^{own} equal to 40% across a selected subset of regions, as described in the Online Appendix.

Online Appendix for "Tradability and the Labor-Market Impact of Immigration: Theory and Evidence from the U.S."

Contents (Appendix)

Part I
Theoretical Appendix

In Appendix A we provide an alternative set of assumptions on the occupation production that yield the same equilibrium equations as the CES occupation production function in equation (1). In Appendix B we consider an isomorphic formulation of our baseline model in which the imperfect substitution between immigrant and native workers within an occupation arises from imperfect substitution between skilled and unskilled labor.

A Alternative occupation production function

Here we provide an alternative set of assumptions on the occupation production that yield the same equilibrium equations as the CES occupation production function in equation (1) (under the restriction, which we do not impose in our baseline model, that $\rho > 1$). For simplicity, here we suppress region indicators.

Setup. Suppose that there are two factors of production, domestic labor and immigrant labor, indexed by $k = D, I$, with wages per efficiency unit of labor within occupation o given by W_o^D and W_o^I. Each occupation production function is itself a Cobb-Douglas combination of the output of a continuum of tasks indexed by $t \in [0, 1]$. Workers within each k may differ in their relative productivity across occupations, but not in their relative productivity across tasks within an occupation.

The production function of task t within occupation o is given by

$$Y_o(t) = L_o^D(t) \left(\frac{Z_o^D}{t}\right)^{\frac{1}{\rho-1}} + L_o^I(t) \left(\frac{Z_o^I}{1-t}\right)^{\frac{1}{\rho-1}},$$

where $L_o^k(t)$ is employment of efficiency units of factor k in task t in occupation o and where $\rho > 1$. Therefore, domestic and immigrant efficiency units of labor are perfectly substitutable in the production of each task, up to a task-specific productivity differential. A lower value of ρ implies that this productivity differential is more variable across tasks. The cost function implied by this production function is $C_o(z) = \min\{C_o^D(z), C_o^I(z)\}$, where the unit cost of completing task t using domestic labor is

$$C_o^D(t) = W_o^D \left(\frac{t}{Z_o^D}\right)^{\frac{1}{\rho-1}},$$

whereas using immigrant labor it is

$$C_o^I(t) = W_o^I \left(\frac{1-t}{Z_o^I}\right)^{\frac{1}{\rho-1}}.$$

The unit cost of producing each occupation equals its price and is given by

$$P_o = \exp \int_0^1 \ln C_o(t) dt.$$

Characterization. There exists a cutoff task, denoted by

$$t_o = \frac{1}{1 + H_o}, \tag{59}$$

for which firms are indifferent between hiring domestic and immigrant workers, where $H_o \equiv w_o^{\rho-1} z_o^{-1}$, $w_o \equiv W_o^D / W_o^I$, and $z_o \equiv Z_o^D / Z_o^I$. The set of tasks in occupation o in which firms employ domestic workers is given by $[0, t_o)$ and the set of tasks in occupation o in which firms employ immigrant workers is given by $(t_o, 1]$. Moreover, the share of expenditure on domestic labor in occupation o is simply t_o.

Given the cutoffs, we have

$$P_o = \exp\left(\int_0^{t_o} \ln C_o^D(t)dt + \int_{t_o}^1 \ln C_o^I(t)dt\right)$$

which can be expressed as

$$P_o = \exp\left(\frac{1}{1-\rho}\right) W_o^I (Z_o^I)^{\frac{1}{1-\rho}} \left(H_o^{t_o} t_o^{t_o} (1-t_o)^{1-t_o}\right)^{\frac{1}{\rho-1}}.$$

The previous expression and equation (59) yield

$$P_o = \exp\left(\frac{1}{1-\rho}\right) W_o^I (Z_o^I)^{\frac{1}{1-\rho}} \left(\frac{H_o}{1+H_o}\right)^{\frac{1}{\rho-1}}.$$

Together with the definition of H_o, we obtain

$$P_o = \exp\left(\frac{1}{1-\rho}\right) \left(Z_o^D (W_o^D)^{1-\rho} + Z_o^I (W_o^I)^{1-\rho}\right)^{\frac{1}{1-\rho}} \tag{60}$$

exactly as in Dekle et al. (2008).

In Appendix A.1, we use equation (1) to derive only two equations: (32) and (33). Log differentiating equation (60) and using equation (59), we obtain

$$p_o = S_o^D w_o^D + S_o^I w_o^I,$$

where $S_o^D = t_o$ and $S_o^I = 1 - t_o$, exactly as in equation (32). Moreover, the fact that t_o is the share of expenditure on domestic labor, equation (59), and the definition of H_o together imply

$$\frac{L_o^D}{L_o^I} = \frac{Z_o^D}{Z_o^I} \left(\frac{W_o^D}{W_o^I}\right)^{-\rho}.$$

Log differentiating the previous expression, we obtain equation (33).

B Imperfectly substitutable skilled and unskilled labor

Here we consider an isomorphic formulation of our model of Section 2 in which the imperfect substitution between immigrant and native workers within an occupation arises from imperfect substitution between skilled and unskilled labor. While this model is isomorphic to our baseline model, the impact of immigration depends on the skill mix of immigrants and the skill-intensity of occupations. For simplicity, here we abstract from changes in productivity and we consider a version of the model with a single g, as in Section A.4.

Occupations are produced combining unskilled and skilled labor according to

$$Q_{ro} = A_{ro}\left(\left(A^U_{or}L^U_{or}\right)^{\frac{\rho-1}{\rho}} + \left(A^S_{or}L^S_{or}\right)^{\frac{\rho-1}{\rho}}\right)^{\frac{\rho}{\rho-1}},$$

where L^e_{or} denotes efficiency units of workers with education $e = U, S$. Efficiency units of native and immigrant workers of a given education are perfect substitutes within an occupation, $L^e_{or} = L^{eD}_{or} + L^{eI}_{or}$, where

$$L^{ek}_{ro} = Z^{ek}_r \int_{\omega\in\Omega^{ek}_{ro}} \varepsilon\left(\omega, o\right) d\omega \text{ for all } o, e, k,$$

Z^{ek}_r denotes the systematic productivity of workers of type $k = D, I$ and education $e = U, S$ (which is equal across occupations), Ω^{ek}_{ro} denotes the set of e, k workers in region r (with measure N^{ek}_{ro}), and $\varepsilon\left(\omega, o\right)$ is drawn independently from a Fréchet distribution. The total measure of e, k workers in region r is given by $N^{ek}_r = \sum N^{ek}_{ro}$.

Under these assumptions, the ratio of efficiency units of native to immigrant workers with education e is equal across occupations, $L^{eD}_{ro}/L^{eI}_{ro} = \left(N^{eD}_r Z^{eD}_r\right)/\left(N^{eI}_r Z^{eI}_r\right)$. Allocations and occupation wages can be solved for given "aggregate" supplies of workers by education, summing up immigrant and natives, $N^e_r = N^{eD}_r Z^{eD}_r + N^{eI}_r Z^{eI}_r$.

This framework is isomorphic to our baseline model, with education groups replacing nativity groups. Hence, our baseline results on the impact of changes in the relative supply of immigrant to native workers translate directly into results on changes in the relative supply of low to high education workers. However, we remain interested in the impact of immigration.

The resulting comparative statics on immigration are very similar to those in our baseline model. Specifically, consider changes in the supply of native or immigrant workers by education, n^{De}_r and n^{Ie}_r, which result in changes in aggregate supplies of workers by education given by

$$n^e_r = \frac{N^{eD}_r Z^{eD}_r n^{eD}_r + N^{eI}_r Z^{eI}_r n^{eI}_r}{N^{eD}_r Z^{eD}_r + N^{eI}_r Z^{eI}_r}.$$

Define the cost share of unskilled workers in occupation o as $S^U_{ro} = W^U_{ro}L^U_{ro}/\left(W^U_{ro}L^U_{ro} + W^S_{ro}L^S_{ro}\right)$. Changes in allocations and occupation wages for any are

$$n^{ek}_{ro} - n^{ek}_{ro'} = \frac{\left(\epsilon_r - \rho\right)\left(\theta + 1\right)}{\epsilon_r + \theta}\tilde{w}_r\left(S^U_{ro} - S^U_{ro'}\right)$$

and

$$w^{ek}_{ro} - w^{ek}_{ro'} = \frac{\epsilon_r - \rho}{\theta + \epsilon_r}\tilde{w}_r\left(S^U_{ro} - S^U_{ro'}\right),$$

where the log change in the wage per efficiency unit of skilled to unskilled workers is $\tilde{w}_r = \Psi^U_r\left(n^U_r - n^S_r\right)$ with $\Psi^U_r \geq 0$ defined analogously to Ψ^I_r in our baseline model. According to these results, an inflow of immigrants that increases the relative supply of unskilled workers, $n^U_r > n^S_r$ (which implies $\tilde{w}_r \geq 0$), decreases relative employment of type e, k workers and (for any finite value of θ) occupation wages in relatively unskill-intensive occupations (crowding out) if and only if $\epsilon_r < \rho$.

