



More hands, more power? Estimating the impact of immigration on output and technology choices using early 20th century US agriculture



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ABSTRACT

We study the impact of immigration-induced changes in labor supply within agriculture in the US during early 20th century, a sector where shifting output mix may be easier than in previously studied industries (manufacturing), on output and production choices. We find evidence of output mix adjustments at the county-level in response to immigration as predicted by trade models. Moreover, that response is only visible in diversified counties. Counties with higher initial specialization, likely with higher degree of factor (land) specificity, responded instead through input mixes and organizational changes. Suggestive evidence indicates that crop mix adjustments alone, without organizational changes, absorbed an important part of changes in labor endowments in diversified counties.

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1. Introduction

How does an economy adjust to an inflow of new workers? This question has been one of the basic motivations of the literature (and the policy debate) regarding the impact of immigration in the United States and other countries in the world. As part of the discussion about the precise estimates of the effects of immigration on the labor market outcomes of natives, the literature has improved our understanding of how natives and immigrants interact in the labor market. Some authors have suggested that native workers, even those with skill levels similar to those of migrants, are not perfect substitutes for immigrant labor (see for example, Cortés 2008, Ottaviano and Peri 2012, Peri 2009). Other authors have argued that adjustments in technology can occur in response to immigration, and these endogenous adjustments may attenuate the wage and employment effects of the inflow of workers.¹ Moreover, as predicted by trade theory, economies may also adjust to immigration by shifts in output mix. For example, in response to an inflow of low-skill labor, firms may increase the production of goods that are more labor intensive, generating a shift in the labor demand that allows the local economy

to absorb the inflow of workers without a change in wages. However, this is only possible in a context in which the cost of altering the output mix is not too costly and can be done relatively rapidly.²

Several studies have examined the relative importance of these adjustment mechanisms in response to immigration flows. According to this evidence, most of the absorption of additional workers seems to be occurring via changes in technology, with shifts in the output mix playing a lesser role: see for example, Card and Lewis (2005), Lewis (2004), Dustmann and Glitz (2011), and Gonzalez and Ortega (2011). One exception to this literature is Hanson and Slaughter (2002) who find evidence that output shifts might have contributed to the absorption of the immigrant inflows to the US, albeit using a different empirical strategy. Overall, one possible explanation for the limited evidence of output mix changes found in these studies may be factor specificity or high adoption costs that limit these types of adjustments.

In this paper we focus on the agriculture sector in the US between 1910 and 1940, a sector in which output (crop) adjustments may have been relatively less costly. The relative malleability of agricultural machinery across different crops may have facilitated output adjustments with respect to, say, the manufacturing sector, where capital equipment tends to be more specific. Moreover, another advantage of focusing on agriculture is that output production (in this case, crop production) is

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¹ Technology may adjust to the change in skill mix brought up by immigration, as predicted by models of capital-skill complementarity such as Krusell et al. (2000). Also, new labor intensive technologies could be endogenously generated or adopted in response to a labor inflow as in the theory of directed technological change of Acemoglu (2002).

² This mechanism corresponds to the Rybczynski theorem, the standard adjustment mechanism to changes in relative endowments in Heckscher–Ohlin trade models. One of the most common frictions that restrict this mechanism is the existence of specific factors.

easily observed and measured. Most previous studies have used shifts in the industry mix to proxy for product mix adjustments, and therefore cannot observe any product shifts within an industry. This may have generated an “aggregation” bias against the importance of product-mix adjustments.³ Thus, our setup has two interesting features: direct measures of production of goods with less potential for aggregation bias, and an economic activity where capital may have a lesser degree of specificity.

This paper examines how firms, or farms in this specific case, adapted to changes in labor supply that were generated by a plausibly exogenous shock to labor endowment in rural US counties stemming from changes in inflows of immigrants during 1910 to 1940. The paper focuses on contrasting potential mechanisms through which responses to immigration may have occurred: changes in output mix versus factor adjustments.⁴ We further explore this question by noting, in certain regions, factor-specificity will make changes to output mix more difficult, forcing farms to adjust by changing techniques and factor use ratios. Moreover, evidence from previous studies provided at the aggregate level may mask much of the heterogeneity in the adjustment mechanisms. This argument has not been previously made nor empirically demonstrated in this literature.

Besides the possibility to observe changes in output mix, several other reasons make the agriculture sector in the early twentieth century an interesting setting to conduct this analysis. First, the large immigration flows at the beginning of this period (e.g., in the early decades of the twentieth century the fraction of the population that was foreign born was larger than during the most recent decades in the United States) came to a precipitous decline in the 1920s and had important variation across time and geographical areas (both destination and origin). Second, the agriculture sector at the time was important for the US economy and received a large number of immigrants: 17% of all migrants arriving were agricultural workers in their country of origin, and more than 10% of the immigrants in the United States reported to be involved in such occupations.⁵ Third, observing how these inflows may have fostered changes in factor use, techniques or crop choice, is facilitated by the availability of relevant data in the United States Agricultural Census and by a large number of contemporaneous studies that describe in detail the production processes and input requirements of various crops. There is, for example, data on the important technological transformations that became available to farmers in this period, with the arrival of tractors as a new source of draft power. Contrastingly, in today's economy, most immigrants work in the services sector in which techniques and capital are difficult to measure. Finally, the period from 1910 to 1940 is particularly appealing because the “frontier” was almost completely established, limiting the incorporation of new land as a mechanism to absorb the inflow of immigrant workers.

Our approach to this question follows a simple motivating framework which emphasizes the role of factor-specificity/specialization. We start by thinking of local labor markets as small open economies with access to a similar set of production technologies that use land, capital and labor. These can be combined to produce three different outputs (crops) with three different levels of labor intensity. Local economies, however, differ in the specificity of their land, which limit reallocations different crops. If local economies can change their production mix, as it is the case in the standard small open economy model in classical trade theory, we would expect capital to reallocate across crops in response to the labor inflow. As long as the economy is

in the “cone of diversification” this adjustment implies that the inflow of workers would bring no changes to the relative factor prices. However, if, due the specificity of its land, the local economy cannot make shifts in crop production or is not in the diversification cone, it will need to resort to changes in the capital intensity within each type of crop in order to absorb the change in labor endowment. These two alternatives will have consequences not only for observed crop shifts but also for a number of other variables that we will explore.

We then examine empirically whether, between 1910 and 1940, immigration-induced shocks to the (relative) supply of low-skilled labor (measured as number of agricultural or low skill workers per acre of farmland) caused farms in the United States to modify their crop choice, input mix and organization of production. We focus on changes in crop choice as a measure of shifts in output mix and also explore other margins of adjustment (input mix, scale of production, tenancy organization and draft power choice). Such variables are obtained from the Census of Agriculture, many of which were digitalized for the purpose of this study. Data on the number of immigrants, agricultural and low-skilled workers in each county were built using the Population Census of the United States.

We exploit the panel dimension of the dataset to control for national trends and other confounding factors using county and state-by-year fixed effects. To obtain causal estimates of the responses to changes to the labor supply, we use *immigration inflows* as shocks to the *total* labor supply. In order to deal with the endogenous location of immigrants across local labor markets, we follow Card (2001) and construct instrumental variables using the location of past immigrants. Furthermore, to avoid potential problems arising because of persistent shocks to the agricultural markets we construct this instrument using the location of *all* past immigrants, regardless of whether they worked in agriculture or not. Our instrument appears to be fairly strong and robust over this period when used to predict the location of immigrant agricultural workers, as well as the location of all (migrants and native) agricultural workers and low-skilled workers, at the county level.

Our results suggest that the increases in the relative endowment of labor due to immigration had a strong effect on output choices. We first present evidence showing that the share of land allocated to specific crops and the share of output value was altered by the increase in the relative endowment of agricultural workers. By comparing counties within a given state in a given year, we find that an increase in the amount of labor per acre reduced the share of land allocated to wheat and raised the share of land allocated to hay and corn as well as the share of land in which no crops were produced. Given that wheat is less labor intensive than corn and hay, we interpret the observed shifts in crop mix as adjustments in production caused by immigration-induced changes in factor availability and provide evidence against alternative causal channels. We consider the possibility that the changes in output mix could be driven by immigration-induced changes in the relative demand of crops, but the absence of changes in local crop prices is evidence against this option. We also explore whether the changes in crop choice are driven by a transmission of agricultural knowledge generated by immigration but find no evidence supporting this.

We do find some limited evidence for changes to the organization of production, particularly on average farm size. However this change is at the aggregate level, so it could reflect adjustments away from more land-intensive crops. We also explore county level changes in other margins of the organization of production, such as tenancy and use of mechanized draft power, and find no evidence of effects. Thus, overall our results using all counties find robust evidence for crop mix changes but not much support for other modes of adjustment.

We then explore some testable implications derived from the conceptual framework in which local economies absorb a change in the relative supply of labor by changing the output mix. In line with the predictions, we find that the aggregate capital–labor ratio fell almost by one percent in response to a one percent increase in the number of workers per acre. Moreover, we find no evidence that crop productivity

³ Dustmann and Glitz (2011) try to surmount this with measures of skill mix at the firm level. While this strategy may ameliorate the bias, changes in product-mix within firms will still go unobserved. See Lewis (2013) for a discussion of this issue.

⁴ See Lewis (2013) for a review of work on the relation between immigration and production technology, also including the channels we study in this paper.

⁵ According to the authors' calculations using Census micro samples for 1910 to 1940, and the Reports of the Commissioner for Immigration between 1900 and 1930. During this period an even larger number of immigrants worked in manufacturing.

was altered, a result that is consistent with factor ratios within crop remaining constant. We further attempt to decompose the changes in the aggregate capital-to-land and labor-to-land ratios and find evidence indicating that shifts in output mix could have absorbed a relevant fraction of the change in factor inputs. Finally, we find no evidence of robust impacts of immigration on land prices, consistent with a scenario in which input prices were not heavily altered. Thus, we find suggestive evidence that shifts in output mix, where possible, may have absorbed a significant part of the labor inflow resulting in limited impact on local factor prices, in contrast with recent evidence of adjustments in the manufacturing sectors in recent decades (Lewis, 2011).

More importantly, we find evidence supporting our hypothesis regarding (the absence of) crop mix changes and factor specificity. In particular, and as our framework suggests, if the previous effects are indeed related to the Rybczynski-type effects, then our results should hold for counties where factors were easily mobile between crops. On the contrary, the results regarding crop mix should not be present in counties where factor specificity is binding (for example because of land or climate conditions). To implement this differential analysis, we proxy for factor specificity by classifying as *specialized* the counties where more than 25% of farmland in 1900 was dedicated to one crop, assuming that this specialization is the result of the specificity of climate and soil conditions and not of the availability of other production factors. We find that in counties that had a lower degree of specialization in a given crop, and consequently are less likely to have specific factors, greater adjustments in crop mix appear to have taken place. On the contrary, in counties that were more specialized in any crop, we do not observe changes in the crop mix. Moreover, in these counties we do find adjustments in technology and organizational changes that are larger in magnitude compared to our aggregate results. In these specialized counties we also find some evidence of changes in land productivity, which is consistent with a story where factor use or technology changed within crops. We interpret this set of results as evidence that, when crop mix adjustments were limited, the changes in relative factor endowments were absorbed via technology and organizational adjustments, as predicted in a model with binding factor specificity.

The rest of the paper is organized as follows. In Section 2 we present a simple conceptual framework that will be used to motivate the empirical model and interpret the results of our estimations. In Section 3 we present the empirical strategy, Section 4 describes the data used in this paper and discusses the relevant historical background of agriculture in the early twentieth century in the US. In Section 5 we present the main results and in Section 6 we conclude.

2. Theoretical framework

Consider an economy where three (agricultural) goods –here crops– are produced combining three different inputs: labor (L), capital (K) and land (T), according to production functions $F_i(L, K, T)$, where the subscript i indicates the crop.⁶ Throughout the paper we assume that all the functions $F_i(\cdot)$ display constant returns to scale in the three factors, thus implying that factor use ratios are fully determined by factor price ratios. The demand for the three crops is perfectly elastic, as is the usual assumption in a small open economy model.

We are interested in the impacts that a change in labor endowments has on the relative output level of each crop, and on aggregate and crop specific factor use ratios. In the rest of this section we consider two alternative scenarios: one in which factors can freely move and one where there are limits to mobility. For each scenario we present testable implications, which we can compare to our empirical results in order to

determine whether there is evidence of “Rybczynski” adjustments in response to immigration.

2.1. Free mobility of factors

We start by considering the case with free mobility of capital, labor and land across crops. In this case, the economy wide use of factors is determined by aggregate supply $(\bar{L}, \bar{K}, \bar{T})$ and factor prices are such that markets clear. Following the standard notation, we denote by $l = L/T$ and $k = K/T$ the labor- and capital-to-land ratios, respectively. This setting corresponds to a n -factors, n -goods (small) open economy model. Following Feenstra (2004), in this case we can have factor price insensitivity, meaning that factor prices are fully determined by crop prices and are independent of factor endowments, if the Nikaido conditions hold.⁷ Thus, under the required assumptions, we have that immigration will not affect within-crop factor use ratios since these are fully determined by crop price ratios. Furthermore, using again the properties of the production function, a change in factor endowment will not impact output per factor since it only depends on factor ratios and those are unchanged under factor price insensitivity.