Part II

Empirical Appendix

C Summary statistics and occupation details

In this section we list the 15 occupations that are the most and least intensive in low-education, middle-education, and high-education immigrants, in Tables 10, 11, and 12. We provide summary statistics illustrating the distribution of immigrant shares of regional employment in 1980 and 2012 in Figure 9, and the distribution across CZs of the within-region (i.e., across occupations) coefficient of variation in immigrant cost shares for 1980 and 2012, where we display this variation separately for nontradable jobs in Figure 10 and for tradable jobs in Figure 11.

Most and least immigrant-intensive occupations (low-education immigrants)	
15 most immigrant-intensive occupations	15 least immigrant-intensive occupations
Agriculture	Police
Food Preparation and Service	Firefighting
Textile Machine Operator	Woodworking Machine Operators
Housekeeping	Social Scientists, Urban Planners and Architects
Arts and Athletes	Engineers
Personal Service	Extractive
Precision Production, Other	Electronic Repairer
Metal and Plastic Machine Operator	Guards
Precision Production, Food and Textile	Misc. Repairer
Metal and Plastic Processing Operator	Science Technicians
Office Machine Operator	Teachers, Non-postsecondary
Printing Machine Operators	Technical Support Staff
Health Technologists and Diagnosing	Managerial Related
Fabricators	Librarians and Curators
Cleaning and Building Service	Therapists

Table 10: The 15 most and least immigrant-intensive occupations, defined in terms of immigrant earning shares at the national level, for low-education immigrants (less than a high-school education)

Most and least immigrant-intensive occupations (medium-education immigrants)	
15 most immigrant-intensive occupations	15 least immigrant-intensive occupations
Housekeeping	Firefighting
Arts and Athletes	Extractive
Food Preparation and Service	Police
Teachers, Postsecondary	Lawyers and Judges
Textile Machine Operator	Woodworking Machine Operators
Personal Service	Transportation and Material Moving
Social Scientists, Urban Planners and Architects	Electronic Repairer
Precision Production, Other	Construction Trade
Health Assessment	Misc. Repairer
Health Service	Science Technicians
Office Machine Operator	Supervisors, Protective Services
Librarians and Curators	Machine Operator, Other
Engineers	Guards
Natural Science	Vehicle Mechanic
Therapists	Fabricators

Table 11: The 15 most and least immigrant-intensive occupations, defined in terms of immigrant earning shares at the national level, for medium-education immigrants (high school graduates and some college education)

Most and least immigrant-intensive occupations (high-education immigrants)	
15 most immigrant-intensive occupations	15 least immigrant-intensive occupations
Textile Machine Operator	Teachers, Non-postsecondary
Metal and Plastic Processing Operator	Lawyers and Judges
Health Diagnosing and Technologists	Firefighting
Housekeeping	Extractive
Precision Production, Other	Supervisors, Protective Services
Metal and Plastic Machine Operator	Police
Health Service	Woodworking Machine Operators
Office Machine Operator	Agriculture
Science Technicians	Therapists
Food Preparation and Service	Social, Recreation and Religious Workers
Engineers	Sales, All
Vehicle Mechanic	Construction Trade
Natural Science	Transportation and Material Moving
Teachers, Postsecondary	Executive, Administrative, and Managerial
Health Assessment	Librarians and Curators

Table 12: The 15 most and least immigrant-intensive occupations, defined in terms of immigrant earning shares at the national level, for high-education immigrants (a college degree or more)

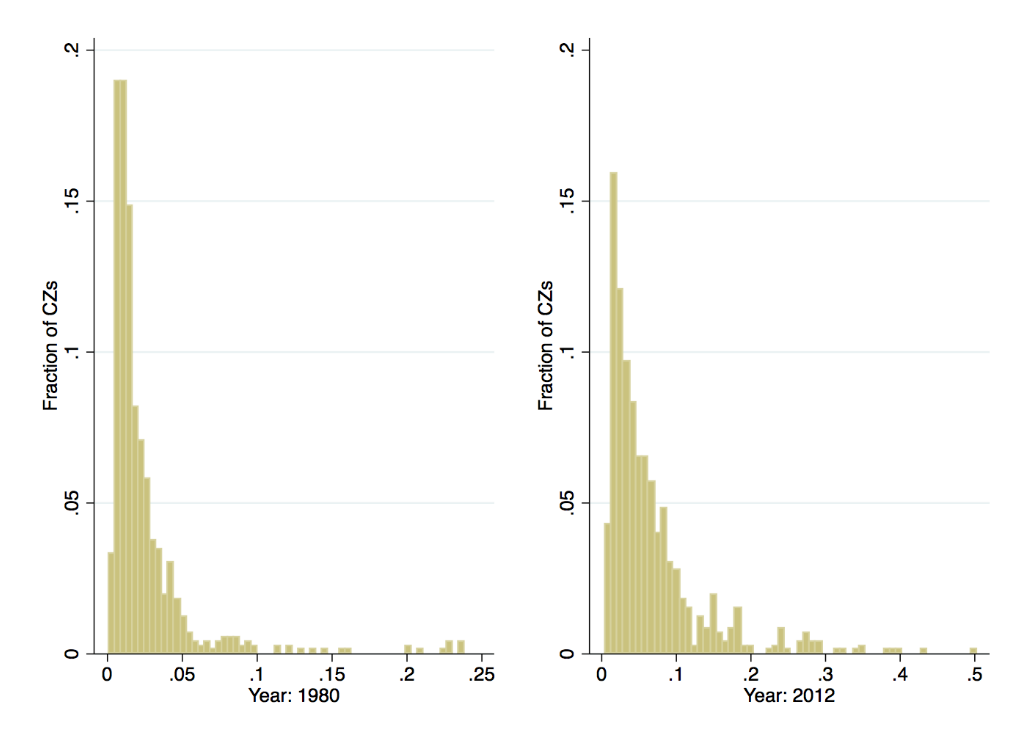

Figure 9: Share of Immigrant Workers in total Commuting Zone Population

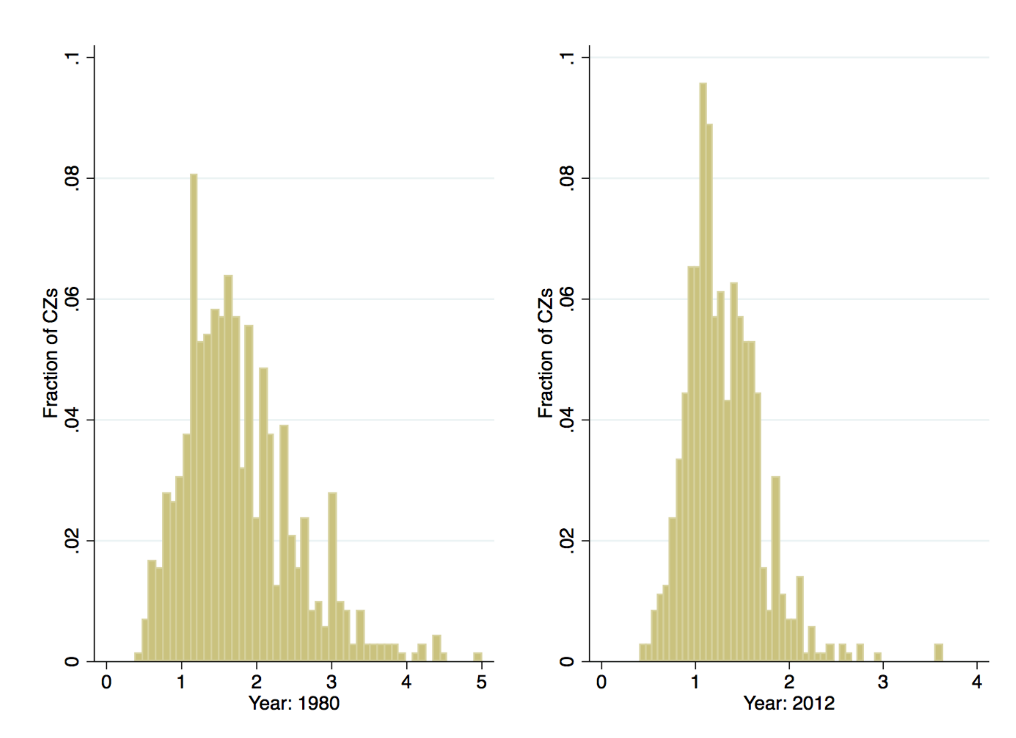

Figure 10: Coefficient of Variation of S^I_{ro} across Nontradable Occupations within CZ

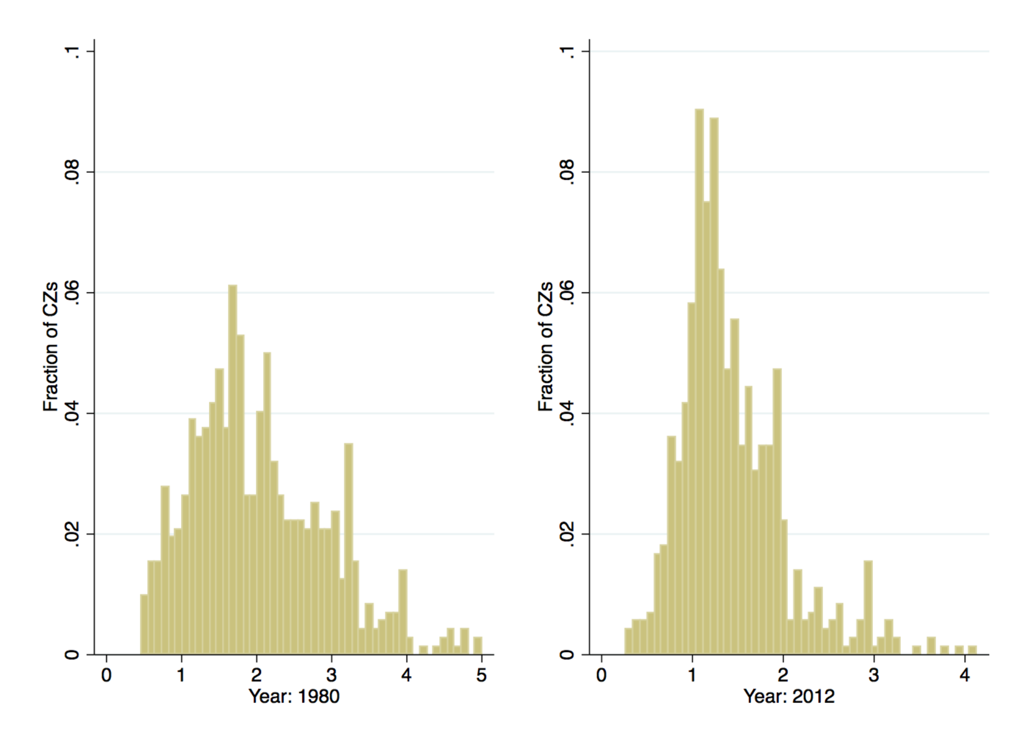

Figure 11: Coefficient of Variation of S^I_{ro} across Tradable Occupations within CZ

D Robustness

In this section we conduct sensitivity analysis of our baseline regressions, where we start by presenting results for the allocation regressions (baseline results are in Table 1) and follow these with results for the labor payment regressions (baseline results are in Table 2).

First, in Section D.1, we examine evidence of persistent confounding trends and check robustness to alternative sample restrictions. By regressing outcomes over 1950 to 1980 on the immigration shock over 1980 to 2012, we check whether our results may be contaminated by secular regional trends in labor demand. Sensitivity to such trends is a common critique of the Card approach. We then vary the time period for our analysis, by changing the start year or the end year, and the set of commuting zones included in the sample, by dropping the five largest immigrant-receiving CZs. These exercises allow us to check whether our results may be subject to confounding factors that are unique to our baseline 1980 to 2012 period and whether our results may be contaminated by the presence of these large CZs, shocks to which may affect national immigration patterns. We discuss results for these analyses in more detail below. In Section D.1, we also alter the start year and the end year of our analysis.

Second, in Section D.2, we consider alternative methods to construct our instrumental variables. We replace initial immigrant cost shares in (26), S^I_{reo}, with alternative cost shares constructed using data on regions with similar aggregate shares of immigrants (shares of foreigners out of total population) as region r, S^I_{-reo}. Specifically, we first calculate the share of immigrants in each region-education cell in 1980.[53] For a given region r, we calculate the absolute difference in the share of immigrants—for each education group—between r and all the other regions that are not in the same state as r. We then take the average value of the differences across the three education groups to obtain a single measure for each of the out-of-state regions. Finally, we select the top 50 regions with the smallest average difference in immigrant shares to construct the alternative immigrant cost share, S^I_{-reo}, using the employment-weighted average immigrant cost shares for these 50 regions. This check addresses concerns about the endogeneity of (initial) immigrant cost shares to (persistent) regional technology shocks In the second check, we replace our baseline cost shares measured in 1980 with alternative cost shares measured as the average of 1970 and 1980 values. This check addresses concerns about measurement error in cost shares. Because the results for these alternative instruments are substantially the same as those reported in Section 4.4 (both for the allocation regressions and for the labor payment regressions), we do not discuss them further below.

Third, in Section D.3, we vary the definition of tradable and nontradable occupations. The exercises we perform include (i) dropping the middle eight occupations in terms of tradability, leaving 21 tradable and nontradable occupations; and (ii) redefining tradable occupations as, instead of being those above the 50^{th} percentile of tradability, being those either above the 40^{th} percentile of tradability or above the 60^{th} percentile of tradability, where the first alternative creates 30 tradable and 20 nontradable occupations and the second creates 20 tradable and 30 nontradable occupations. Again, because these results are very similar to those reported in Section 4.4 (both for the allocation and the labor payment regressions), we do not discuss them in more detail below.

Fourth, in Section D.4, we present evidence to rule out alternative explanations for our empirical results, by dropping workers employed in the top quartile of occupations in terms of intensity in routine tasks or by dropping workers in occupations in the top quartile of occupations in terms of intensity in communication tasks. The first restriction addresses concerns about confounding factors related to pressures for automation in routine-intensive jobs, while the second addresses concerns about the insulation of native workers from immigration impacts in jobs requiring language-based interaction. These results are also very similar to those reported in Section 4.4 and we do not discuss them further.

Fifth, in Section D.5, we examine the sensitivity of the results to alternative aggregation schemes for the 50 occupations that we use in the analysis in order to verify that our results are not somehow conditioned by the particular scheme that we employ (from 69 occupations based on the sub-headings of the 1990 Census Occupational Classification System, up to 64 occupations that are consistent across time following David Dorn's categorization (http://www.ddorn.net/) and combining agriculture related occupations, and then up to 50 occupations to combine occupations that are similar in education profile and tradability but whose small size creates measurement problems, given the larger number of CZs in our data). When we either expand the set of occupations to 59—by breaking out all but the five occupations with the smallest cell sizes at the tenth percentile across CZs in the 1980 Census—or contract the set of occupations to 41—by dropping all of our baseline occupations

[53]The education groups are less than a high-school education, high-school graduates and those with some college education, and college graduates.

that are aggregates of David Dorn's categorization—we obtain results that are substantially the same as those in Section 4.4 and we do not elaborate on these findings.

Sixth, in Section D.6, we move from separating occupations according to their tradability to separating industries according to their tradability. Following convention, we define tradable industries to include goods producing sectors—agriculture, manufacturing, and mining—and nontradable industries to include services. Our discussion of these results is below.

D.1 Persistent regional trends and alternative periods

In Section D.1.1, we redefine the time period for the dependent variable to be changes over 1950 to 1980, rather than over 1980 to 2012, while keeping the regressors the same. In this manner, we check whether current immigration shocks relate to common changes in native allocations and total labor payments in both the current period and the pre-period, which if true could indicate that our results are the byproduct of persistent local labor demand shocks (that drive both immigration and changes in local labor market outcomes). Because region-occupation labor markets are subject to myriad shocks across space and time, we recognize that the immigration flows on which we focus may not be the most important shock affecting these units. Our intent in this section is, in the presence of many possible shocks, to verify that our results on native allocations and total labor payments are not the result of persistent regional labor demand shocks (such that our regressions would deliver qualitatively similar impact coefficients no matter if the time period for the immigration shock preceded or succeeded the change in outcomes to which they were matched).

Table 13 shows that the 2SLS-estimated impact of the current immigration shock on the allocation of low-education native workers within tradable occupations in the pre-period is negative and insignificant, whereas this impact is zero in our baseline results in Table 1. The analysis also yields a 2SLS coefficient on the immigration shock interacted with the nontradable dummy that is positive and insignificant, as opposed to negative and precisely estimated in Table 1. Turning to high-education workers, the 2SLS coefficient on the immigration shock in Table 13 is negative and significant, as opposed to zero in Table 1, indicating that future immigration shocks, x_{ro}, are higher in tradable occupations with lower past native employment growth; the 2SLS coefficient on the immigration shock interacted with the nontradable dummy reverses sign from Table 1 and is positive and significant. The null effects of immigration on native-born employment in tradable occupations and the crowding-out effect of immigration on native-born employment in nontradable occupations are thus not evident when we examine the correlation of current immigration shocks with past changes in native-born employment.

A potential explanation for the coefficient estimates in Table 1 having the opposite signs from those in Table 13—in which the native employment change is for 1950-80 and the immigration shock is for 1980-2012—is that the immigration shock for 1980-2012 is negatively correlated with the corresponding shock for 1950-80. We cannot test this hypothesis for the same reason that we cannot estimate the impact of immigration shocks on native labor market outcomes in the 1950-1980 period: we cannot construct the region-occupation immigration shock, x_{ro}, for the period 1950-1980. To construct x_{ro}, we require immigrant cost shares by education cell, S^I_{reo}. However, in the 1950 census, the vast majority of observations are missing either education or income information.