Thus, in response to an increase in the supply of one production factor, we should observe that

1. Factor prices should not change (factor price insensitivity).
2. Average output per factor within crops will remain unchanged because unit requirements are a function of factor prices only.
3. The share of production of each crop will respond such that the full change in aggregate factor use will be absorbed through it, namely that

$$dj = j_1 d\frac{T_1}{\bar{T}} + j_2 d\frac{T_2}{\bar{T}} + j_3 d\frac{T_3}{\bar{T}}, \quad \text{for } j = l, k \quad (1)$$

since $j = \sum j_i T_i$, because of market clearing, and j_i remain unchanged within each crop i . In this model, which corresponds to a standard small open economy model, these crop changes correspond the well-known “Rybczynski effects”.⁸

Because we have three factors, the reallocation between sectors will be a bit more complex than in a two good-two sector model but can be obtained analytically (and is derived in Appendix A.1) as

$$\begin{aligned} \frac{\partial T_1}{\partial \bar{L}} &= \frac{(k_2 - k_3)}{k_1(l_3 - l_2) + k_2(l_1 - l_3) + k_3(l_2 - l_1)} \\ \frac{\partial T_2}{\partial \bar{L}} &= \frac{(k_3 - k_1)}{k_1(l_3 - l_2) + k_2(l_1 - l_3) + k_3(l_2 - l_1)} \\ \frac{\partial T_3}{\partial \bar{L}} &= \frac{(k_1 - k_2)}{k_1(l_3 - l_2) + k_2(l_1 - l_3) + k_3(l_2 - l_1)} \end{aligned} \quad (2)$$

where $k_i = \frac{K_i}{T_i}$ and $l_i = \frac{L_i}{T_i}$, $i = 1, 2, 3$, and will thus depend on the capital-land and labor-land intensities of these sectors. Notice that this is different from a 2×2 case since here it is not necessarily the case that the factor with the highest l_i ratio will necessarily expand.

If we were to simplify our model to a more typical two-good, two-factor model, we would predict that sectors with the lowest labor-land and labor-capital (depending on which factor we eliminate) ratio would contract and those with the largest ratios would expand in response to an increase in labor endowment. We test this in a simplified version of our empirical model later on.

⁶ We call the third factor land because of the context of our study, but of course our argument is more general and you could think of other factors in different situations.

⁷ See Feenstra (2004) for a formal statement of these conditions. These conditions imply that the leading principal minors of the matrix of factor requirements are bounded between two strictly positive finite constants.

⁸ See Rybczynski (1955).

Note that in this model the aggregate capital-to-labor ratio falls, mechanically, while the aggregate capital-to-land ratio remains constant in response to the change in labor endowment since those are determined by endowments only.

2.1.1. Longer run adjustments

Now, let us assume capital could move between counties but that its response is slower than the crop adjustments. In this case, if we start from a situation where the local (rental) price of capital is equal to the international price, capital would only flow if the return to capital after the crop adjustments has changed in response to the change in labor endowment. However, we know that in this model local factor prices are unchanged and, thus, there is no incentive for capital to flow between counties. In this situation, with crop mix absorbing all the change in factor endowments we would also find that:

4. The aggregate capital-to-labor ratio will fall by the same percentage as the increase in labor-to-land ratio as there will be no additional inflow of capital in response to this shock since factor prices are unchanged.
5. The aggregate capital-to-land ratio will remain unchanged by the same argument. In our empirical specification this implies that changes in capital-to-land should not systematically respond to changes in labor endowment, i.e. the estimated causal impact should be 0.

2.2. Adjustment with binding factor specificity

Suppose now that unlike the previous section that a county is not in the cone of diversification or that land cannot move between crops. Assume also that, in the short run, there is no factor mobility across economies, but that, unlike land, labor and capital can be freely reallocated across crops within the local economy. In this case, factor price insensitivity no longer holds. Given that factor prices will change in response to changes in factor endowments (labor in our case), factor use ratios within each crop will also respond. Remaining with our assumption that the production function displays constant returns to scale, this implies average land productivity will also change. Furthermore, we will observe that reallocation across crops cannot fully absorb the change in the aggregate labor endowment, thus some of the adjustment will come from changes in factor intensities within crops.⁹

In particular, in this case we will observe that in response to a change in labor endowment

1. Factor prices (wages, rental rate of capital and land) will change.
2. Average output per land for each crop will be altered since factor ratios change.
3. The shock to the labor endowment will not be absorbed only by sectoral shifts as there will also be a change in factor ratios within crops. More formally,

$$dj^*j_1 d\frac{T_1}{T} + j_2 d\frac{T_2}{T} + j_3 d\frac{T_3}{T}, \quad \text{for } j = l, k$$

Note that here again, the aggregate capital-to-labor ratio will, mechanically, fall while the aggregate capital-to-land ratio will remain constant in response to a change in labor endowment since capital and land are fixed at the economy-level.

2.2.1. Longer-run adjustment

Without factor price insensitivity, the return to capital will change. Thus, in the long run, if capital is able to move between economies, the change in the labor endowment should lead to capital flows until the return to capital is again equal to the international value:

4. The aggregate capital-to-labor ratio will not change by the same percentage as the increase in labor-to-land ratio since capital will either enter or exit the county in response to the change in labor input.
5. The aggregate capital-to-land ratio will respond to a change in the labor endowment by the same argument.

In [Appendix A.2](#) we develop a model that illustrates that the signs of the responses presented in points 4 and 5 will depend on whether factors are q-complements or q-substitutes, as is common in the immigration literature.

3. Empirical strategy

3.1. Baseline equation

Using this simple framework, we explore empirically how immigration-induced labor supply shocks may have impacted the output and technological choices of agricultural producers in early twentieth century US. We examine variation in *local* US economies using county-level data. In the construction of our empirical model we take into account three other adjustment mechanisms that can affect our estimates of the responses of agriculture and which are different from those discussed in [Section 2](#). The first mechanism corresponds to the skating rink effect, i.e. an outflow of native workers that leaves total labor supply unchanged in response to the arrival of new immigrants. We address this issue by considering specifications in which we study the impact of changes in the *total* number of agricultural workers in a given county regardless of their country of birth. Thus, our estimates take into consideration the fact that immigration does not lead to a one-to-one increase in the total availability of workers in a given county.¹⁰

Second, in response to an inflow of immigrants, there may be an adjustment in the total amount of land dedicated to agricultural activities. In our empirical specifications we consider this potential change and divide all labor supply measures by the amount of land farmed.¹¹ We also adjust our instrumental variable strategy to control for this endogenous response of land farmed.

Finally, within a given county, an increase in the supply of workers of a given occupation due to immigration may induce natives (and former immigrants) to switch to a different occupation. Therefore, in some specifications we will consider the full stock of low-skilled workers and thus account for the potential occupation switching generated by immigration.

Our main estimation equation is:

$$y_{cst} = \theta \ln \frac{L_{cst}}{T_{cst}} + \beta' \ln X_{cst} + \nu_c + \mu_t + \nu_{st} + \varepsilon_{cst} \quad (3)$$

¹⁰ In studies of contemporary immigration to the US, [Borjas et al. \(1997\)](#) and [Cortés \(2008\)](#) provide evidence that immigration leads to a displacement of natives. However, these displacement flows may not be large enough to fully offset the immigration inflows. In such case, immigration inflows may effectively translate into a higher labor supply, as seems to be the case in our sample.

¹¹ During the 19th century, the development of US agriculture was characterized by a westward expansion. This expansion came to a dramatic slowdown by 1910, when the settlement was so dense that many claimed the frontier had virtually closed. However, the number of acres farmed could still be altered by cutting down trees in wooded lands or putting under cultivation areas that were not yet exploited.

⁹ See [Feenstra \(2004\)](#) for an analysis of a similar situation within a specific factor model.

where the left hand side variable is an agricultural outcome observed in year t , state s and county c . L_{cst} represents the corresponding measure of labor supply which can either be the stock of all agricultural workers or the stock of low-skilled workers in county c . The variable T_{cst} measures the area devoted to farmland in each county. Regressions are weighted by amount of farmland in 1900 and standard errors are clustered at the county-level to adjust for heteroskedasticity and within-county correlation over time.¹²

We include various controls in an attempt to isolate the impact of a change in the labor input from confounding factors. We first consider shocks that generate a co-movement of agricultural labor supply and agricultural production decisions in a way that is not differential across regions such as, for instance, the onset of World War I, which increased the prices of US crops and affected the availability of labor at a national level. We deal with these shocks by including a set of year fixed effects, μ_t . We also control for time-invariant county-specific characteristics that determine the location patterns of agricultural workers with county level fixed effects, ν_c . Thus, confounding factors such as the geographic conditions that jointly influence agricultural practices and the location choices of agricultural workers (e.g. rivers, weather, distance to the coast) are partialled out.

Nonetheless, the numerous transformations affecting the agricultural sector over this period constitute sources of unobservable time-varying shocks that may have affected agricultural outcomes and labor outcomes in a differential manner across regions.¹³ For example, the New Deal, which was implemented in 1933 as a response to the Great Depression, had a regional component since the First Agricultural Adjustment Act (AAA) determined the maximum acreage to be planted of each major crop in each state and growing season. The acreage was then allotted to each farm on the basis of its recent cropping history and payments were made to individual farmers to encourage compliance.¹⁴ We try to address this by including state-year fixed effects in the regression v_{st} . This means that we will only be exploiting variation *between counties within a given state*. Our identification strategy will therefore not be affected by, say, state-level policies, such as the AAA, or shocks that simultaneously affected crop choice and agricultural employment. This is very costly in terms of precision but increases the validity of our empirical estimate.¹⁵ We further include the term X_{cst} , a vector of county level exogenous time-varying controls, which includes interactions of time dummies with 1900 characteristics of the county. This allows counties that differed in 1900 to have evolved differently than others over time.

Finally, there was some great agricultural damage in the Great Plains region due to a major environmental catastrophe that became widely known as the “Dust Bowl.” Due to severe drought and erosion, the soil was blown off from the fields in huge dust storms that, in some areas, removed almost 75% of the soil (Hornbeck, 2012). We therefore test

whether our results are sensitive to the exclusion of Oklahoma, Kansas and Nebraska, which were the states most affected by the Dust Bowl.¹⁶

The coefficient of interest is θ , which we interpret as the effect on agricultural decisions of a change in the endowment of labor per area of farmland. Estimates of θ based on OLS regressions are unlikely to be informative of the causal effect of a change in labor supply since workers potentially select their location based on unobserved determinants of agricultural outcomes. We now turn to our strategy to deal with this issue.

3.2. Identification strategy

More specifically, we build an instrument that exploits the tendency of newly arriving immigrants to move to enclaves established by earlier immigrants of the same country. Similar identification strategies have been used previously by Card (2001), Cortés (2008), Lewis (2011), and others. Formally, the instrument for the logarithm of the stock per acre of all agricultural or low-skill workers per acre in county i and year t is:

$$\log \left[\sum_j \left(\frac{N_{jsc, 1900}}{N_{j, 1900}} \right) \left(\frac{L_{jt}}{T_{c, 1900}} \right) \right] \quad (4)$$

where $N_{jsc, 1900}$ is the stock of immigrants from ethnic group j in state s and county c in 1900; $\frac{N_{jsc, 1900}}{N_{j, 1900}}$ is the fraction of immigrants from ethnic group j that were located in county c in 1900; and, L_{jt} is the stock of immigrant agricultural or low-skilled workers from ethnic group j in the United States in decade t and $T_{c, 1900}$ is the acres farmed in 1900. Thus, the instrument uses the 1900 distribution of immigrants across counties to allocate the national stock of agricultural or low skill workers in each decade. It should be noted that the location shares, $\frac{N_{jsc, 1900}}{N_{j, 1900}}$, are obtained from Census tabulates, as opposed to micro-samples. This makes their measurement more reliable and thereby attenuates concerns of measurement-error bias.

The identification strategy that combines the instrumental variable with year, county and state-by-year fixed effects has to fulfill the following two requirements. First, the total national stock of immigrant agricultural workers from a particular ethnic group at time t must not be correlated with differential shocks to agriculture across counties within a given state. Second, the location choice made by immigrants in 1900 among counties within a given state should be uncorrelated with differential changes in the agricultural practices in these counties to be seen over the next decades. Regarding this second condition, the stock of agricultural/low skill workers will be predicted using the 1900 ethnic group distribution of *all immigrants* as opposed to the ethnic distribution of *immigrant agricultural workers*. This is preferred because the location choices of *agricultural workers* in 1900 may be more related to the anticipated changes in agricultural practices than the location choices of *all immigrants* and, therefore, ameliorates concerns of identification.

This instrument will only generate enough predictive power if over the period we study immigration substantially altered the aggregate labor supply in rural counties. The source of variation we exploit comes from the fact that immigration decreased substantially over the period of our study, with a greater effect on counties where immigrants were relatively more important for the labor market. Agricultural activities were a popular occupation for immigrants, with 7% of recently arrived immigrants working in agricultural occupations and 10% of the overall farmer stock over this period being foreign-born. More importantly, there is a large amount of variation in how important the immigrants were to the total labor supply with a standard deviation in the

¹² To study the correlation pattern, we also derive estimates of the county level effects using standard errors clustered by state. Those standard errors were very similar to those clustered by county, suggesting a low degree of correlation of the error terms across counties in the same state.

¹³ For example, the agricultural south, the corn belt and the agricultural mountain states were particularly hit hard by the 1920s decrease in agricultural prices which led to farm bankruptcy and increased tenancy rates. The onset of the Great Depression dramatically worsened the situation when farm prices declined further, lowering the farmers' terms of trade by 37% in the period 1929–1932. The economic distress was particularly severe for farmers with high levels of debt: foreclosures increased, peaking at 38.1 per thousand in 1932 (Walton and Rockoff, 1998).

¹⁴ Good weather, increases in fertilizer use and violation in the allotments limited the effects of the First AAA, which, in 1936 was declared unconstitutional. In 1938 a Second AAA was implemented. This incorporated a system of quotas that could be instituted upon agreement of two-thirds of the growers and the implementation of government purchase operations to keep prices above a minimum threshold. With some modifications, the Second AAA endured for the next 35 years.