In Table 14, we repeat the analysis in Table 13, now defining the outcome variable to be the change in total labor payments by region and occupation over the 1950 to 1980 period. Whereas in our baseline Table 2 the immigration shock for 1980 to 2012 causes a contemporaneous increase in labor payments to more immigrant-intensive occupations within tradables and a null effect within nontradables, we see no such impact of the same shock on outcomes for labor payments in the pre-period. The 2SLS coefficients in Table 14 show a zero effect of the current-period immigration shock on the pre-period change in labor payments, either within nontradables or within tradables. We interpret the results in Tables 1 and 14 as evidence against the hypothesis that our results are the byproduct of persistent local labor demand shocks that are responsible both for immigration inflows to a region and for regional changes in occupational employment and labor payments.

In Section D.1.2, we alter the beginning year or the end year of our analysis. When altering the end year from 2012 to 2007 in Tables 15 and 16, such that the sample period now excludes the Great Recession and subsequent recovery, the results are qualitatively very similar to those in Section 4.4: immigration leads to stronger crowding out of natives within nontradables compared to within tradables and to a larger increase of total labor payments within tradables compared to within nontradables. When altering the beginning year of the analysis from 1980 to 1990 in Tables 17 and 18,[54] there is still clear evidence among high-education workers of stronger crowding out within nontradables relative to within tradables, but among low-education workers evidence of stronger crowding out within nontradables is weaker. While for the high-education group the 2SLS-estimated impact of immigration on native allocations within nontradables is negative and precisely estimated, for the low-education group it is close to zero and imprecise. The labor payments regressions, however, continue to show evidence of stronger output adjustment within tradables compared to within nontradables. Within tradables, immigration leads to a significant increase in labor payments in more immigrant-intensive occupations, whereas within nontradables this impact is much smaller and statistically indistinguishable from zero.

Finally, in Section D.1.3, we rerun our allocation and labor payment regressions, excluding from the sample the five largest immigrant-receiving commuting zones (Los Angeles/Riverside/Santa Ana, New York, Miami, Washington, DC, and Houston). These CZs are major gateway cities for immigrants. It is conceivable that productivity shocks to immigrant-intensive occupations in these localities could affect immigrant inflows in the aggregate for the U.S., which could create a source of simultaneity bias in the estimation. In Tables 19 and 20 we see, however, that our are results are materially unchanged by excluding these commuting zones.

[54] When calculating x^*_{ro}, allocations of immigrants by source country across regions, f^{Ic}_{re}, are calculated using 1980 data. When calculating x_{ro} and x^*_{ro}, immigration cost shares, S^I_{reo}, are calculated using 1990 data.

D.1.1 Persistent regional employment trends

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1950-1980

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	-.290**	-.405	-.460**	-.377*	-.785***	-.576***
	(.141)	(.327)	(.217)	(.204)	(.266)	(.187)
$\mathbb{I}_o(N)\,x_{ro}$	.314**	.184	.219	.985***	1.545***	1.162***
	(.124)	(.222)	(.142)	(.237)	(.270)	(.199)
Obs	21669	21669	21669	6420	6420	6420
R-sq	.717	.716	.718	.654	.653	.655
Wald Test: P-values	0.78	0.18	0.10	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		35.28			18.81	
$\mathbb{I}_o(N)\,x_{ro}$		20.31			53.08	

Notes: 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. Significance levels: * 10%, ** 5%, ***1%.

Table 13: Testing for persistent trends in region-occupation employment growth

Dependent variable: log change in labor payments in a region-occupation, 1950-1980

	(1)	(2)	(3)
	OLS	2SLS	RF
x_{ro}	-.010	-.005	-.179
	(.156)	(.365)	(.306)
$\mathbb{I}_o(N)\,x_{ro}$	.224	.025	.078
	(.177)	(.341)	(.267)
Obs	23321	23321	23321
R-sq	.808	.808	.808
Wald Test: P-values	0.01	0.91	0.45
A-P F-stats (first stage)			
x_{ro}		42.58	
$\mathbb{I}_o(N)\,x_{ro}$		23.04	

Notes: 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. Significance levels: * 10%, ** 5%, ***1%.

Table 14: Testing for persistent trends in region-occupation employment growth

D.1.2 Alternative time periods

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2007

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.018	-.139	-.125	-.015	-.024	-.0212
	(.076)	(.160)	(.106)	(.050)	(.076)	(.070)
$\mathbb{I}_o(N)\, x_{ro}$	-.410***	-.352***	-.296**	-.353***	-.413**	-.363**
	(.075)	(.115)	(.115)	(.121)	(.162)	(.138)
Obs	33291	33291	33291	25876	25876	25876
R-sq	.832	.832	.832	.693	.692	.693
Wald Test: P-values	0.00	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		120.63			67.24	
$\mathbb{I}_o(N)\, x_{ro}$		64.89			66.80	

Notes: 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. Significance levels: * 10%, ** 5%, ***1%.

Table 15: Alternative period: 1980-2007

Dependent variable: log change in labor payments in a region-occupation, 1980-2007

	(1)	(2)	(3)
	OLS	2SLS	RF
x_{ro}	.355***	.353**	.261**
	(.107)	(.139)	(.106)
$\mathbb{I}_o(N)\, x_{ro}$	-.392***	-.457***	-.345***
	(.124)	(.132)	(.083)
Obs	34738	34738	34738
R-sq	.888	.888	.887
Wald Test: P-values	0.51	0.12	0.12
A-P F-stats (first stage)			
x_{ro}		64.02	
$\mathbb{I}_o(N)\, x_{ro}$		104.47	

Notes: 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. Significance levels: * 10%, ** 5%, ***1%.

Table 16: Alternative period: 1980-2007

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1990-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.187**	.140	.191**	-.048	-.222*	-.146
	(.090)	(.103)	(.077)	(.089)	(.132)	(.119)
$\mathbb{I}_o(N)\,x_{ro}$	-.270**	.015	-.007	-.216**	-.339***	-.305***
	(.115)	(.374)	(.231)	(.105)	(.131)	(.112)
Obs	33957	33957	33957	28089	28089	28089
R-sq	.776	.776	.776	.601	.600	.602
Wald Test: P-values	0.25	0.60	0.36	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		64.13			56.23	
$\mathbb{I}_o(N)\,x_{ro}$		21.33			39.41	

Notes: To construct the Card instrument, we use the 1980 immigrant distribution by source region and education. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 17: Alternative period: 1990-2012

Dependent variable: log change in labor payments in a region-occupation, 1990-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.559***	.513***	.718***
	(.082)	(.130)	(.119)
$\mathbb{I}_o(N)\,x_{ro}$	-.464***	-.260*	-.557***
	(.091)	(.150)	(.095)
Obs	35127	35127	35127
R-sq	.869	.869	.870
Wald Test: P-values	0.08	0.17	0.02
A-P F-stats (first stage)			
x_{ro}		71.57	
$\mathbb{I}_o(N)\,x_{ro}$		24.01	

Notes: 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. Significance levels: * 10%, ** 5%, ***1%.

Table 18: Alternative period: 1990-2012

D.1.3 Dropping large commuting zones

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.088	.034	.025	.008	-.051	-.047
	(.053)	(.091)	(.073)	(.043)	(.072)	(.059)
$\mathbb{I}_o(N)\,x_{ro}$	-.272***	-.351***	-.339***	-.179*	-.225*	-.195
	(.085)	(.080)	(.093)	(.087)	(.129)	(.116)
Obs	33473	33473	33473	26405	26405	26405
R-sq	.827	.827	.827	.687	.687	.687
Wald Test: P-values	0.03	0.00	0.00	0.00	0.00	0.01
A-P F-stats (first stage)						
x_{ro}		29.86			22.79	
$\mathbb{I}_o(N)\,x_{ro}$		27.66			41.44	

Notes: Drop 5 largest immigrant-receiving CZs: LA/Riverside/Santa Ana, New York, Miami, Washington DC, Houston. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 19: Dropping top 5 immigrant-receiving commuting zones

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.284***	.155	.129
	(.074)	(.106)	(.100)
$\mathbb{I}_o(N)\, x_{ro}$	-.207**	-.189**	-.177*
	(.088)	(.096)	(.091)
Obs	34642	34642	34642
R-sq	.895	.895	.895
Wald Test: P-values	0.14	0.49	0.30
A-P F-stats (first stage)			
x_{ro}		40.76	
$\mathbb{I}_o(N)\, x_{ro}$		35.57	

Notes: Drop 5 largest immigrant-receiving CZs: LA/Riverside/Santa Ana, New York, Miami, Washington DC, Houston. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 20: Dropping top 5 immigrant-receiving commuting zones