¹⁵ Results excluding the state-year fixed effects are available upon request and are more statistically significant than the ones presented in the paper.

¹⁶ Hornbeck (2012) details that counties with the highest erosion levels during the Dust Bowl were located in these three states.

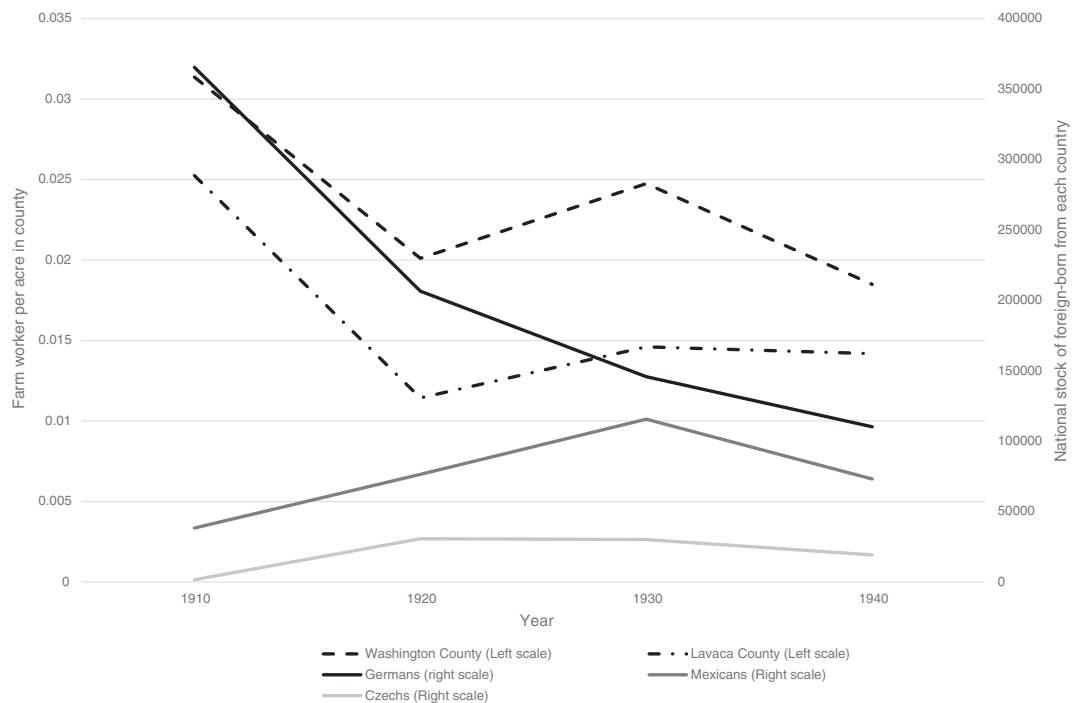


Fig. 1. An example of the instrumentation strategy.

fraction of agricultural workers being immigrants equal to 13%, almost twice the mean of the sample.¹⁷

We only measure “local” availability of workers, thus, if many agricultural workers were temporary migrants from other counties (see for example Lescohier 1924), our measure would suffer from measurement error. However, one may think that this migratory flow would have been more costly to agricultural producers than to local workers and thus the number of workers in a county may still capture the relevant availability of workers ready to supply their services.

To show how our instrument operates, we offer a simple example in Fig. 1. We take two counties within the state of Texas, Washington and Lavaca, since our identification comes from across counties within a given state. The county of Washington, had, in 1900, a large number of Mexican migrants. On the other hand, the county of Lavaca had a large number of Germans and Czechs migrants. We can see that as the number of immigrants from Germany living in the US declines and that of Mexican migrants increases, the farmer to acre ratio in Washington decreases much more rapidly than the one in Lavaca. However, the labor-to-land ratio of Lavaca is much more strongly impacted by the increase in the peak in the number of Mexican migrants in 1930 and then its fall in 1940 than Washington county is.

For this strategy to be effective, we need sufficient variance in the change in the stock of migrants at the national level and in their location choice. In 1900, the US had a large number of immigrants from Germany, Scandinavian countries, Great Britain and its ex-colonies. Over the period, however, these stocks started to greatly diminish as the number of new migrants from these countries dwindled. The countries that experienced the largest change in stock between 1910 and

1940 were Mexico, Poland, Japan and some Eastern European countries. While there were a few counties that were more popular with immigrants than others, there is a lot of diversity across country of birth, sufficiently so to generate the variation we need for our instrument. For example, Appendix Table 1 shows the top 10 counties where the 4 ethnic groups with the highest increase and decrease in stock over the period had located in 1900. It shows a large variation across ethnic groups, not only in the geographic zones where they located but also in how concentrated each county was in 1900.

Note that this identification strategy is not violated if, for example, states in the South were less likely to adopt combustion engine technologies and, simultaneously, were less likely to attract immigrants. Instead, our identification strategy will be violated if county specific shocks *within each state* are highly persistent and if the same shocks that determined the county-level ethnic distribution of immigrants from 1900 within each state still affect county-level agricultural outcomes at time t . We use two approaches to deal with this issue. First, as was discussed previously, the instrument uses the past location choices of immigrants of all occupations, not only those involved in agriculture, reducing the concern that agricultural workers in the past may have selected their location within each state anticipating changes in agricultural conditions. Second, as was mentioned earlier, in addition to the instrumental variables and the fixed effects, we include a rich set of time-varying (exogenous) controls that proxy for differential trends for counties with different agricultural conditions. These controls are built from interactions between decade dummies and key county level variables that measure the number of farms in 1900, the 1900 allocation of land across crops, the 1900 share of whites in the population and the 1900 distribution of farms across tenancy systems. Thus, for example, we control for the fact that, within the same state, a county that had a large share of tenants or a large share of wheat in 1900 may have evolved differently than a county with a large share of owner-operators or one with lots of cotton plantations. In the results section we evaluate the sensitivity of the first stage estimates to the inclusion of this set of control variables. A substantial change in the coefficient of the instrumental variable in the first stage regression would suggest a threat to the validity of the identification assumption.

¹⁷ We also explored an instrument that would use only the variation stemming from the newly arrived immigrants by constructing it as the stock of 1900 plus the allocated flow arrived since then using shares as mentioned above. The first stage was less powerful but still sufficiently so to obtain some results. However, given that the year of migration is not recorded after 1930, we would have lost 1940 as a year of observation and thus decided not to pursue this alternative. However, the fact that the first stage was present suggests that most of our power comes from variation in the number of newly arrived migrants and not to other changes to the existing stock of migrants in the US.

Table 1
Summary statistics.

Variable	Mean	SD	N
<i>Labor endowment measures</i>			
Stock of immigrant agricultural workers	480	1075	10,780
Stock of total agricultural workers	4873	5405	10,780
Stock of total low skill workers	10,306	23,453	10,828
<i>Predicted labor endowment</i>			
Predicted number of immigrant agricultural workers	348	1530	10,780
Predicted number of immigrant low skill workers	1648	8509	10,828
<i>Crop choice and productivity</i>			
Acres farmland	591,920	850,624	10,828
Share of total farm acres planted in corn	0.11	0.10	10,828
Share of total farm acres planted in wheat	0.06	0.09	10,828
Share of total farm acres planted in hay	0.08	0.07	10,828
Share of total farm acres planted in cotton	0.04	0.08	10,828
Bushels of corn per acre	21.22	12.50	10,513
Bushels of wheat per acre	14.14	7.60	9230
Tons of hay per acre	1.31	1.74	10,793
Bales of cotton per acre	0.36	0.19	3378
<i>Measure of farm organization</i>			
Farms	2917	2890	10,828
Share of farms operated by owner	0.64	0.15	10,828
Share of farms operated by tenant	0.30	0.15	10,828
Share of farms operated by management	0.05	0.10	10,828
Number of horses	8484	10,753	10,828
Number of mules	2345	4599	10,828
Number of tractors	333	666	10,828
<i>Capital intensity and factor prices</i>			
Capital–labor ratio	419.64	342.16	10,764
Capital–land ratio	3.58	3.34	10,828
Land value ('000s 1930 constant \$)	17,708	26,331	10,828

4. Data and descriptive statistics

The estimations are conducted using county level data for the years 1910 and 1940 and for all US states except for Hawaii, Alaska and the District of Columbia. Given that during this period county boundaries changed, with some counties merging or ceasing to exist, we track all the boundary changes and grouped the counties whenever it was necessary to keep the unit of observation constant over time. We exclude counties in which the number of predicted agricultural workers (as based on the instrumental variable described above) was less than 0.1. We also exclude counties in which the number of low-skilled workers was predicted to be less than 0.6 for those regressions in which that variable was used. Thus, the regressions that use the instrument of predicted agricultural workers were estimated with a balanced panel of 2,695 counties. In the case of the regressions that use the instrument of low-skilled workers, the balanced panel has 2,707 counties. The average number of counties by state is 58, with the smallest including only 3 counties (Delaware) and the largest, 219 (Texas).

4.1. Labor supply and immigration data

We use the one percent micro samples of the 1910–1940 Integrated Public Use Microdata Series (IPUMS; see Ruggles et al., 2008) to identify immigrants and all residents of a county who worked as farmers or as low-skilled workers. Since in 1940 we also have aggregate tables by county for the number of agricultural and low skill workers, we employ that source to build the endogenous variable.¹⁸ Agricultural workers are

defined as individuals whose primary occupation, as reported in the Census, is being a farmer or a farm laborer.¹⁹ We chose to couple farmers and farm workers as the decision to own land could be endogenous in this context. Running the first stage using only farm workers, we are able to predict well the location choice of immigrant farm workers but not that of the aggregate population suggesting some natives may change their land-owning status in response to the arrival of immigrant workers. We thus use the composite measure of farm workers and farmers for the rest of the paper. Low-skilled workers are also defined using occupational categories in the census and include farmers as well as laborers, servants, fishermen, housekeepers and other low-skilled trades.²⁰ Immigrants are defined as individuals who answered the US Census and were born outside the US, as is traditional in the immigration literature.

The shares of immigrants located in each county that are used to compute the instrument, $\frac{N_{j,i,1900}}{N_{j,1900}}$ in Eq. (4), are built using data on the number of immigrants in every county by country of birth. This data is available in the 1900 Census county level tables that are available in digital format at the National Historical Geographic Information System (NHGIS; see Minnesota Population Center 2011).

4.2. Agriculture data

We use data from the 1910, 1920, 1930 and 1940 Censuses of Agriculture to construct a wide variety of agricultural variables at the county-level.²¹ To the best of our knowledge, there is no public data available at the farm level nor any other finer level of disaggregation. Also, we are not aware of available data on agricultural income or wages.²²

Our framework suggests that, in response to changes in (relative) labor supply due to immigration, the first type of adjustment that one could expect is a change in output towards a more labor intensive mix. In the context of a local agricultural economy, such changes in output mix correspond to shifts in crop production. We therefore obtain measures of physical output, value and area planted for the four most important crops during this period: corn, wheat, hay and cotton.²³ We also include a measure of non-crop land, which corresponds to the land within a farm that is not devoted to crop production, to capture the extensive adjustment.²⁴ To measure individual crop production, we use variables of physical output per crop reported in the Census (e.g., bales of corn and tons of hay.) To measure overall crop production we use the monetary value of crop production provided in the Census and deflate it using the CPI.²⁵ Finally, we obtain a proxy for the price of each output in the county, a unit value, by dividing the value of the crop reported by the physical output of that crop.

¹⁹ More specifically, we elected individuals who, based on the 1950 occupation classification, reported as their occupation one of the following activities: 640 Fruit, nut, and vegetable graders, and packers; 810 Farm foremen; 820 Farm laborers, wage workers; 830 Farm laborers, unpaid family workers; 840 Farm service laborers, self-employed; 100 Farmers (owners and tenants); 123 Farm managers.

²⁰ For the complete list of occupations, see Appendix Table B-1 of Lafortune and Tessada (2014).

²¹ Some of the relevant variables were available in digital format at the NHGIS and the Inter-University Consortium for Political and Social Research (ICPSR) repository. However, for some years and states, key variables such as tractors and acres and production by crop were only available in printed Census books, so we worked on their digitalization for the purpose of this study.

²² Expenses for labor are available, but the definition changed too many times over the period to make the comparison meaningful and appears to exclude the farmer's own imputed wages.

²³ During 1910–1940, these crops ranked highest in terms of area farmed. Their combined area amounted to the majority of the cropland in the country. In 1910, for example, 82% of the total area dedicated to crop production was allocated to these four crops.

²⁴ In 1910 and 1930, all land devoted to crops was included while in 1940, only land where crops were harvested were entered digitally in the NHGIS database. However, our results are robust to the exclusion of 1940, suggesting that what we are finding is not driven by these changes in definitions. In 1920, the variable was not available in the database and we did not digitalize it.

²⁵ We use the historic CPI series provided by the Minneapolis Fed in <http://www.minneapolisfed.org/>.

¹⁸ The results are very similar when using the IPUMS to measure these stocks in 1940. Results are available upon request.

Our framework emphasizes the key role that factor specificity will play in the adjustment process. We classify counties as high or low producers of a specific crop in 1900 as our proxy for factor specificity. Counties that devoted more than 25% of the farmland to the production of a given crop are defined as “high producers” of this crop. Counties that devote more than 25% of their farmland to any given crop are defined as “specialized”. The patterns in 1900 could, in addition to measuring the suitability of the land for a given crop, represent effects of factor prices (a location was specialized in wheat because it had access to cheaper machines than another). We find that using 1900 as the year in which we measure specialization patterns is sufficiently distant from the period of study and therefore unlikely to reflect factor price trends over the period. Later on we explore whether using soil and weather characteristics from FAO provides similar results.

We proxy changes in technology by measuring county-level changes in the organization of agricultural production. Specifically, we obtain data on the number of farms and farm area per county, as well as data on the number of farms within several specified area ranges,²⁶ and the number of farms per county that are operated by owners, tenants or managers.²⁷ Measures of scale and tenancy are likely correlated with the use of technologies since large farms and farms cultivated by their owner were more likely to be capital-intensive than smaller and tenant-operated farms. Also, agricultural economies where land was frequently farmed by tenants were characterized by thin labor markets. As discussed by Whatley (1987), given the seasonal nature of agricultural production, thin labor markets were very costly for farmers. Tenant contracts were implemented to reduce the costs of fluctuations in labor requirements. In such an environment, immigration-induced labor inflows may have reduced the need for tenancy arrangements.

We also measure the number of horses, mules and tractors in each county as a proxy for a change in technology. This variable choice is motivated by Olmstead and Rhode (2008), who document that the adoption and diffusion of new farm technologies in the US went hand-in-hand with the adoption of draft power coming from draft animals or from tractors (see, for instance, Cochrane 1993, and Olmstead & Rhode, 2001). The period we study saw a rapid adoption of tractors that has been documented as one of the most important technological innovations in modern agriculture.²⁸ The diffusion of tractors was very rapid, although there was a significant variation in the pace of the adoption across regions.²⁹ Tractors worked faster, their maintenance required much less labor than caring for horses and their adoption freed the labor and land devoted to the production of animal feed (e.g. hay).³⁰ Thus, we explore how the substitution of animal traction for

tractors was affected by an increase in the amount of labor, since this shift in draft power represents capital upgrading. County-level data on the number of tractors is available in the Census of 1925, 1930 and 1940. In 1920, the information is only available by state and not by county. We assume that the fraction of tractors in the state by county was constant between 1920 and 1925 and generate a proxy for the number of tractors in each county for 1920. Lastly, since the national number of tractors is very low in 1910, we use zeroes as a proxy of the number of tractors in every county for 1910.

Finally, we exploit additional data from the Agricultural Census to obtain measures of capital. In all the relevant years, the Census of Agriculture reports values for four categories of farm assets: land, buildings, livestock and implements and machinery. We chose the value of implements and machinery to measure the stock of capital on the farms. County-level measures of this outcome were available in digital format and, like the value of crop production, were deflated using the CPI.

4.3. Summary statistics

Table 1 presents the main summary statistics for the population characteristics and agricultural outcomes in the 1910–1940 sample of counties. On average, there was a stock of 480 immigrant agricultural workers in each county, a number that corresponds to approximately 10% of the total stock of such workers per county. Agricultural workers represented about 47% of all low skill workers in a given county and the county-level stock of low skill workers was, on average, 10,306.

Counties had on average 2,917 farms and 592 thousand acres in farmland. Note, however, that not all of the farmland was devoted to crop production, as areas used in livestock, woodlands or unimproved forests and bushland were also included in the Census. We will refer to these as land with no crops. Thus, even though the land devoted to the four main crops amounted to 82% of the total crop area, it only constituted 29% of the total farmland, as is shown in Table 1. Table 1 also reports productivity measures. While an average of 21 bushels of corn were produced per acre, in the case of wheat, 14 bushels per acre were produced. An average acre of land produced 1.3 t of hay (about 0.4 bales) and 1 ton of cotton. Data for crops is missing for several states where no cotton or wheat production was reported. It is also worth noting that there was a large variation in the measures of land allocation and productivity by county.

Farms over this period were very large. More than 50% of all farms had an area greater than 100 acres. 64% of farms were farmed by their owner and 30% by their tenants. Farms were also fairly capital intensive: the value of implements and machinery in 1910 dollars was 420 per worker and 3.58 per acre. Horses, over this period, were still the major source of draft power with close to 8,500 on average per county. In contrast, a typical county had approximately 2,400 mules and 300 tractors. Large variations in this input mix and draft power measures are observed across counties.

5. Results

5.1. First stage

Estimation of the first stage of Eq. (3) is presented in Table 2, where each observation is a county-year cell. The table presents regressions for 3 different sets of outcomes. Panel A reports regressions in which the left-hand side variable is the log number of immigrant agricultural workers. Although the log number of immigrant agricultural workers will not be used as an (endogenous) explanatory variable, we present this first stage in Panel A to show that the relevance of the instrument is due to the fact that it predicts the location of immigrant agricultural workers, as opposed to the natives. Panel B presents the results of the first stage in which the left-hand side variable is the log number of all agricultural workers (both native and foreign), and Panel C presents the results of the first-stage when the left-hand side variable consists

²⁶ According to the 1920 Census General Report, a farm for census purposes is defined as: “all the land which is directly farmed by one person managing or conducting agricultural operations, either by his own labor alone or with the assistance of members of his household or hired employees. The term *agricultural operations* is used as a general term, referring to the work of growing crops, producing other agricultural products, and raising domestic animals, poultry, and bees.”

²⁷ According to the Census General Report a farm will be classified as operated by: i) the owner, if it is “operated by the person who owns it”; ii) the renter, if it is “operated by the person who rents it either for a fixed money rental or for a share of products”; iii) the manager, if it is “operated for the owner or under general supervision by salaried managers or overseers”.

²⁸ From 1920 onward there was a dramatic transformation in the use of combustion engine draft power. While only 4% of farms in 1920 had a tractor, by 1940 this fraction had increased to 23%. Improvements in the design and progress in mass production made tractors more versatile and affordable, facilitating the expansion in their adoption. By 1940, tractors could be used for plowing, harrowing, belt work and cultivation (Olmstead and Rhode, 2008).

²⁹ The Pacific and West North Central regions were leaders in their adoption by 1920. Improvements in design in the mid 1920s sped the diffusion in the East North Central region and, to a lesser extent, in the southern regions (Olmstead and Rhode, 2001).

³⁰ According to contemporary studies cited by Olmstead and Rhode (2001), in 1944 the tractor saved roughly 940 million man-hours in field operations and 760 million man-hours in caring for draft animals relative to the 1917–1921 period. This is equivalent to 8% of total labor requirements in 1944 (Olmstead and Rhode, 2001). Moreover, as Olmstead and Rhode (2008) and Bogue (1983), the adoption of tractors freed the labor devoted to the production of animal feed (e.g. hay and oats).

Table 2
First stage.

	(1)	(2)	(3)	(4)
<i>Panel A: immigrant agricultural workers</i>				
Ln predicted stock of immigrant ag. workers	0.308*** (0.113)	0.330** (0.145)	0.294*** (0.107)	0.309*** (0.112)
Ln predicted stock of immigrant non-ag. workers		−0.040 (0.187)		
R-squared	0.737	0.737	0.739	0.757
N	10780	10780	10780	9892
<i>Panel B: all agricultural workers</i>				
Ln predicted stock of immigrant ag. workers	0.196*** (0.073)	0.243*** (0.077)	0.179*** (0.069)	0.193*** (0.072)
Ln predicted stock of immigrant non-ag. workers		−0.086 (0.101)		
R-squared	0.907	0.907	0.910	0.908
N	10780	10780	10780	9892
<i>Panel C: all low skilled workers</i>				
Ln predicted stock of immigrant low skilled workers	0.188** (0.072)	0.206 (0.171)	0.157** (0.065)	0.184*** (0.069)
Ln predicted stock of immigrant high skilled workers		−0.023 (0.196)		
R-squared	0.941	0.941	0.944	0.943
N	10,828	10,828	10,828	9940
1900 controls	No	No	Yes	Yes
Excluding dust bowl states	No	No	No	Yes

All regressions include fixed effects for county, time and fixed effects for each year*state. All regressions are weighted by the acres of farmland in 1900.

Standard errors are clustered at the county level.

* 10% significance.

** 5% significance.

*** 1% significance.

of the log of all low skill workers. The construction of a measure of labor supply in terms of the availability of low skill workers is motivated by the possibility that agricultural and low skill workers are substitutes.

All specifications include decade, county and state-by-year fixed effects. Column (2) adds, as an additional control, the predicted stock of either non-agricultural or high skill immigrants.³¹ These controls in column (2) are included to test whether the predictive power of the instrument is driven by the fact that in the computation of the 1900 location distribution of immigrants, non-agricultural and high-skilled workers were included. Column (3) includes the set of time varying county level controls built from interactions of decade dummies and the 1900 value of agricultural variables. Finally, column (4) is estimated after excluding all counties in states which were greatly affected by the Dust Bowl.

Panel A indicates that the first stage relationship between the instrument and the stock of immigrant agricultural workers is strong, even though the instrument was constructed using the 1900 location choices of immigrants of all occupations, not only those involved in agriculture. A predicted change of 1% in the stock of immigrant agricultural workers translates into a change in the actual number of immigrants farmers per acre of 0.3%. This result is robust to the inclusion of the predicted location of non-agricultural workers, the inclusion of time varying county variables and the exclusion of the states most affected by the Dust Bowl. The fact that the first stage estimate is relatively insensitive to the inclusion of proxy measures of county-level agricultural trends is reassuring. This lends support to the identification assumption that the instruments are uncorrelated with unobserved county-level agricultural trends.

Panel B shows the results of specifications in which the instrument is used to predict the total number of agricultural workers (both immigrants and natives). Although immigrants represent just 10% of all agricultural workers in our sample period, the change in the stock of all

agricultural workers per acre seems to be significantly driven by the immigrant flows. An increase of 1% in the predicted number of agricultural workers in a county translates into an increase of about 0.2% in the total number of such workers per acre in that county. Thus, these results suggest that the effect of the inflow of immigrants on the county-level endowment of labor was not completely undone by natives out-migrating from counties that have an immigrant influx. The reduction in the significance level of the coefficients with respect to Panel A is not surprising, as it can be explained by the inclusion of native agricultural workers in the dependent variable. While not reported, we find no significant correlation between our instrument and the log of the number of native farmers per acre. Finally, the instrument does not lose its predictive power when a control for the predicted stock of non-immigrant agricultural workers and the set of time-varying country-level controls are included.

The last panel presents the result of an analogous regression to that in Panel B, but the instrument allocates the national stock of low skill immigrants to predict the stock of all low skill workers. The results indicate that low skill immigrants had an impact on the endowment of low skill workers per acre, a result that is robust to all specifications except for the model in column (2) when the high skill workers control is included. This may be due to the fact that few immigrants over this period were high skill workers and thus this specification is highly demanding on the data. Reassuringly, the point estimate does not change very much, but the precision of the estimate falls significantly.

Thus, the first stage provides evidence in favor of the identification assumption. Nonetheless, even if this identification assumption is valid, the interpretation of the estimates still depends on the validity of the exclusion restriction. Specifically, our identification strategy assumes that the only casual channel through which the immigration shocks affect agricultural production decisions is by changing the availability of labor relative to land. However, if immigrants transformed agricultural outcomes by importing knowledge on agricultural practices from foreign countries, then our interpretation of the results would be inaccurate. We explore this potential channel in the next section. Given that our first-stage F-statistics are sometimes lower than what one would hope for in an IV setting, we will present the reduced-form F-statistics for all IV regressions. The reduced form is unbiased, thus providing us with a way to ensure that our results are not due to a weakness of our instruments.

5.2. Adjustments in crop choice

As we discussed in Section 2, local economies may have absorbed the labor supply shock generated by immigrant inflows by shifting production towards crops that employ labor more intensively. Table 3 presents the results of the estimates in which the outcome variable is the area planted with four types of crops –corn, wheat, hay and cotton–, as well as the area planted with no crops in the first 3 panels and the share of output value for these same crops in Panel D. For each outcome, the first column presents the regressions with the extensive set of fixed effects (i.e., year, county and state-by-year). The second column adds the time-varying controls and the last excludes observations of the Dust Bowl states. Panel A presents the estimates from an OLS regression. The results show that the correlation between the number of agricultural workers per acre and the share devoted to each crop is very small but in all cases positive, indicating that immigrants tended to locate in counties where crop production overall was growing. Panel B presents the results of instrumental variable (IV) models in which the instrumented endogenous variable is the log stock of all agricultural workers per acre. We find that within each state, an exogenous increase in the relative availability of agricultural or low skill workers of 1% results in a decline in the share of land allocated to wheat of 5 to 8 percentage points. This fall in the area devoted to wheat is in turn compensated by an increase in the share of land devoted to corn and hay as well as the share of land in which no crops are produced. This translates into

³¹ Predicted stocks of non-agricultural (high skill) workers are constructed using the formula in (2) where L_{jt} is the stock of non-agricultural (high skill) workers from ethnic group j in decade t .

Table 3
Effects on crop choice.