D.2 Instrumentation

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.089*	.216	.126	.022	-.096	-.08
	(.049)	(.167)	(.101)	(.036)	(.126)	(.085)
$\mathbb{I}_o(N)\, x_{ro}$	-.303***	-.810***	-.524***	-.309***	-.992***	-.645***
	(.062)	(.241)	(.164)	(.097)	(.224)	(.170)
Obs	33723	33723	33723	26644	26644	26644
R-sq	0.84	0.83	0.84	0.70	0.69	0.70
Wald Test: P-values	0.00	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		54.62			46.42	
$\mathbb{I}_o(N)\, x_{ro}$		35.67			49.07	

Notes: S_{-reo} is constructed using 50 out-of-state CZs with share of immigrants most similar to r. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 21: Using S_{-reo} to calculate the instrument

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.089*	-.006	-.005	.022	-.068	-.033
	(.049)	(.095)	(.057)	(.036)	(.072)	(.047)
$\mathbb{I}_o(N)\, x_{ro}$	-.303***	-.290**	-.220**	-.309***	-.523***	-.227**
	(.062)	(.117)	(.084)	(.097)	(.181)	(.101)
Obs	33723	33723	33723	26644	26644	26644
R-sq	.836	.836	.836	.699	.697	.699
Wald Test: P-values	0.00	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		131.70			25.76	
$\mathbb{I}_o(N)\, x_{ro}$		45.28			47.09	

Notes: 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. Significance levels: * 10%, ** 5%, ***1%.

Table 22: Using the average values in 1970 and 1980 to construct immigrant share of labor payments S^I_{reo}

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1)	(2)	(3)
	OLS	2SLS	RF
x_{ro}	.392***	1.293***	.727***
	(.115)	(.208)	(.169)
$\mathbb{I}_o(N)\, x_{ro}$	-.351***	-1.212***	-.648***
	(.116)	(.204)	(.149)
Obs	34892	34892	34892
R-sq	0.90	0.89	0.90
Wald Test: P-values	0.38	0.40	0.31
A-P F-stats (first stage)			
x_{ro}		52.56	
$\mathbb{I}_o(N)\, x_{ro}$		46.25	

Notes: S_{-reo} is constructed using 50 out-of-state CZs with share of immigrants most similar to r. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 23: Using S_{-reo} to calculate the instrument

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.392***	.593**	.352**
	(.115)	(.236)	(.154)
$\mathbb{I}_o(N)\,x_{ro}$	-.351***	-.635***	-.374***
	(.116)	(.225)	(.138)
Obs	34892	34892	34892
R-sq	.897	.897	.897
Wald Test: P-values	0.38	0.58	0.68
A-P F-stats (first stage)			
x_{ro}		175.66	
$\mathbb{I}_o(N)\,x_{ro}$		57.73	

Notes: 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. Significance levels: * 10%, ** 5%, ***1%.

Table 24: Using the average values in 1970 and 1980 to construct immigrant share of labor payments S^I_{reo}

D.3 The cutoff between tradable and nontradable occupations

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.238***	.152*	.116*	.087*	.036	.046
	(.059)	(.085)	(.067)	(.051)	(.087)	(.086)
$\mathbb{I}_o(N)\, x_{ro}$	-.439***	-.477***	-.391***	-.396***	-.487***	-.420***
	(.096)	(.095)	(.087)	(.110)	(.131)	(.116)
Obs	28035	28035	28035	21262	21262	21262
R-sq	.827	.827	.827	.692	.691	.692
Wald Test: P-values	0.02	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		74.19			63.81	
$\mathbb{I}_o(N)\, x_{ro}$		56.58			46.09	

Notes: Include the top 21 most tradable (and least tradable) occupations, dropping 8 middle occupations. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 25: Alternative tradability cutoff (21T and 21N)

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.035	-.089	-.041	-.011	-.065	-.058
	(.051)	(.086)	(.057)	(.031)	(.055)	(.048)
$\mathbb{I}_o(N)\,x_{ro}$	-.226***	-.248***	-.243***	-.303***	-.383***	-.301***
	(.073)	(.082)	(.075)	(.093)	(.116)	(.093)
Obs	33723	33723	33723	26644	26644	26644
R-sq	.832	.832	.832	.700	.700	.700
Wald Test: P-values	0.02	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		126.73			52.29	
$\mathbb{I}_o(N)\,x_{ro}$		55.62			47.39	

Notes: Separate 50 occupations into 30 tradable and 20 nontradable occupations. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 26: Alternative tradability cutoff (30T and 20N)

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1)	(2) Low Ed	(3)	(1)	(2) High Ed	(3)
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.232***	.144*	.114*	.087	.030	.0481
	(.059)	(.085)	(.066)	(.057)	(.094)	(.091)
$\mathbb{I}_o(N)\,x_{ro}$	-.393***	-.290***	-.228***	-.318***	-.353***	-.322***
	(.084)	(.083)	(.073)	(.094)	(.118)	(.113)
Obs	33723	33723	33723	26644	26644	26644
R-sq	.840	.84	.839	.698	.698	.698
Wald Test: P-values	0.01	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		72.34			71.89	
$\mathbb{I}_o(N)\,x_{ro}$		53.20			42.21	

Notes: Separate 50 occupations into 20 tradable and 30 nontradable occupations. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 27: Alternative tradability cutoff (20T and 30N)

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.590***	.647***	.507***
	(.128)	(.158)	(.111)
$\mathbb{I}_o(N)\,x_{ro}$	-.553***	-.691***	-.529***
	(.133)	(.132)	(.084)
Obs	29122	29122	29122
R-sq	.893	.893	.892
Wald Test: P-values	0.41	0.63	0.76
A-P F-stats (first stage)			
x_{ro}		50.58	
$\mathbb{I}_o(N)\,x_{ro}$		88.03	

Notes: Include the top 21 most tradable (and least tradable) occupations, dropping 8 middle occupations. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 28: Alternative tradability cutoff (21T and 21N)

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.349***	.288*	.269**
	(.104)	(.154)	(.127)
$\mathbb{I}_o(N)\, x_{ro}$	-.323***	-.341***	-.297***
	(.093)	(.083)	(.068)
Obs	34892	34892	34892
R-sq	.895	.895	.895
Wald Test: P-values	0.52	0.57	0.70
A-P F-stats (first stage)			
x_{ro}		81.81	
$\mathbb{I}_o(N)\, x_{ro}$		89.99	

Notes: Separate 50 occupations into 30 tradable and 20 nontradable occupations. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 29: Alternative tradability cutoff (30T and 20N)

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.605***	.677***	.522***
	(.132)	(.163)	(.114)
$\mathbb{I}_o(N)\, x_{ro}$	-.563***	-.680***	-.503***
	(.124)	(.122)	(.085)
Obs	34892	34892	34892
R-sq	.902	.901	.901
Wald Test: P-values	0.31	0.97	0.78
A-P F-stats (first stage)			
x_{ro}		55.32	
$\mathbb{I}_o(N)\, x_{ro}$		65.89	

Notes: Separate 50 occupations into 20 tradable and 30 nontradable occupations. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 30: Alternative tradability cutoff (20T and 30N)

D.4 Alternative mechanisms

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1)	(2) Low Ed	(3)	(1)	(2) High Ed	(3)
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.083*	.137**	.110	-.052	-.075	-.052
	(.044)	(.066)	(.067)	(.036)	(.061)	(.057)
$\mathbb{I}_o(N)\, x_{ro}$	-.304***	-.435***	-.359***	-.221**	-.326**	-.290**
	(.097)	(.083)	(.064)	(.092)	(.128)	(.115)
Obs	32997	32997	32997	24693	24693	24693
R-sq	.822	.822	.822	.706	.706	.707
Wald Test: P-values	0.01	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		82.28			43.91	
$\mathbb{I}_o(N)\, x_{ro}$		63.32			56.13	

Notes: Drop workers in routine-intensive occupations, defined as occupations that have a routine intensity (Autor and Dorn, 2013) higher than 75% of all workers. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 31: Dropping workers employed in routine-intensive occupations

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.328**	.385*	.346*
	(.134)	(.217)	(.175)
$\mathbb{I}_o(N)\, x_{ro}$	-.290**	-.429**	-.377***
	(.138)	(.176)	(.126)
Obs	33817	33817	33817
R-sq	.890	.890	.891
Wald Test: P-values	0.46	0.69	0.70
A-P F-stats (first stage)			
x_{ro}		63.20	
$\mathbb{I}_o(N)\, x_{ro}$		86.31	

Notes: Drop workers in routine-intensive occupations, defined as occupations that have a routine intensity (Autor and Dorn, 2013) higher than 75% of all workers. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 32: Dropping workers employed in routine-intensive occupations

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012						
	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.112*	-.047	-.026	-.015	-.136	-.116
	(.066)	(.116)	(.082)	(.054)	(.088)	(.085)
$\mathbb{I}_o(N)\, x_{ro}$	-.296***	-.211*	-.200*	-.234***	-.342***	-.278***
	(.074)	(.115)	(.103)	(.079)	(.120)	(.010)
Obs	31172	31172	31172	22972	22972	22972
R-sq	.839	.838	.839	.672	.671	.672
Wald Test: P-values	0.01	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		63.60			120.90	
$\mathbb{I}_o(N)\, x_{ro}$		95.72			101.70	