	Corn			Wheat			Hay			Cotton			No crop		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
<i>Panel A: OLS-share of farm acreage devoted to each crop</i>															
ln(Ag. workers/T)	0.008*** (0.001)	0.007*** (0.001)	0.007*** (0.001)	0.004*** (0.001)	0.003** (0.001)	0.002* (0.001)	0.002** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.017*** (0.002)	0.012*** (0.002)	0.012*** (0.002)	−0.040*** (0.006)	−0.035*** (0.006)	−0.035*** (0.006)
N	10780	10780	9892	10780	10780	9892	10780	10780	9892	10780	10780	9892	8085	8085	7419
<i>Panel B: IV — agricultural workers — share of farm acreage devoted to each crop</i>															
ln(Ag. workers/T)	0.057*** (0.019)	0.057*** (0.020)	0.062*** (0.021)	−0.054** (0.025)	−0.077** (0.033)	−0.067** (0.029)	0.018** (0.009)	0.013* (0.008)	0.014* (0.008)	−0.036 (0.030)	−0.046 (0.032)	−0.047 (0.031)	0.122* (0.066)	0.143** (0.073)	0.127* (0.067)
Reduced-form F-stats	29.81	28.73	40.45	9.49	15.76	14.14	8.07	3.69	4.45	2.46	4.20	4.62	7.62	12.53	10.05
N	10780	10780	9892	10780	10780	9892	10780	10780	9892	10780	10780	9892	8085	8085	7419
<i>Panel C: IV — low skilled workers — share of farm acreage devoted to each crop</i>															
ln(LowSkill/T)	0.059*** (0.022)	0.058** (0.025)	0.063*** (0.024)	−0.065* (0.029)	−0.102** (0.044)	−0.087** (0.035)	0.021** (0.010)	0.019* (0.011)	0.017* (0.009)	−0.046 (0.039)	−0.050 (0.043)	−0.043 (0.038)	0.152* (0.078)	0.195** (0.097)	0.163** (0.082)
Reduced-form F-stats	17.31	12.96	21.07	9.80	15.76	15.92	7.13	4.71	4.75	2.40	2.28	1.99	9.00	12.67	9.36
N	10828	10828	9940	10828	10828	9940	10828	10828	9940	10828	10828	9940	8121	8121	7455
<i>Panel D: IV — agricultural workers — share of crop value captured by each crop</i>															
ln(Ag. workers/T)	0.079** (0.041)	0.095** (0.046)	0.090** (0.043)	−0.082* (0.045)	−0.112** (0.055)	−0.115** (0.053)	−0.028 (0.070)	0.039 (0.072)	0.035 (0.070)	0.098 (0.099)	0.073 (0.098)	0.056 (0.095)			
Reduced-form F-stats	7.90	9.80	9.80	5.57	9.24	11.36	0.17	0.29	0.24	1.00	0.55	0.35			
N	10828	10828	9940	10828	10828	9940	10828	10828	9940	10828	10828	9940	8121	8121	7455
1900 controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Excl. Dust Bowl st.	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

The dependent variable is the share of total farmland allocated to each crop. All regressions include fixed effects for county and time and fixed effects for each year * state. Regressions are weighted by the acres of farmland in 1900. Standard errors are clustered at the county level.

* 10% significance.

** 5% significance.

*** 1% significance.

a decrease in the share of output value from wheat and an increase in the share of output value of corn. The effect is not significant for hay. The share of land allocated to cotton appears to decline, but the results are not statistically significant.³² In contrast, the share of output value of cotton rose in response to an exogenous shift in labor supply although not significantly. The impacts of changes in the relative availability of low skill workers presented in Panel C are of similar magnitude and signs to those in Panel B. In general, all results are insensitive to the inclusion of time varying county-level controls and to the exclusion of the states most affected by the Dust Bowl. F-statistics from the reduced form also suggest that our significance is not driven by weak instruments.

We also use “improved” acres as a measure of agricultural intensity on farms. We find that the share of total farm acres that are improved increased substantially when the number of agricultural workers per acre exogenously increases. The magnitudes are such that an increase in one worker per acre would lead to 20% more of a farmer’s land to be “improved”.³³

Using agricultural studies of the period, we assess the relative labor-intensity and degree of mechanization of each of these crops. Specifically, we use the result of the studies conducted by the National Research Project during the 1930s that determine the trends in the amount of labor used to produce corn, cotton, wheat and oats between 1909 and 1936 (Elwood et al., 1939; Holley and Lloyd, 1938; Macy et al., 1938). The estimations of labor requirements in these monographs were based on a retrospective nationally representative survey conducted by the National Research Project in 1936 and complemented with other secondary sources.³⁴ The studies show that the average number of hours of labor required to grow and harvest an acre of corn was 28.7 in 1909–1913 and 22.5 in 1932–1936. Cotton was by far the most labor intensive crop: labor requirements per acre ranged from 105 h in 1907–1911 to 88 h in the period 1933–1936. Production and harvesting of an acre of wheat required an average of 12.7 h of work in 1909–1913 and just 6.1 h in 1934–1936. Accounts from contemporary researchers and economic historians also show how these crops differed in their ability to integrate new technologies. Wheat stood out as the crop with fewer labor requirements and whose production suffered the greatest transformations in technology, as threshers, reapers, combiners and tractors were rapidly introduced (Olmstead and Rhode, 2008). In addition to the simplicity of the essential operations in the tasks required to produce wheat, the large scale of farms and the topographic characteristics of wheat producing regions facilitated mechanization and the use of tractors (see Olmstead and Rhode, 2001; Elwood et al., 1939; Holley and Lloyd, 1938; Macy et al., 1938). On the contrary, cotton stood out as the crop that mostly “resisted the tendency to mechanization in agriculture”. The literature has attributed this lag in cotton mechanization to the relative complexity of the operations associated with its production, the small scale of farms and the uneven terrain. It has also been argued that the long-term share tenancy contracts in cotton production may have reduced the incentives to adopt the existing technologies, which mechanized only specific stages of production leaving peaks in the labor requirements (for a discussion, see Whatley, 1987). Finally, the labor requirements of hay and corn were in between those of cotton and wheat (Elwood et al., 1939; Holley and Lloyd, 1938; Macy et al., 1938).

Since wheat was the less labor intensive crop in the study, the findings in Table 3 that show a decline in the area allocated to wheat are consistent with the framework in which there is free mobility of factors across sectors, as described in Section 2.1. Shifting production from

wheat to corn and hay is consistent with an environment in which the local agricultural economy absorbs an increase in labor supply by moving away from a more capital-intensive output mix and towards a more labor-intensive mix. The negative effect on cotton production, albeit not statistically different from zero, may be due to the high geographic concentration of cotton production in zones with limited immigrant inflows. Increases in the share of land with no crop production may be consistent with our framework if this farm area were mostly devoted to livestock and the labor requirements in this activity exceeds those of wheat.

In a more traditional “2 × 2” trade model, the shares of land devoted to each crop would respond more clearly than in the framework outlined earlier. We test this directly by grouping wheat and other crops in the low labor–land ratio group and cotton, hay and corn as the high labor–land ratio group. We also classify crops by their capital–labor ratios, where we group wheat and hay as more capital–labor intensive and corn and cotton as the least. We do this using both the historical accounts and the results we later estimated in Table 8. Table 4 shows that the results are consistent with the basic prediction of the “2 × 2” trade model, namely that when there is an increase in the labor–land ratio, relatively labor intensive sectors expand (whether measured in land allocated or share of crop value) and relatively less labor intensive sectors contract. Not all results are significant but they are all rightly signed. We only present the results using low skill workers as explanatory variables but the results are qualitatively similar and with the same sign, although a bit noisier, when the number of agricultural workers is used as the main variable in the regression. We find these results to be similar whether the endogenous variable is the share of land allocated, as in the top panel, or the share of crop value, as in the second. Thus, even if we had assumed away either land or capital, the results would be consistent with a reallocation across crops to those most intensive in labor in response to an increase in labor endowment.

Thus far, we have interpreted our estimates in light of a framework in which an immigration shock impacts agricultural production decisions by changing the relative endowment of labor inputs. However, one can consider two alternative causal paths that could explain our results. First, if the markets for crops were relatively local, immigrants may have demanded a different basket of consumption goods and thus could have affected the (local) crop prices. This is an unlikely channel since, already in this period, crop markets were nationally integrated and, in fact, prices were affected by global shocks. The impact of international price shocks on domestic producers over this period is well documented. However, to explore this possible channel, we constructed a proxy for the (log of) output price by dividing the value of crops by their physical output and tested whether (the log of) these unit values responded to the inflow of immigrants in Panel A of Table 5. In no case we observe that the price of output responded significantly to a change in the labor input at the county-level.³⁵

Second, changes in the availability of workers due to immigration may have affected agricultural outcomes if immigration involved a transfer of knowledge of agricultural practices. Indeed, economic historians have provided some anecdotal evidence suggesting this kind of mechanism. For instance, Olmstead and Rhode (2008) describe how German Mennonites, who migrated to the Great Plains in the late nineteenth century, introduced to the US the “Turkey” wheat, a kind of winter variety that was entirely new to North America. The introduction of “Turkey” wheat was a notable breakthrough that played a critical role in the successful spread of wheat cultivation to Kansas, Nebraska, Oklahoma and the surrounding region.

In Table Appendix B-2 we provide auxiliary evidence to assess the importance of this alternative causal channel. We re-estimate the

³² In addition, when we eliminate state-by-year fixed effects, that coefficient becomes positive although still not significant.

³³ Results are available upon request from the authors.

³⁴ The authors present very detailed estimates of labor requirements, that are disaggregated by regions, stages of production and production methods. They also report averages of total labor requirements at the national level. Calculations are done for several years, ranging from 1909 to 1936.

³⁵ One may fear that this non-significant result is driven by the fact that there is little variation in the data. However, only about 40 to 70% of price variation can be explained by county, year and state-year fixed effects (more in the case of hay prices, less in the case of wheat prices).

Table 4
Simplification with 2 sector-2 factors.

	High L/T			Low L/T			High K/L			Low K/L		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
<i>Panel A: IV — low skilled workers — share of farm acreage</i>												
ln(Ag. workers/T)	0.034 (0.029)	0.029 (0.033)	0.038 (0.030)	−0.234** (0.091)	−0.315** (0.125)	−0.281*** (0.106)	−0.044* (0.024)	−0.082** (0.038)	−0.068** (0.030)	0.012 (0.030)	0.009 (0.033)	0.020 (0.030)
N	10778	10778	9890	10778	10778	9890	10778	10778	9890	10778	10778	9890
<i>Panel B: IV — low skilled workers — share of crop value</i>												
ln(Ag. workers/T)	0.273** (0.136)	0.348** (0.163)	0.293** (0.137)	−0.014 (0.038)	−0.059 (0.046)	−0.066* (0.037)	−0.062 (0.089)	−0.033 (0.095)	−0.056 (0.087)	0.320** (0.158)	0.323* (0.167)	0.283** (0.143)
N	10826	10826	9938	10826	10826	9938	10826	10826	9938	10826	10826	9938
1900 controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Excl. Dust Bowl st.	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

The dependent variable is the share of total farmland allocated to group of crops in Panel A and the share of crop value captured by each crop in Panel B. All regressions include fixed effects for county and time and fixed effects for each year * state. Regressions are weighted by the acres of farmland in 1900. Low L/T crop include wheat and other crops while high L/T crops include cotton, corn and hay. High K/L crops include wheat and hay and low K/L crops include corn and cotton.

Standard errors are clustered at the county level.

* 10% significance.

** 5% significance.

*** 1% significance.

Table 5
Effects on crop unit values and productivity.

	Corn		Wheat		Hay		Cotton	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Panel A: Effects on crop unit values</i>								
ln(Ag. workers/T)	−0.618 (0.580)	−0.736 (0.628)	0.597 (0.658)	0.358 (0.456)	−0.607 (0.608)	−0.922 (0.698)	0.032 (0.164)	0.047 (0.254)
Reduced-form F-stats	1.51	1.99	1.21	0.66	1.41	2.95	0.04	0.03
N	7761	7761	6279	6279	10744	10744	2417	2417
<i>Panel B: Effects on crop productivity</i>								
ln(Ag. workers/T)	−0.145 (0.295)	−0.165 (0.303)	−0.319 (0.290)	−0.330 (0.286)	−0.166 (0.220)	−0.175 (0.238)	−0.010 (0.213)	−0.318 (0.272)
Reduced-form F-stats	0.28	0.35	0.92	1.10	0.64	0.66	0.00	2.40
N	10434	10434	9049	9049	10742	10742	3283	3283
1900 controls	No	Yes	No	Yes	No	Yes	No	Yes

The dependent variable is the log physical output per acre for each crop in Panel B and the log of the value of the crop per unit of physical output of that crop in Panel A. All regressions include fixed effects for county and time and fixed effects for each year * state.

Standard errors are clustered at the county level.

*: 10% significance, **: 5% significance, ***: 1% significance.

main results in this paper but we modify the baseline Eq. (3) and introduce interactions between the measure of agricultural labor $\log L_{CST}/T_{CST}$ and dummy variables which indicate whether the major ethnic group migrating to the region is of German or British origin.³⁶ Thus, with these interactions we test if the impact of immigration-induced labor supply shocks varies according to the origin of the most prevalent immigrant group. If a transfer of knowledge is the main channel driving our results and if immigrants from different origins bring knowledge to different practices, then the regional impacts should depend on the origin of the immigrant groups. The results in Appendix Table Appendix B-2 show that differences between the two major ethnic groups are not statistically significant, with the exception of the share of cotton, a margin that appears to have been subject to larger adjustments in counties located in states with a high concentration of German immigrants. In

the case of all other outcomes, adjustments in mostly German counties are not statistically different from adjustments in mostly English counties. We interpret this as evidence against the hypothesis according to which the observed adjustments in crop mix are explained by an inflow of agricultural knowledge brought by immigrants.

5.3. Alternative adjustments

Shifts in crop mix as those described in subsection 5.2 are just one possible mechanism to absorb immigration-induced labor supply shocks. Agricultural economies may also adjust to changes in labor supply by changing the organization of production towards more labor-intensive techniques. In this section we look for evidence of this type of adjustments by estimating effects on farm size, tenancy and the mechanization of draft power. However, due to the fact that these variables are not measured within-crops but at an aggregate level, any evidence of adjustments in these margins is empirically confounded with shifts in crop mix. For instance, reductions in farm area may be reflecting changes in crop composition towards crops that use land less intensively.

Table 6 presents the results of the estimations. The first two columns show results of the models of the number of farms per acre (inverse of

³⁶ We build these dummy variables using information on the country of origin of immigrants arriving to each state. Immigrants who were born in Australia, English Canada, England, Scotland, and Wales are classified as having a English origin, while those coming from Austria, Germany, Luxembourg, Netherlands and Switzerland are classified as having a German ancestry. We then build a dummy variable that identifies states in which either of these groups represented the majority of immigrants. We focus on these two ethnic groups since they represented the main ethnic group in the majority of states during our reference period.

Table 6
Effects on other margins of adjustments.

	Log farms per acre		% Operated by owner		% Operated by tenant		Log tractors per animal	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Panel A: OLS</i>								
ln(Ag. workers/T)	0.250*** (0.028)	0.233*** (0.028)	0.009 (0.009)	0.012 (0.009)	0.011 (0.008)	0.008 (0.008)	0.041 (0.059)	0.047 (0.056)
N	10780	10780	10780	10780	10780	10780	10778	10778
<i>Panel B: IV – Agricultural workers</i>								
ln(Ag. workers/T)	0.415** (0.143)	0.416*** (0.150)	−0.109 (0.088)	−0.150 (0.105)	0.038 (0.039)	0.050 (0.043)	−0.824 (0.829)	−0.877 (0.804)
Reduced-form F-stats	3.92	4.00	2.46	3.84	1.08	1.74	1.32	1.66
N	10780	10780	10780	10780	10780	10780	10778	10778
<i>Panel C: IV – Low skilled workers</i>								
ln(LowSkill/T)	0.471** (0.193)	0.554** (0.215)	−0.085 (0.105)	−0.133 (0.129)	0.015 (0.045)	0.028 (0.052)	−1.179 (1.136)	−1.373 (1.186)
Reduced-form F-stats	3.06	3.65	0.85	1.54	0.11	0.29	1.49	1.90
N	10828	10828	10828	10828	10828	10828	10826	10826
1900 controls	No	Yes	No	Yes	No	Yes		

The dependent variable is the log number of farms in columns (1) and (2), the share of farms operated by owners and by tenants in the next four columns and the log of tractors per animals (horses and mules) in the last two. All regressions include fixed effects for county and time and fixed effects for each year * state. All regressions are weighted by the acres of farmland in 1900.

Standard errors are clustered at the county level.

* 10% significance.

** 5% significance.

*** 1% significance.

the average size of a farm). Estimates of models in which the outcome variables are the share of farms operated by owners and tenants are shown in the next four columns and those in which the outcome is the tractors/animal ratio are in the last two. As in previous tables, Panel A presents OLS estimates while Panels B and C show IV estimates of the effects of agricultural and low skill workers, respectively.

Results in the first two columns of Panel A show that, when comparing counties within the same state, an increase in the number of agricultural workers per acre in a county is associated with smaller farms. These OLS estimates are smaller than the IV coefficients in Panel B, suggesting that immigrant agricultural workers are disproportionately located in counties that have small farms. As shown in the first two columns of Panel B, the causal impact of a 1% increase in the number of workers per acre is an increase of 0.4% in the number of farms per acre. Results omitted here suggest that this decline in the average size of a farm is driven by a decline in the number of farms of more than 175 acres and an increase in the number of medium sized farms (50 to 100 acres).

The evidence of a reduction in average farm size is consistent with a relative decline in the use of more mechanized techniques. As discussed above, economic historians have documented that a larger farm size facilitated the adoption of mechanized farming technologies, such as tractors. However, these adjustments in farm size may also be reflecting shifts in crop mix out of crops such as wheat, which were more capital-intensive and more likely to be produced in relatively larger farms.

The next four columns in Table 6 show that, at the county level, there is no significant impact of changes in labor availability on the nature of the farm operators. A shift in the operation from the hands of the owner into those of the tenant and manager would have been associated with mechanization, to the extent that tenancy contracts were typical of thin labor markets with higher incentives for labor-saving technological investments. However, we don't see evidence of a statistically significant shift in this direction. Comparisons with the OLS estimates in Panel A are an indication that immigrant agricultural workers are more likely to be located in counties where more farmland is operated by tenanted farms.

Finally, the last column measures whether the ratio of tractors to draft animal changed in response to exogenous shifts in l , as a way to measure “capital deepening”. The OLS estimates suggest there is no

significant correlation between higher labor-to-land ratios and the relative importance of tractors compared to draft animals. The IV estimate is also relatively large: an increase of 1% in the number farm workers per acre reduced the number of tractors to draft animal by about 1%, but the estimate is not statistically different from zero. Once more, the table indicates that the results are not altered by the inclusion of time-varying county-level controls.³⁷ Results in Panel C are similar to those in Panel B.

Overall, these results suggest that changes in the relative availability of agricultural labor had a more marginal impact on the organization of agricultural production than on output choices, consistent with the hypothesis that crop choices were able to absorb a lot of the shift brought about by immigration.

5.4. Additional testable implications

Having shown that crop choice was significantly impacted by the exogenous change in labor availability, we now turn to explore additional predictions that were derived in the conceptual framework. At the end of Section 2.1, we enumerated several testable predictions that are consistent with a model in which the local economy is able to absorb an inflow of labor via shifts in output mix. In Section 2.2 we explain what would happen in a world where specificity prevents output (crop) choices from fully absorbing changes in labor endowment. In this section we examine these predictions empirically to see whether we see more similarity with a model where factor price insensitivity holds or one where prices do respond.

According to the first testable implication, if crop mix is able to absorb changes in input ratios, we should find a one to one correspondence between changes in the capital–labor ratio and changes in the labor to land ratio. Secondly, we should observe no change in the aggregate capital–land ratio when the labor to land ratio increases. The underlying argument behind these implications is that the local economy does not respond to an increase in labor supply shock by absorbing more capital.

³⁷ The exclusion of counties located in states greatly affected by the Dust Bowl also has no impact on the estimation. These results are not presented in the table for space constraints but are available upon request.

Table 7
Effects on capital ratios.

	Capital–labor ratio			Capital–land ratio		
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A: OLS</i>						
ln(Ag. workers/T)	−0.730*** (0.030)	−0.754*** (0.030)	−0.748*** (0.031)	0.270*** (0.030)	0.246*** (0.030)	0.252*** (0.031)
N	10780	10780	9892	10780	10780	9892
<i>Panel B: IV – agricultural workers</i>						
ln(Ag. workers/T)	−0.920*** (0.251)	−1.041*** (0.272)	−1.052*** (0.266)	0.080 (0.272)	−0.041 (0.272)	−0.052 (0.266)
Reduced-form F-stats	12.53	13.54	14.67	0.09	0.02	0.04
N	10,780	10780	9892	10780	10780	9892
<i>Panel C – IV low skilled workers</i>						
Log(Low Skill/T)	−1.074*** (0.377)	−1.322*** (0.461)	−1.252*** (0.413)	−0.008* (0.348)	−0.151 (0.403)	−0.113** (0.365)
Reduced-form F-stats	9.00	9.67	10.11	0.00	0.16	0.11
N	10828	10828	9940	10828	10828	9940
1900 controls	No	Yes	Yes	No	Yes	Yes
Excluding dust bowl states	No	No	Yes	No	No	Yes

The dependent variable is the log of the capital–labor ratio (in the first three columns) and the log of the capital–land ratio (in the last three).

All regressions include fixed effects for county and time and fixed effects for each year * state.

Standard errors are clustered at the county level.

* 10% significance.

** 5% significance.

*** 1% significance.

To test these predictions (4. and 5. in Sections 2.1 and 2.2), we estimate the effects of the change in the labor–land ratio on the capital–labor and capital–land ratios. The results are shown in Table 7 and the panels are organized as in previous tables. Columns (2) and (5) correspond to estimates in which time-varying county controls are included while Columns (3) and (6) correspond to estimates that exclude states highly affected by the Dust Bowl. The results are in line with a case where changes in crop mix absorb the change in labor supply. IV estimates in Columns (1) to (3) report negative changes in the capital–labor ratio in response to an increase in the relative endowment of labor. An increase of one percent in the labor–land ratio leads to a fall in the capital–labor ratio of approximately one percent and we cannot reject the hypothesis that our estimates are equal to one. Moreover, in Columns (4) to (6) we see that a change in the relative supply of labor has no significant effect on capital–land ratios as predicted if output adjustments were fully able to absorb the shock to factor ratios. While this is consistent with a framework in which crop mix adjusts in response to labor supply changes, it could also simply indicate that capital cannot move between counties, in which case these are just mechanical results, so we consider this to be suggestive evidence.

A third prediction (2. in Sections 2.1 and 2.2) indicates that under price insensitivity, we should not find any impact of a change in labor endowment on crop-specific output ratios. While we do not have data on capital or labor by crop, we can compute land productivity using physical output per acre. The results, presented in Panel B of Table 5, suggest that immigration-induced changes in land-to-labor ratio did not have a significant impact on land productivity of each crop, consistent with the hypothesis that crop adjustment may have absorbed a large fraction of the change in input ratio.

The next prediction (3. in Sections 2.1 and 2.2) concerns the decomposition of the changes in aggregate factor endowment ratios between shifts in crop mix, holding factor ratios constant for each crop, and shifts in factor use ratios within crops. We can express the aggregate level of capital–land (k) and labor-to-land (l) ratios as the weighted average of the ratios within each crop/method of production

$$j = \sum_i \omega_i j_i, \quad (5)$$

where $j = l, k$ is the aggregate factor ratio, j_i is the factor ratio of crop i ,

and ω_i is the land share of crop i . We can decompose, akin to an Oaxaca decomposition (Oaxaca, 1973), the aggregate change in capital–land ratio into two components: that accounted for by changes in the ratios within each crop i and that accounted for by changes in the relative importance of each crop

$$\Delta j = \sum_i [\Delta \omega_i * j_i] + \sum_i [\omega_i * \Delta j_i]. \quad (6)$$

We can also derive the equivalent expression for elasticities as

$$\frac{\Delta \ln j}{\Delta \ln l} = \frac{\sum_i \Delta \omega_i j_i}{j * \Delta \ln l} + \frac{\sum_i \omega_i \Delta j_i}{j \Delta \ln l} \quad (7)$$

With some algebra we obtain

$$\beta = \underbrace{\frac{\sum_i \theta_i j_i}{j}}_{\text{Shifts in crop mix}} + \underbrace{\Psi}_{\text{Shifts within crops}} \quad (8)$$

where β is the elasticity of j with respect to L/T ; Ψ is the second term at the right hand side of (6); and θ_i is the change in ω_i in response to a change in log of L/T .³⁸ We can obtain estimates of the parameter β from the results in Table 7 and can also make an estimation of the first term to the right hand side of (8), which captures the component of β that is accounted for by shifts in crops. θ_i can be simply obtained from Table 3 and we need to obtain proxies of j_i by crop.

To do this, we use the fact that within each county, the following relationship $j = \sum_i \omega_i * j_i$ for $j = k, l$ must hold. By combining the data on all counties in 1910, we obtain an estimate of the factor intensities relative to land within each crop as the parameter $\hat{\delta}_i$ in the linear regression below.

$$j_c = \sum_i \delta_i (T_{ic}/T_c) + \varepsilon_c \quad \text{for } j = k, l \quad (9)$$

where c corresponds to each county in our sample. The fundamental assumption for this methodology is that any unobservable characteristic

³⁸ More specifically, this is $\theta_i = \frac{(\Delta \omega_i)}{\Delta \ln(L/T)}$.

Table 8
Within crop factor intensity estimates and decomposition.

	Capital/land	Labor/land	Δ land	% change in k	% change in l
	(1)	(2)	(3)	(4)	(5)
Wheat	0.946	0.000	−0.102	−3.600	−0.000
Corn	2.522	0.030	0.058	5.487	12.229
Hay	19.338	0.034	0.019	14.545	4.540
Cotton	4.112	0.105	−0.050	−7.742	−36.896
No crop	0.154	0.012	0.195	1.090	16.445
Other crop	7.463	0.013	−0.120	−31.684	−10.963
Aggregate	2.631	0.014	0.000	−15.100	100.00
Predicted by crop change (including cotton)				−20.748 [−82.7, 45.2]	−14.646 [−67.8, 55.7]
Predicted by crop change (excluding cotton)				−13.353 [−80.2, 59.3]	22.250 [11.1, 37.9]

The first two columns correspond to the coefficients of a regression of the county-level factor ratio on the share of land devoted to each crop in 1910. The last two columns use these factor ratios multiplied by column (3) and divided by the aggregate factor ratio as listed in the bottom row. Finally, the change in land allocations corresponds to the estimates of Panel C which controlled for 1910 characteristics but included all states in Table 3.

that may alter a county's aggregate factor ratio is uncorrelated with the way the production is distributed across crops within that county. The results of this exercise are presented in the first two columns of Table 8 where the units are per acre of land. The last row of the two first columns depicts the average aggregate factor ratio in 1910 for consistency with the rest of the values. We find our results to be consistent with the historical account we presented above: the ranking of crops in terms of their factor ratios is similar to the one presented in Section 5.2. However, we also find some reasons to be cautious about these estimates. First, for farm sizes and tenancy regimes, we are able to repeat this exercise and compare it to the actual 1910 factor ratio within each type of farm (on average in the United States) since this number is published by the Census of Agriculture. We do not find our estimates to be very close to the “real” average factor ratios. Secondly, we find our estimates of labor-to-land ratio potentially more subject to measurement error as our capital-to-land ratio per county comes from the Census of Agriculture while our labor-to-land ratio per county comes from a 1% sample of IPUMS where individuals self-identified themselves as farm workers. It seems to us that this may be introducing more measurement error than the estimates for capital-to-land ratios. Finally, it is possible that our estimation suffers from some endogeneity bias if, for example, counties with higher labor to land ratios are exactly the ones specializing in crops that have higher labor requirements. As a demonstration of these potential problems, the actual estimate of l for wheat using Eq. (9) was negative. Thus, to obtain the results in Table 8 we force estimate of l for wheat to be almost 0. We have also estimated a number of different specifications for our robustness exercises and in some cases, more factor ratios are estimated to be negative.