Notes: Drop workers in communication-intensive occupations, defined as occupations that have a communication intensity index (Peri and Sparber, 2009) higher than 75% of all workers. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 33: Dropping workers employed in communication-intensive occupations

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.444***	.408**	.378***
	(.119)	(.168)	(.135)
$\mathbb{I}_o(N)\,x_{ro}$	-.364***	-.326**	-.311**
	(.126)	(.160)	(.127)
Obs	31974	31974	31974
R-sq	.883	.883	.882
Wald Test: P-values	0.12	0.33	0.25
A-P F-stats (first stage)			
x_{ro}		66.80	
$\mathbb{I}_o(N)\,x_{ro}$		113.15	

Notes: Drop workers in communication-intensive occupations, defined as occupations that have a communication intensity index (Peri and Sparber, 2009) higher than 75% of all workers. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 34: Dropping workers employed in communication-intensive occupations

D.5 Alternative occupation aggregations

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.106**	.019	.018	-.024	-.088	-.071
	(.047)	(.089)	(.063)	(.032)	(.06)	(.052)
$\mathbb{I}_o(N)\,x_{ro}$	-.244***	-.245***	-.208***	-.264***	-.336***	-.278***
	(.066)	(.073)	(.066)	(.088)	(.111)	(.098)
Obs	40218	40218	40218	31069	31069	31069
R-sq	.825	.825	.825	.671	.670	.671
Wald Test: P-values	0.06	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		90.36			39.79	
$\mathbb{I}_o(N)\,x_{ro}$		78.33			100.35	

Notes: From 50 occupations, we disaggregate all but the five occupations that have the smallest cell sizes at the tenth percentile across CZs in the 1980 Census. These are Social Scientists and Urban Planners, Health Diagnosing, Adjusters and Investigators, Precision Textile, and Precision Wood. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 35: Disaggregating to 59 occupations

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.375***	.359**	.301**
	(.103)	(.147)	(.118)
$\mathbb{I}_o(N)\, x_{ro}$	-.302***	-.346***	-.285***
	(.108)	(.119)	(.090)
Obs	41390	41390	41390
R-sq	.889	.889	.888
Wald Test: P-values	0.08	0.85	0.75
A-P F-stats (first stage)			
x_{ro}		58.65	
$\mathbb{I}_o(N)\, x_{ro}$		99.70	

Notes: From 50 occupations, we disaggregate all but the five occupations that have the smallest cell sizes at the tenth percentile across CZs in the 1980 Census. These are Social Scientists and Urban Planners, Health Diagnosing, Adjusters and Investigators, Precision Textile, and Precision Wood. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 36: Disaggregating to 59 occupations

Dependent variable: log change in the employment of domestic workers in a region-occupation, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.213***	.087	.095	-.050	-.143	-.113
	(.079)	(.124)	(.116)	(.053)	(.092)	(.086)
$\mathbb{I}_o\left(N\right)x_{ro}$	-.394***	-.436***	-.391***	-.238***	-.275**	-.230*
	(.120)	(.127)	(.111)	(.090)	(.135)	(.125)
Obs	27475	27475	27475	20565	20565	20565
R-sq	.837	.837	.837	.712	.712	.712
Wald Test: P-values	0.04	0.00	0.00	0.00	0.00	0.00
A-P F-stats (first stage)						
x_{ro}		96.12			53.21	
$\mathbb{I}_o\left(N\right)x_{ro}$		70.21			94.91	

Notes: Drop all nine baseline occupations that are aggregates of David Dorn's categorization. Occupations dropped are Social Scientists, Urban Planners and Architects, Health Technologists and Diagnosing, Secretaries and Office Clerks, Records Processing, Misc. Administrative Support, Precision Food and Textile, Precision Other, Production Other, and Transportation and Material Moving. 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 $\mathbb{I}_o\left(N\right)x_{ro}$ is zero. We report Angrist-Pischke (AP) F-statistics for the first stage regressions. Significance levels: * 10%, ** 5%, ***1%.

Table 37: 41 occupations

Dependent variable: log change in labor payments in a region-occupation, 1980-2012

	(1) OLS	(2) 2SLS	(3) RF
x_{ro}	.530***	.547**	.449**
	(.163)	(.260)	(.188)
$\mathbb{I}_o(N)\,x_{ro}$	-.500***	-.606***	-.487***
	(.153)	(.191)	(.130)
Obs	28447	28447	28447
R-sq	.894	.894	.894
Wald Test: P-values	0.42	0.49	0.57
A-P F-stats (first stage)			
x_{ro}		81.08	
$\mathbb{I}_o(N)\,x_{ro}$		93.18	

Notes: Drop all nine baseline occupations that are aggregates of David Dorn's categorization. Occupations dropped are Social Scientists, Urban Planners and Architects, Health Technologists and Diagnosing, Secretaries and Office Clerks, Records Processing, Misc. Administrative Support, Precision Food and Textile, Precision Other, Production Other, and Transportation and Material Moving. 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. Significance levels: * 10%, ** 5%, ***1%.

Table 38: 41 occupations

D.6 Industry analysis

In this section, we report results for our labor allocation and labor payments regressions applied to industries rather than to occupations. We categorize all goods-producing industries—agriculture, mining, and manufacturing—as tradable and all service-producing industries as non-tradable. In Table 39, we list the 34 industries considered in this analysis, based on the sub-headings of the 1990 Census Industry Classification System. This alternative industry-based classification has the advantage of using categories that are familiar to trade economists in terms of the activities that are conventionally deemed tradable or nontradable. It has the disadvantage, however, of excluding from tradables portions of the service sector in which activity appears to be highly traded. Because these activities are often occupation specific (e.g., programming software, managing businesses, designing buildings), we use an occupation-based measure in our baseline analysis.[55]

[55] Alternative categorizations of industry tradability include Mian and Sufi (2014), who measure tradability according to geographic Herfindahl-Hirschman Indexes, following the logic that more geographically concentrated industries are likely to be more tradable. Relative to our approach, HHIs have the appealing property of designating some services as tradable (e.g., finance and insurance), but the unappealing property of designating some obviously tradable goods as nontradable (e.g., agriculture, food products, lumber, metal products, mining, non-metallic minerals, paper products, plastics). Nevertheless, we find qualitatively similar results using our designation of industry tradability and in unreported results in which we define tradable (nontradable) industries as those with above (below) median HHIs.

Tradable and non-tradable industries (goods vs. services)$^{+}$	
Tradable industries	Non-tradable industries
Agriculture, forestry and fisheries	Retail trade
Mining	Personal services
Transportation equipment	Professional and related services
Professional and photographic equipment and watches	Transportation
Petroleum and coal products	Wholesale trade, durables
Toys, amusement, and sporting goods	Wholesale trade, nondurables
Printing, publishing and allied industries	Communications
Apparel and other finished textile products	Business and repair services
Manufacturing industries, others	Finance, insurance, and real estate
Machinery and computing equipment	Entertainment and recreation services
Rubber and miscellaneous plastics products	Utilities and sanitary services
Textile mill products	
Chemicals and allied products	
Leather and leather products	
Electrical machinery, equipment, and supplies	
Furniture and fixtures	
Tobacco manufactures	
Food and kindred products	
Lumber, woods products (except furniture)	
Paper and allied products	
Stone, clay, glass and concrete products	

Table 39: Tradable and non-tradable industries

Notes: $^{+}$: We group all goods, i.e. agriculture, mining and manufacturing, as tradable industries; and all services as non-tradable industries. We drop the construction industry for this analysis.

When we revisit our baseline analyses using industries, Table 40 shows that our allocation regressions are largely robust to using industries in place of occupations, and Table 41 shows that our labor payments regressions are fully robust to replacing occupations with industries. In the allocation regressions, the impact of the immigration shock on tradables is positive but imprecisely estimated, consistent with the absence of crowding in or crowding out within tradables in our baseline analysis. Of course, the elasticity of substitution between natives and immigrants within industries need not take the same value as its counterpart within occupations. Hence, the key prediction is for the interaction between the immigration shock and the nontradable dummy. This interaction term is negative and precisely estimated in all regressions for high-education workers; while it is negative in all regressions for low-education workers, it is only significant in the OLS specification. The results for our labor payments regression applied to industries are very similar to our baseline results. There is a positive and significant effect of immigration on labor payments for more immigrant-intensive industries within tradables and an effect within nontradables that is indistinguishable from zero.