Despite these concerns, we pursue our decomposition exercise with these estimates. The last two columns of Table 8 present the percent changes in capital-to-land and labor-to-land ratio that one could expect from the change in land allocation we measured in Table 3. It is thus the product of the coefficients from column (3) with the factor ratios from the first 2 columns divided by the average aggregate factor ratio as detailed at the bottom of the table. The fall in the share of acres of wheat, for example, would have caused a 3% decrease in the capital-to-land ratio but no significant change in the labor-to-land ratio. This is repeated for all crops. The last two rows sum the effects for all crops. Here we present totals with and without cotton, since the point estimate of the change in acreage of this crop was not significant. We

present the estimates derived from Panel C of Table 3 and explore alternatives in Table Appendix B-3.

This assumes that we know for sure θ_i and crop-specific factor intensity. However, both of these are estimated and not known. To capture the impact of that uncertainty, we repeated the estimation of each of the parameters θ_i and j_i by bootstrapping 100 times.³⁹ We then combined the 100 parameter estimates of θ_i with each of the 100 estimates of j_i to obtain 10,000 estimates of our decomposition exercise. We present in brackets at the bottom of the table the 95% confidence interval of our estimates.

For capital-to-land ratio, we find that the shift in output mix could explain a fall in the aggregate capital-to-land ratio of about 0.13 to 0.21%, depending on whether one includes the non-significant impact of cotton or not. We compare this to the small, non statistically significant estimates presented in Table 7. The results are similar in magnitude to the estimates in Panel C and larger than those in Panel B. This result suggests that most of the shift in K/T could be explained by changes in crop allocation, although the precision of our exercise is limited, given the confidence intervals presented. Also, notice that these results are different if we repeated the same exercise for farm size, since the changes observed in farm size would have actually increased the aggregate capital-to-land ratio instead of lowering it.⁴⁰

When we repeat the exercise for the labor-to-land ratio, our results are more sensitive to the assumptions. This is because the non-statistically significant decrease in the share of land devoted to cotton strongly alters the results. All the changes in labor reallocation across crops would have actually lowered the number of farmers per acre in each county according to this calculation. However, once we exclude the non-significant change in cotton acreage, we actually predict that a one percent increase in the number of low skill workers per acre in the county would have led to a 20% increase in the number of farmers per acre in that county, simply through its impact on crop acreage. The imprecision caused by the inclusion of the cotton estimation is visible in the confidence interval presented underneath the estimates. While when including cotton, our 95% confidence interval includes a large decrease in the factor ratio or more than 50% of the total change, when we exclude the cotton estimate, we obtain a confidence interval that includes only positive values and relatively narrow: between 11 and 38% of the change would have been absorbed by crop change. This would thus suggest that the impact we document on wheat, corn, hay and other crops was sufficient to absorb the 1/5 of the change in the aggregate farmers per acre observed. While we see this decomposition exercise as merely suggestive, it supports the evidence that a relevant fraction of the change in factor input could have been absorbed through changes in crop choice.

We explore how robust these results are in Table Appendix B-3. The first row repeats the results of Table 8. We then explore where the “variance” in our estimation comes from. The second row assumes that our estimates of k and l by crop were known exactly. The third assume, at the opposite, that our estimates from Table 3 are known exactly but that there is some noise in the estimation of k and l . Specifically, we use the set of 100 bootstrap estimates for either sets of parameters and the average of the bootstrap iterations for the other. We find that our estimate is noisy because of the randomness in our estimates from Table 3 and not because of the noise in the estimation of k and l which are rather precise. The confidence intervals of the second row are almost identical to the baseline one while the ones of the third are much more narrow. This suggests that incorrectly using the point estimates of Table 3 would lead us to overestimate the precision of our decomposition exercise. The next row explores the results when we use the estimates from Panel B instead of Panel C from Table 3. The results are

³⁹ Formally, we used a wild bootstrap of the residuals for the estimates of θ_i since we had issues with clustering and weighting. For estimating the j_i , we used a simple bootstrap of the X_s and ran a transformed model to capture the weights.

⁴⁰ Results available upon request.

Table 9
Effect on land unit value.

	Log per acre land value		
	(1)	(2)	(3)
<i>Panel A: OLS</i>			
ln(Ag. workers/T)	0.131*** (0.018)	0.119*** (0.018)	0.125*** (0.019)
N	8085	8085	7419
<i>Panel B: IV — agricultural workers</i>			
ln(Ag. workers/T)	0.249* (0.148)	0.149 (0.150)	0.147 (0.145)
Reduced-form F-stats	2.31	0.82	0.86
N	8085	8085	7419
<i>Panel C — IV low skilled workers</i>			
Log(Low Skill/T)	0.277* (0.160)	0.152** (0.185)	0.164 (0.170)
Reduced-form F-stats	2.16	0.55	0.76
N	8121	8121	7455
1900 controls	No	Yes	Yes
Excluding dust bowl states	No	No	Yes

All regressions include fixed effects for county and time and fixed effects for each year * state.

Standard errors are clustered at the county level.

* 10% significance.

** 5% significance.

*** 1% significance.

extremely similar for labor and slightly lower for capital (although in line with the estimates of Table 7 in Panel B for that variable).

We then change the way we estimate k and l to see how different the results may be. We find that, while in each iteration, the estimates are relative precisely estimated, they differ sufficiently between methods to change the magnitudes of our decomposition. The second to last row presents the results when k and l are estimated using 1910 data, as in our baseline, but this time without weighting the regression by the acres of farmland in 1910 like we had previously done, to keep consistency with the rest of the estimates. These results suggest that our decomposition for l is, if anything, strongly understating the potential role for crop mix adjustment. Under these estimates, we could explain up to 64% of the change in labor endowment through changes in crop mix and the confidence intervals even include more than 100%. The results for k , however, are less negative but equally noisy. Using estimates from the 1930 weighted data, as presented in the second to last row, leads to estimates that are larger in magnitude for k and lower for l . Finally, we also use only 1920 to estimate share effects as this guarantees that our shares actually sum to 1. The results are very similar in that case. Overall, we see these results as suggesting that in all cases, crop mix adjustments can have absorbed a relevant fraction of the change in labor endowment and that the results highly depend on the accuracy of factor ratios.

The final testable implication outlined in Section 2.1 states that if crop mix adjustments were sufficient to absorb most of the inflow of workers, factor prices should remain unchanged. Land is the only factor for which there is county-level data available over this period. We compute a proxy of per-acre land price by measuring the log of the value of farm land divided by the acres of farmland in the county. Table 9 presents the results in the same format as previous tables. The OLS estimates suggests a strong positive correlation between land prices and the number of agricultural workers per acre: more farmers live where the land unit values are larger. However, Panels B and C indicate that while we observe a significant causal increase in land prices in response to an increase in the number of workers per acre, this result is not robust to the inclusion of our 1900 controls nor to the exclusion of Dust Bowl states. Furthermore, the reduced-form estimates are not significant even in the two cases where the IV is marginally significant, suggesting that the results are not really statistically significantly different from 0 (the first stage is slightly different than the one we have used so far

Table 10
Heterogeneity by specific crop specialization.

	Corn	Wheat	Hay	Cotton
	(1)	(2)	(3)	(4)
<i>Panel A: share of land allocated</i>				
ln(Ag. workers/T) * specialized in that crop	0.013 (0.028)	−0.102 (0.062)	−0.008 (0.034)	−0.068 (0.047)
ln(Ag. workers/T) * Not specialized in that crop	0.056*** (0.020)	−0.077** (0.033)	0.013* (0.008)	−0.047 (0.032)
P-value difference	0.004***	0.650	0.501	0.319
N	10780	10780	10780	10780
<i>Panel B: land productivity</i>				
ln(Ag. workers/T) * specialized in that crop	1.891*** (0.639)	−0.444 (0.295)	−0.445 (0.274)	−0.530 (0.380)
ln(Ag. workers/T) * not specialized in that crop	0.694 (0.432)	−0.332 (0.286)	−0.177 (0.237)	−0.323 (0.276)
P-value difference	0.000***	0.467	0.330	0.112
N	10434	9049	10742	3283

The dependent variable in the first panel is the share of total farmland allocated to each crop.

The dependent variable in the second panel is the log physical output per acre for each crop.

All regressions include fixed effects for county and time and fixed effects for each year * state.

Standard errors are clustered at the county level.

* 10% significance.

** 5% significance.

*** 1% significance.

since we do not have land value data for 1940). Thus, we do not find strong evidence that land prices were robustly affected by factor input changes. To gather more evidence of possible factor price effects, we collected agricultural wage data at the state-level for the period 1910 to 1940. County-level data was not available, but we were able to digitalize monthly state-level wages without board for every state and decade in the period of study. This is obviously a very gross measure of the true variable we are interested in. In this case, the instrument is only strong enough to be exploited in models in which the labor supply is measured only with immigrant farmers and no natives. Thus, we ran the reduced-form and the IV using only immigrant farmers for 1910 to 1940.⁴¹ In both cases we found limited evidence of a negative impact of immigration on wages, and if anything the estimated coefficient is small, positive and insignificant. However, this exercise is done with only 192 data points and a methodology that is not the same as the one we used in the rest of this paper so we are more cautious in our interpretation and see it as suggestive evidence of limited wage effects.

Overall, the results presented in this section seem to support the hypothesis that the output mix adjustments we documented in Table 3 absorbed a significant part of the change in input mix in an average county. In the next section we further explore this issue by analyzing whether this general result may mask heterogeneous responses linked to cross-county differences in factor specificity.

5.5. The importance of specialization

According to the theoretical framework in Section 2.1, local economies where factor specificity is not a binding constraint and that are in the cone of diversification will absorb the increase in labor supply via output mix adjustments. Alternatively, adjustments can be made via changes within crops, such as altering crop-specific factor use ratios. We explore this issue by examining the margins in which counties with different measures of land specificity adjusted to immigration-induced labor supply shocks. First, we define a county as specialized in

⁴¹ Results not presented but are available upon request from the authors.

Table 11
Heterogeneity by overall crop specialization.

	Farms/acre	Owners	Tenants	Tractors/animal	K-L ratio
	(1)	(2)	(3)	(4)	(5)
ln(Ag. workers/T) * diversified	0.414*** (0.153)	−0.157 (0.108)	0.055 (0.045)	−0.937 (0.827)	−1.073*** (0.283)
ln(Ag. workers/T) * specialized	0.379* (0.194)	−0.255* (0.136)	0.115** (0.058)	−1.740* (1.023)	−1.507*** (0.356)
P-value difference	0.538	0.003***	0.001***	0.007***	0.000***

N = 10,780. The dependent variables are labeled in each column. All regressions include fixed effects for county and time, fixed effects for each year * state and interactions between 1900 characteristics and year dummies.

Standard errors are clustered at the county level.

* 10% significance.

** 5% significance.

*** 1% significance.

a particular crop if in 1900 it had more than 25% of its land in that particular crop. Then, we define a county as specialized if it is specialized in any crop in 1900, and as diversified if it is not specialized in any crop.⁴²

We start by estimating models in which the outcome variable is the share of land allocated to each crop, separating the data between counties that were and were not specialized in each given crop.⁴³ As can be seen in Panel A of Table 10, there is evidence that adjustments in the production of a given crop are observed in counties that were not specialized in that crop in 1900. Specifically, the only statistically significant estimates we observe for changes in the share of land devoted to a given crop are for counties not specialized in that given crop. Effects are also larger in magnitudes in non-specialized counties for corn and hay, although they are only statistically different in the case of corn. More consistently, as shown in Panel B, adjustments in productivity in specialized counties are larger in magnitude than in non-specialized counties. However, in this case, the two estimates are only statistically significant different in the case of wheat. This is consistent with the idea that specialized counties are more likely to rely on mechanisms other than crop mix changes to adjust their factor ratios in response to an increase in the relative endowment of labor. This is also consistent with our hypothesis that in diversified counties, output mix adjustments absorbed a larger fraction of the change in labor while in specialized counties, factor ratios within crop must explain a larger fraction of the adjustment.⁴⁴

⁴² We explored an alternative measure of specialization using the agro-ecological information for 1960–1990 computed by the Food and Agriculture Organization's (FAO) Global Agro-Ecological Zones (GAEZ) project. Using these measures we weren't able to replicate the patterns of specialization in wheat, corn, hay or cotton that we saw in the data. This is likely explained by the well documented processes of biological innovations that took place over the course of the 20th century and changed the patterns of agricultural suitability in the US. As discussed by Olmstead and Rhode (2008) the varieties of crops grown at the beginning of the 20th century were dramatically different to those grown in the later decades and these developments radically transformed the adaptability of crops to the local soil and climatic conditions. Nonetheless, we made the estimations and found similar but weaker results than those reported in Table 11. These results are not presented but are available upon request from the authors.

⁴³ These results were obtained by first obtaining the first stage for the full sample, obtaining the predicted value of the endogenous variable through it and then interacting this predicted variable with an indicator of specialization or diversity and using these interactions as instruments for our endogenous variable interacted with the same indicator of specialization or diversity. Wooldridge (1997) suggests this methodology is a more efficient way of estimating IV with interactions. Comparing these estimates with those of the aggregate sample in Table 3, however, will not necessarily lead the aggregate results to correspond to a weighted average of the divided ones because the instruments may have an effect on the “other” endogenous variable. The aggregate reduced form estimates, on the other hand, always correspond to a weighted average of the two reduced form estimates by specialization levels (results not presented here but available upon request.)

⁴⁴ We repeated our decomposition exercise of the previous section restricting ourselves only to counties not specialized in any given crop and found the results to be similar to the baseline estimates and similarly noisy.

We then explore in greater detail in Table 11 if there is any evidence of changes in modes of production in specialized counties. In particular, we test whether specialized counties, which should be less able to adjust through output mix changes, made greater adjustments in technologies and changed factor ratios more than counties that were diversified. The results of these estimations are also consistent with our hypothesis: counties that were more specialized in 1900 responded to the labor supply shock by altering the technologies and organization of their production to a greater extent than counties that were diversified. Specifically, we find that specialized counties had greater declines in their ownership and tenancy shares, tractors per animal (a more direct measure of technology adoption), and in the capital–labor ratios. All these differences are statistically significant. For farm size, however, the two types of counties appear to have responded in a similar way.

To confirm that the categorization between “specialized” and “diversified” counties is not artificial, we replicate the exercise but, instead, we separate counties between those that had larger or smaller farms on average in 1900. We find no evidence of similar patterns as those displayed in Table 11. We also separate the counties between high- and low-tenancy rate counties in 1990, and between those located in the South or non-South states, since tenancy incidence and region may be correlated with the degree of specialization. In both alternative classifications we find no evidence of a pattern that replicates the results obtained with our classification according to the degree of specialization.⁴⁵

6. Conclusions

We study how local economies in the US early 20th century responded to immigration-induced shifts in the total availability of workers. We focus on the agricultural sector and find that an important part of the adjustment to changes in labor supply took place via output mix, while adjustments in the organization of production played a smaller role. When comparing counties within a state, we find that increases in the labor supply of agricultural workers in a county (relative to farmland) led to land reallocation away from capital intensive crops and towards labor intensive ones. This result is predicted by trade theory, in an environment where factors are fully mobile so that the local economies can adjust their production mix in response to labor supply shocks. We provide auxiliary evidence against alternative causal channels through which immigration may have affected agricultural choices, such as the transfer of knowledge of international agricultural practices and demand-driven changes in local crop prices.

We empirically evaluate a set of implications that can be derived from a conceptual framework in which local economies adjust to increases in the relative availability of labor supply by shifting the output mix. The overall set of results is in line with the predictions. First, we look at the adjustments in the aggregate level of capital intensity and find that there appears to be no additional inflow of capital to the local economy in response to the shock. Auxiliary, suggestive evidence from a decomposition exercise is consistent with a scenario in which a relevant fraction of the change in input mix was absorbed via shifts across crops. Finally, we find only mild evidence of responses in the price of land (the only factor of production for which price data is available).

We then go one step further and separate counties according to their initial degree of crop specialization, suggesting some degree of land specificity. We provide some evidence indicating that, compared to counties with a high degree of specialization in a given crop, diversified counties were more likely to respond to a labor supply shock by shifting their output mix. In contrast, counties that were more specialized and, therefore, were more constrained to shift their crop mix, were more likely to adjust the organization and technology of production.

Our results highlight the role of changes in output mix and production techniques as mechanisms to adjust to an influx of labor inputs.

⁴⁵ The results of these estimations are not presented due to space restrictions, but are available upon request from the authors.

Furthermore, suggestive evidence conveys that, where possible, output mix adjustments were sufficient to absorb a relevant fraction of the inflow of workers, thus potentially leading to a more limited impact on local wages. In particular, and unlike the previous authors (e.g., Card and Lewis (2005), Lewis (2004), Dustmann and Glitz (2011), Gonzalez and Ortega (2011)), we find evidence of a relevant role for shifts in the output mix as a mechanism to absorb an increase in the availability of labor due to immigration. We highlight that we are able to find these effects in a context in which factor specificity (in this case, land) is low. More research is likely warranted in considering the specificity of factors in other sectors, like manufacturing, as well as the divergence between short-run and long-run adjustment mechanisms. This may explain results such as the one by Lewis, 2011, who finds that firms in the manufacturing sector changed their capital–labor ratio and lowered wages in response to the immigration flow. Further study of other sectors during this same historical period can also shed light on the role of other mechanisms in the adjustment to migration flows and the adoption of new techniques.

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Appendix A. Derivations from Section 2

Appendix A.1. Proof of Eq. (2)

The market clearing conditions for factors in this economy are

$$\sum_{i=1}^3 J_i = \bar{J}, \quad J = K, L, T.$$

where $\bar{J}$ is the endowment of factor J , and i indexes the crops. If we differentiate both sides of each of the three equations with respect to $\bar{L}$ we obtain that,

$$\sum_{i=1}^3 \frac{\partial T_i}{\partial \bar{L}} = 0 \quad (\text{A.1})$$

$$\sum_{i=1}^3 \frac{\partial K_i}{\partial \bar{L}} = 0 \quad (\text{A.2})$$

$$\sum_{i=1}^3 \frac{\partial L_i}{\partial \bar{L}} = 0. \quad (\text{A.3})$$

We also know that factor ratios within each crop will also remain constant. This implies that for each crop

$$k_i \frac{\partial T_i}{\partial \bar{L}} = \frac{\partial K_i}{\partial \bar{L}} \quad (\text{A.4})$$

and

$$l_i \frac{\partial T_i}{\partial \bar{L}} = \frac{\partial L_i}{\partial \bar{L}} \quad (\text{A.5})$$

Now we can combine Eqs. (A.1) and (A.2), and use (A.4) to obtain

$$k_1 \frac{\partial T_1}{\partial \bar{L}} + k_2 \frac{\partial T_2}{\partial \bar{L}} + k_3 \left(-\frac{\partial T_1}{\partial \bar{L}} - \frac{\partial T_2}{\partial \bar{L}} \right) = 0.$$

Similarly, if we use Eqs. (A.1), (A.3), and (A.5) we obtain

$$l_1 \frac{\partial T_1}{\partial \bar{L}} + l_2 \frac{\partial T_2}{\partial \bar{L}} + l_3 \left(-\frac{\partial T_1}{\partial \bar{L}} - \frac{\partial T_2}{\partial \bar{L}} \right) = 1.$$

Using these last two equations, we can find that:

$$\frac{\partial T_1}{\partial \bar{L}} = \frac{k_3 - k_2}{k_1 - k_3} \frac{\partial T_2}{\partial \bar{L}}$$

and that

$$(l_1 - l_3) \frac{\partial T_1}{\partial \bar{L}} + (l_2 - l_3) \frac{\partial T_2}{\partial \bar{L}} = 1$$

which combined, and with some algebra, gives us that

$$\frac{\partial T_2}{\partial \bar{L}} = \frac{k_3 - k_1}{k_1(l_3 - l_2) + k_2(l_1 - l_3) + k_3(l_2 - l_1)}$$

Using a similar derivation we can also obtain that

$$\frac{\partial T_1}{\partial \bar{L}} = \frac{k_2 - k_3}{k_1(l_3 - l_2) + k_2(l_1 - l_3) + k_3(l_2 - l_1)}$$

$$\frac{\partial T_3}{\partial \bar{L}} = \frac{k_1 - k_2}{k_1(l_3 - l_2) + k_2(l_1 - l_3) + k_3(l_2 - l_1)}$$

thus obtaining the results in Eq. (2).

A.2. Adjustments with capital flows: an example

In this example, we extend Lewis (2011) to a more general production function and a different set of inputs. Assume that there is one good and three production factors. The production function exhibits constant returns to scale. Land and labor endowments are fixed, but there is a perfectly elastic supply of capital at an exogenous rate of r , a common assumption in papers exploring similar mechanisms and in the immigration literature, see for example (Lewis, 2011).

Under these assumptions we have that

$$d \ln \left(\frac{\partial r}{\partial K} \right) = 0. \quad (\text{A.6})$$

With a constant returns to scale production function, this translates into:

$$d \ln K_i = \frac{L \frac{\partial^2 r}{\partial K \partial L}}{T \frac{\partial^2 r}{\partial K \partial T} + L \frac{\partial^2 r}{\partial K \partial L}} d \ln L + \frac{T \frac{\partial^2 r}{\partial K \partial T}}{T \frac{\partial^2 r}{\partial K \partial T} + L \frac{\partial^2 r}{\partial K \partial L}} d \ln T. \quad (\text{A.7})$$

and factor use will change in the following way:

$$d \ln K - d \ln L = - \frac{T \frac{\partial^2 r}{\partial K \partial T}}{T \frac{\partial^2 r}{\partial K \partial T} + L \frac{\partial^2 r}{\partial K \partial L}} (d \ln L - d \ln T) \quad (\text{A.8})$$

$$d \ln K - d \ln T = \frac{L \frac{\partial^2 r}{\partial K \partial L}}{T \frac{\partial^2 r}{\partial K \partial T} + L \frac{\partial^2 r}{\partial K \partial L}} (d \ln L - d \ln T) \quad (\text{A.9})$$

This will thus imply that aggregate capital-to-land ratios will not remain constant and the aggregate capital–labor ratio will fall by more or less than the shock to labor inputs depending on whether capital and land are q-substitutes or complements.

Appendix B. Additional tables

Table Appendix B-1

Most popular locations of various ethnic groups.

Rank	Mexicans	Poles	Japanese	Czechs	Germans	English	Irish	Scandinavians
1	Webb, TX	Cook, IL	King, WA	Cook, IL	Erie, NY	Bristol, MA	Worcester, MA	Douglas, NE
2	El Paso, TX	New York, NY	Sacramento, CA	Cuyahoga, OH	Hudson, NJ	Essex, MA	Essex, MA	Suffolk, MA
3	Bexar, TX	Wayne, MI	Multnomah, OR	New York, NY	Cuyahoga, OH	Erie, NY	Hudson, NJ	Otter Tail, MN
4	Starr, TX	Erie, NY	Solano, CA	St. Louis City, MO	St. Louis City, MO	Kings, NY	Allegheny, PA	Worcester, MA
5	Cameron, TX	Luzerne, PA	Yolo, CA	Lavaca, TX	Milwaukee, WI	Wayne, MI	Middlesex, MA	St. Louis, MN
6	Graham, AZ	Milwaukee, WI	Monterey, CA	Douglas, NE	Allegheny, PA	Philadelphia, PA	Cook, IL	New York, NY
7	Pima, AZ	Allegheny, PA	Chouteau, MT	Linn, IO	Philadelphia, PA	New York, NY	Suffolk, MA	Ramsey, MN
8	Maricopa, AZ	Kings, NY	San Bernardino, CA	Saline, NE	Kings, NY	Middlesex, MA	Kings, NY	Kings, NY
9	Zapata, TX	Cuyahoga, OH	Cook, IL	Ramsey, MN	Cook, IL	Cook, IL	Philadelphia, PA	Hennepin, MN
10	Nueces, TX	Philadelphia, PA	Pierce, WA	Tama, IO	New York, NY	Suffolk, MA	New York, NY	Cook, IL
Top 10	38.07%	51.04%	72.02%	52.73%	33.40%	26.61%	41.51%	22.03%

Table Appendix B-2

Heterogeneity by main ethnic group.

	(1)	(2)	(3)	(4)	(5)
	Corn	Wheat	Hay	Cotton	Farms per acre
<i>Panel A: effects on crop share and farm size</i>					
ln(Ag. workers/T)	0.061** (0.025)	−0.077** (0.038)	0.016* (0.009)	−0.055 (0.040)	0.370** (0.178)
ln(Ag. workers/T) * German	−0.047 (0.047)	0.002 (0.070)	−0.020 (0.029)	0.114* (0.062)	0.367 (0.333)
ln(Ag. workers/T) * Anglo	0.021 (0.059)	0.003 (0.068)	−0.016*** (0.051)	−0.096 (0.101)	0.141 (0.343)
N	10780	10780	10780	10780	10780
	Land by owners	Land by tenants	Horses	Mules	Tractors
<i>Panel B: effects on tenancy and draft power</i>					
Log(Ag. workers/T)	−0.19 (0.136)	0.059 (0.051)	−0.143 (0.180)	0.256 (0.313)	−0.911 (1.034)
ln(Ag. workers/T) * German	0.261 (0.190)	−0.070 (0.106)	0.224 (0.391)	1.197 (0.813)	1.878 (1.512)
ln(Ag. workers/T) * Anglo	0.301 (0.237)	−0.038 (0.153)	−1.502 (1.253)	1.628 (1.190)	−1.511 (2.294)
N	10780	10780	10780	10780	8085

The dependent variables are labeled in each column. All regressions include fixed effects for county and time, fixed effects for each year * state and interactions between 1900 characteristics and year dummies.

Standard errors are clustered at the county level.

* 10% significance.

** 5% significance.

*** 1% significance.

Table Appendix B-3

Robustness of the decomposition exercise.

	<i>k</i>		<i>l</i>	
	With cotton	Without cotton	With cotton	Without cotton
Baseline	−20.748 [−82.7, 45.2]	−13.353 [−80.2, 59.3]	−14.646 [−67.8, 55.7]	22.25 [11.1, 37.9]
Factor ratios are exact	−20.748 [−79.2, 44.4]	−13.527 [−73.8, 59.7]	−10.273 [−65.0, 54.3]	24.651 [12.9, 35.6]
Impact on shares is exact	−20.748 [−27.3, −14.9]	−13.527 [−19.6, −7.4]	−10.273 [−15.1, −5.2]	24.652 [20.2, 29.0]
Share impacts from Panel B	−15.765 [−45.7, 11.8]	−8.380 [−42.0, 21.4]	−16.002 [−45.5, 15.1]	19.716 [12.1, 27.6]
Unweighted 1910 factor ratios	−1.724 [−68.3, 48.6]	5.63 [−66.3, 63.9]	23.688 [−70.5, 153.9]	64.086 [16.2, 179.4]
Weighted 1930 factor ratios	−47.302 [−163.8, 85.5]	−42.914 [−163.3, 94.1]	−24.755 [−112.3, 39.5]	1.013 [−99.8, 88.0]
Share impacts excl. 1920	−15.689 [−60.8, 25.7]	−9.198 [−59.6, 38.8]	−14.086 [−50.7, 36.3]	21.339 [9.9, 31.2]

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