Dependent variable: log change in the employment of domestic workers in a region-industry, 1980-2012

	(1)	(2)	(3)	(1)	(2)	(3)
		Low Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.244**	.571	.609	.430***	.540	.576*
	(.117)	(.439)	(.410)	(.131)	(.395)	(.293)
$\mathbb{I}_o(N)\,x_{ro}$	-.347**	-.486	-.474	-.725***	-.963**	-.887***
	(.137)	(.418)	(.353)	(.180)	(.489)	(.323)
Obs	22067	22067	22067	17202	17202	17202
R-sq	.827	.826	.828	.723	.723	.723
Wald Test: P-values	0.35	0.40	0.24	0.01	0.01	0.01
A-P F-stats (first stage)						
x_{ro}		50.00			100.92	
$\mathbb{I}_o(N)\,x_{ro}$		27.70			15.06	

Notes: Robust standard errors (in parentheses) are clustered on state. Models are weighted by start of period CZ-industry-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. Significance levels: * 10%, ** 5%, ***1%.

Table 40: Domestic allocation of workers across industries using goods-producing industries as tradable and service industries as non-tradable

Dependent variable: log change in labor payments in a region-industry, 1980-2012

	(1)	(2)	(3)
	OLS	2SLS	RF
x_{ro}	.444**	.960**	.733**
	(.166)	(.464)	(.313)
$\mathbb{I}_o(N)\,x_{ro}$	-.474**	-.847*	-.576*
	(.180)	(.512)	(.319)
Obs	22014	22014	22014
R-sq	.838	.836	.839
Wald Test: P-values	0.80	0.36	0.16
A-P F-stats (first stage)			
x_{ro}		52.84	
$\mathbb{I}_o(N)\,x_{ro}$		31.93	

Notes: Robust standard errors (in parentheses) are clustered on state. Models are weighted by start of period CZ-industry 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. Significance levels: * 10%, ** 5%, ***1%.

Table 41: Labor payments across industries using goods-producing industries as tradable and service industries as non-tradable

Part III
Quantitative Model Appendix

E Additional details of the extended model

In this section we present additional details of the extended model.

E.1 Measuring CZ-level export shares in tradables in the data

To measure CZ-level trade shares within tradables, we use public tables from the 2007 Commodity Flow Survey (CFS), which include region-to-region trade flows. For each of the 49 CFS origin areas (henceforth CFS regions), this data includes the value of shipments that originate from the CFS region and are destined to all U.S. destinations as well as the value of shipments that originate from and are destined for the same CFS region. For each region we construct the own sales share, S_r^{own}, as the value of shipments that both originate from and are destined for the CFS region relative to the value of shipments that originate from the CFS region and are destined for all U.S. destinations. To concord these CFS regions to our CZs (of which there are 722), we take the following steps. We overlay 2007 CFS regions with 1990 CZ boundaries using QGIS. For each CFS region, we calculate the area of intersection and the area of the union between the boundaries of the CFS region and the nearest CZ. We consider a CFS region to be matched with a CZ if the area of the *intersection* of the two boundaries is at least 70% of the area of the *union* of the two boundaries. Using this procedure, we obtain 23 CFS regions that each match with one of our CZs, listed in Table 42. We then construct the weighted average across these 23 CFS regions of the own sales share, weighing by the CFS region's total sales destined for all U.S. destinations, which is equal to roughly 40%.

CFS Area	Matched CZ code
Austin-Round Rock	31201
Baltimore-Towson	11302
Baton Rouge-Pierre Part	03500
Beaumont-Port Arthur	32100
Charleston-North Charleston	08202
Cleveland-Akron-Elyria	15200
Dayton-Springfield-Greenville	12501
Detroit-Warren-Flint	11600
Hartford-West Hartford-Willimantic	20901
Jacksonville	07600
Lake Charles-Jennings	03700
Laredo	31503
Los Angeles-Long Beach-Riverside	38300
Mobile-Daphne-Fairhope	11001
New Orleans-Metairie-Bogalusa	03300
Phoenix-Mesa-Scottsdale	35001
Pittsburgh-New Castle	16300
Raleigh-Durham-Cary	01701
San Antonio	31301
San Diego-Carlsbad-San Marcos	38000
Seattle-Tacoma-Olympia	39400
Tampa-St. Petersburg-Clearwater,	06700
Tucson	35100

Table 42: List of matched CFS regions and CZs

E.2 Aggregate elasticity of substitution between natives and immigrants

Because it is not a structural parameter in our model, in our parameterization we do not target the elasticity of substitution between domestic and immigrant workers with similar education levels at the national level. Ottaviano and Peri, 2012 (henceforth OP) have estimated this parameter, σ_N, using annual variation in factor supplies and average wages at the national level. In our notation, their estimating equation is

$$\ln \frac{Wage_{et}^{I}}{Wage_{et}^{D}} = \mathbb{I}_e + \mathbb{I}_t + \frac{1}{\sigma_N} \ln \frac{N_{et}^{D}}{N_{et}^{I}} + \iota_{et}$$

where $\mathbb{I}_e$ and $\mathbb{I}_t$ are skill-group (OP leverages variation across education-experience cells whereas we only have education cells in our model) and time effects. Differencing between two time periods, the previous regression becomes

$$wage_{et}^{I} - wage_{et}^{D} = \tilde{\mathbb{I}}_t + \frac{1}{\sigma_N} \left(n_{et}^{D} - n_{et}^{I} \right) + \tilde{\iota}_{et}. \tag{61}$$

To estimate this regression in data generated by our model, we take the following steps. First, starting the 2012 equilibrium, we feed into our quantitative model the change in national supplies of immigrants within each education group and source country that we consider in our two counterfactual exercises in Section 6, $\{n_e^{Ic}\}_{e,c}$, and solve the model's general equilibrium. Second, since we have three immigrant and only two native education groups, within each region we aggregate wage changes across low- (high school dropout) and medium- (high school graduate and some college) education immigrants to construct changes in average wages for immigrants without a college degree by region. Similarly, since we have many regions, we aggregate wage changes across CZs to construct national average wage changes for immigrants with and without college degrees and for natives with and without college degrees. Finally, the parameters $\tilde{\mathbb{I}}_t$ and σ_N are then exactly identified in equation (61), where $\sigma_N = \left(n_{Ht}^D - n_{Ht}^I - n_{Lt}^D + n_{Lt}^I\right) / \left(wage_{Ht}^I - wage_{Ht}^D - wage_{Lt}^I + wage_{Lt}^D\right)$. We recover a value of σ_N equal to 6.9 in the first and 8.6 in the second counterfactual exercise in Section 6. These estimates of σ_N are higher than the structural elasticity of substitution within occupations, $\rho = 4.6$.

F Immigrant occupation reallocation

In Section 4 we analyze empirically how native workers reallocate across occupations in response to immigration. In this section, we analyze the reallocation of immigrant workers, both in the extended model and in the data. We show that the predictions of our extended model are qualitatively consistent with the data for all immigrant education groups: both in the model and in the data there is stronger immigrant crowding out within nontradable occupations than within tradable occupations, immigrants are crowded out of immigrant-intensive nontradable occupations, and (unlike natives) immigrants are also weakly crowded out of immigrant-intensive tradable occupations.[56]

At our baseline parameterization, we now show that our model predicts that a foreign labor inflow generates crowding out of immigrants within tradable and stronger crowding out of immigrants in nontradable occupations (i.e., in response to an immigrant inflow, the shares of immigrants employed in immigrant-intensive occupations decline within the tradable and the nontradable groups, though more within the former than within the latter). We then show that we obtain qualitatively similar results empirically.

First using model-generated data from our extended model and then using Census/ACS data, we estimate separately for the three immigrant education groups the regression,

$$n_{ro}^I = \alpha_{rg}^I + \alpha_o^I + \beta^I x_{ro} + \beta_N^I \mathbb{I}_o (N) x_{ro} + \nu_{ro}^I. \tag{62}$$

Table 43 reports three sets of results for immigrant education groups when estimating regression (62) using model-generated data. First, we find more crowding out within nontradable than within tradable occupations, $\beta_N^I < 0$, consistent with our empirical results for natives. Second, we find crowding out within nontradable occupations, $\beta^I + \beta_N^I < 0$, again consistent

[56] We emphasize that crowding out does not imply that in response to an increase in the number of immigrants, the employment *level* of immigrants in immigrant-intensive occupations falls, but instead that the *share* of immigrant employment in immigrant intensive occupations falls (across either T or N jobs).

with our empirical results for natives. Finally, for two of the three education groups we find crowding out within tradable occupations, $\beta^I < 0$, unlike our empirical results for natives. While two of these three results are similar to our empirical (and quantitative) results for natives, the third is not.

	Low Ed	Med Ed	High Ed
x_{ro}	-0.044	0.008	-0.049
$\mathbb{I}_o(N)x_{ro}$	-0.202	-0.320	-0.247
R-sq	1.00	0.99	0.99

Table 43: Allocation for immigrant workers across occupations in model-generated data

Turning to Census/ACS data, Table 44 reports a corresponding set of estimation results for the three immigrant education groups. First, we find more crowding out of immigrant workers within nontradable than within tradable occupations, $\beta_N^I < 0$, for all education groups and across all empirical specifications, consistent with our quantitative results in Table 43. Second, we find crowding out within nontradable occupations, $\beta^I + \beta_N^I < 0$, for all immigrant education groups and across all empirical specifications, again consistent with our quantitative results in Table 43. Finally, we find some evidence of crowding out within tradable occupations, consistent with our quantitative results in Table 43, although these results are somewhat less clear cut than in the model-generated data. Specifically, within tradables we obtain statistically significant crowding out for high-education immigrants but obtain imprecise estimates for both low- and medium-education immigrations (with one positive and the other negative). In summary, our model's predictions for immigrant allocations—reported in Table 43—are qualitatively consistent with immigrant allocations observed in the data—reported in Table 44.

Dependent variable: log change in the employment of immigrant workers in a region-occupation, 1980-2012

	(1a)	(2a)	(3a)	(1b)	(2b)	(3b)	(1c)	(2c)	(3c)
		Low Ed			Med Ed			High Ed	
	OLS	2SLS	RF	OLS	2SLS	RF	OLS	2SLS	RF
x_{ro}	.335	.652	.183	-.213	-.376	-.255	-.825***	-1.391***	-.962***
	(.289)	(.611)	(.331)	(.193)	(.309)	(.193)	(.172)	(.266)	(.198)
$\mathbb{I}_o(N)\,x_{ro}$	-1.425***	-2.044**	-1.379***	-.894***	-1.208***	-.850***	-.472***	-.696**	-.404**
	(.399)	(.847)	(.377)	(.232)	(.353)	(.133)	(.174)	(.289)	(.180)
Obs	5042	5042	5042	13043	13043	13043	6551	6551	6551
R-sq	.798	.797	.799	.729	.728	.73	.658	.649	.662
Wald Test: P-values	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AP F-stats (first stage)									
x_{ro}		60.90			69.11			77.62	
$\mathbb{I}_o(N)\,x_{ro}$		289.00			86.49			29.26	

Notes: The table reports estimates of $n_{ro}^I = \alpha_{rg}^I + \alpha_o^I + \beta^I x_{ro} + \beta_N^I \mathbb{I}_o(N)\,x_{ro} + v_{ro}^I$ separately for each education group. Robust standard errors (in parentheses) are clustered on state. Models are weighted by start of period CZ-occupation-education group foreigh-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. Significance levels: * 10%, ** 5%, ***1%.

Table 44: Allocation for immigrant workers across occupations

Finally, we remark that while our empirical results for immigrant allocations are consistent with our model-based predictions, it may appear puzzling that at our baseline parameter values our model predicts crowding out for immigrants within tradables ($\beta^I < 0$) but neither crowding in nor out for natives within tradables ($\beta^D \approx 0$). How could immigration lead to more crowding out among immigrants than among natives within tradables? To be sure, the divergence between native and immigrant reallocations within tradable jobs is inconsistent with the analytic results for our model in Section 3, derived under the assumption that education cells do not differ in their relative productivities across occupations, in which case the impact parameter that indicates crowding out (in), $\beta^k \equiv \frac{(\epsilon_{rg}-\rho)(\theta+1)}{\epsilon_{rg}+\theta}\Phi_r^I$, is common across natives and immigrants. In subsection A.5, we provide an analytic result that suggests why divergence in results on crowding out for immigrants and natives becomes possible once occupation comparative advantage differs between education groups. We show in a special case in which $\epsilon_{rT} = \rho$ (i.e., the output price elasticity in tradables equals the immigrant-native substitution elasticity) that an influx of immigrants will induce neither crowding in nor crowding out of natives (consistent with our results with only one education group) but that it will induce crowding out for immigrants. Specifically, when $\epsilon_{rT} = \rho$, our model's prediction for reallocation for group $k = D, I$ into (or out of) occupation o in region r contains an additional term, which is a linear function of $\sum_e \frac{L_{reo}^k}{L_{ro}^k}\left(\theta wage_{re}^k - n_{re}^k\right)$. Because changes in native average wages, $wage_{re}^D$, and native supplies, n_{re}^D, at the region-education level do not vary much across regions with an immigrant influx, this term is small for natives. By contrast, this term is larger for immigrants since variation in $wage_{re}^I$ and n_{re}^I across regions is larger. The presence of this additional term for immigrants (which is closer to zero for natives) allows crowding out effects for natives and immigrants within tradables to be dissimilar. Note that as long as our Card instrument is valid, the presence of this additional term in the allocation regression does not complicate estimation because this regression is reduced form. This reduced-form immigrant allocation regression provides useful identified moments that we do not target and with which our model is qualitatively consistent, as we show in Tables 43 and 44.

G Labor allocation regression using model-generated data

Figure 12 displays the results of estimating equation (24) using model-generated data. The plots show the sensitivity of estimated values of β^D and β_N^D to varying the value of η. See Section 5.2 for further details on the calibration that produces these data.

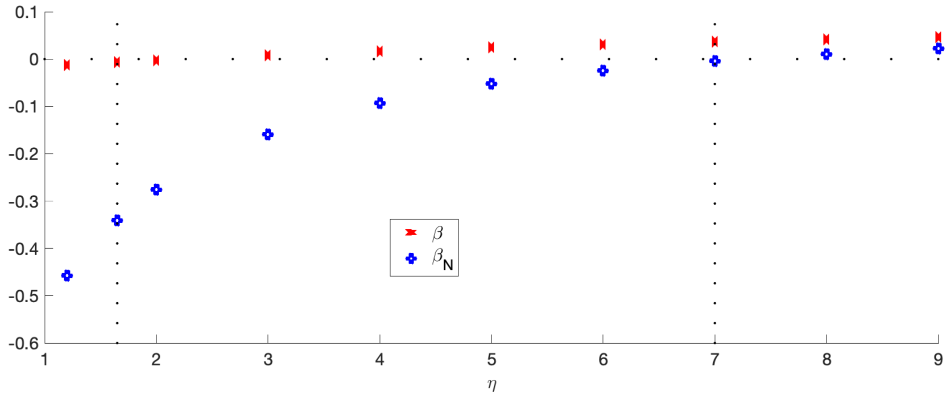

Figure 12: Estimates from allocation regression (model generated data)

Figure varies η from 1.2 to 9, holding all other parameters at their baseline levels. The vertical lines represent the baseline value of $\eta = 1.65$ and the value of $\alpha = 7$.

H Counterfactual exercises

The figures below depict 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, first, in Figure 13 for the counterfactual in which immigration from Latin America is reduced by 50%, and, second, in Figure 14 for the counterfactual in which immigration of high-skilled workers is doubled. See Section 6 for further details.

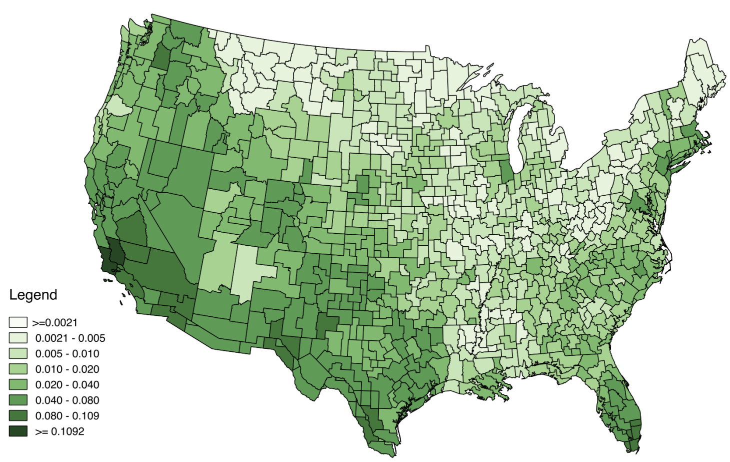

Figure 13: 50% reduction in Latin American Immigrants: highest minus lowest occupation wage increase for nontradable occupations across CZs

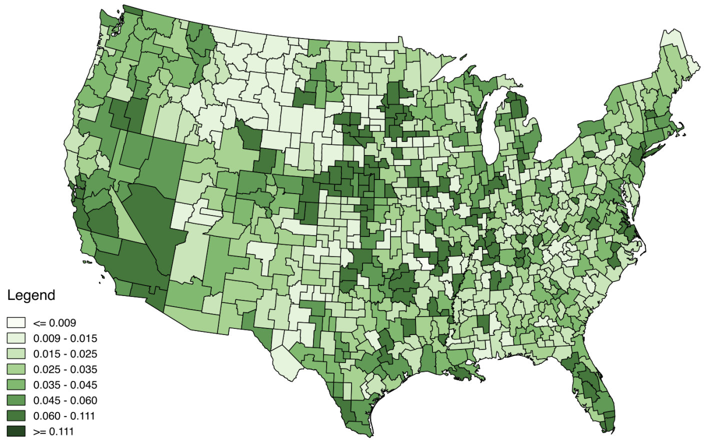

Figure 14: Doubling of high education immigrants: highest minus lowest occupation wage increase for nontradable occupations across CZs