# More Hands, More Power? The Impact of Immigration on Farming and Technology Choices in US Agriculture in Early 20th Century*

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**Abstract**

How do local economies adjust to an inflow of immigrants in addition than through price adjustments? This paper answers this question in the context of US agriculture in the first three decades of the 20th century. We estimate, using the location of past immigrants as instrument for the location choice of new immigrants, its impact on a number of margins of adjustments (output mix, technological choices and organizational structure) at the county level using Census of Agriculture data. We find that larger immigrant flows led to slower adoption of labor-saving technologies, a decrease in farm size, an increase in the share of land cultivated by tenants and a shift towards more labor-intensive crops. Crop mix adjustments appear to have been more used by counties that were previously less specialized in a given crop while technological and organizational changes were preferred in counties that were particularly well-suited for a given production (and thus were constrained to making crop mix changes). Nevertheless, an increase in the number of workers per acre farmed in a particular country led the farms to a lower capital-labor ratio, even once accounting for changes in crop or tenure, suggesting that these adjustments we document did not fully absorb the increase in labor supply without impacting wages.

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# 1 Introduction

How do labor markets adjust to an inflow of new workers? This question has been the basic motivation of the literature (and the policy debate) regarding the impact of immigration in the United States and elsewhere in the world. While there is still a discussion about the precise estimates of the effect of immigration on native wages and employment, the overall conclusion implies, somewhat surprisingly, that there is a fairly small impact of immigration for natives. While some have suggested that this is because native workers, even those with skill-levels similar to those of migrants, are not perfect substitutes for immigrant labor (see for example Cortés 2008 and Peri 2009), others have argued that this may be explained by adjustments in other factors of production which attenuate the wage and employment effects of the inflow of workers.

One of the margins of adjustments at play that is often mentioned is that capital or technology will change in response to the skill/quantity of labor available, attenuating the potential effects on native employment and wages. For example, in response to an inflow of low-skill labor in the economy, firms may increase the production of goods and/or use technologies that are less capital-intensive and more labor intensive.[1] Furthermore, new technologies could even be endogenously generated in response to that inflow as in the theory of directed technological change of Acemoglu (2002). While changes in techniques or technology adoption are an interesting hypotehsis, identifying this channel in today's economy poses some problems. First, most immigrants work in the services sector where techniques and capital are difficult to measure. Second, current immigrant waves do not represent a large fraction of employment in the manufacturing sector where the data is available. However, Lewis (2011), using data from the Survey of Manufactures for the late 1980s and early 1990s, finds that immigration-induced increments in the relative supply of low-skilled labor made firms less likely to adopt automation machinery. The results in this paper also extend the results in Lewis (2011) to a different sector and historical period, and extend them also by looking at organizational choices and the size of firms (farms in our setting).

This paper examines how firms, or farms in this specific case, adapt to changes in labor supply driven by flows of immigrants arriving to a local labor market. The early decades of the twentieth century provide an interesting setting in which this analysis can be conducted for several reasons. First, immigration flows over this period were large (with foreign born population representing a larger fraction of total population than it is today), making this a context from which lessons are potentially relevant for today's markets. Second, the US economy at that time was much more concentrated in manufacturing and agriculture, two sectors in which capital and technologies can be more easily measured than in the services sector. Indeed, observing the adoption of technologies and the choice of crops in the agricultural sector is facilitated by

[1] The first mechanism corresponds to the Rybczynski theorem, the standard adjustment mechanism to changes in relative endowments in HeckscherâĂŞOhlin in trade models.

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 of various crops. Furthermore, during this period a large number of immigrants were working in the agricultural sector (although an even larger number of immigrants worked in the manufacturing sector): 17 percent of all migrants arriving during this period were farmers in their country of origin, and more than 10 percent of the immigrants in the United States reported to be farm workers.[2] Finally, the period from 1910 to 1940 is particularly appealing for two additional reasons. First, the fact that the "frontier" was almost completely established, limited the incorporation of new land as a mechanism to absorb the inflow of immigrant workers. Second, this is a period in which important technological transformations became available to farmers with the arrival of the combustion engine and tractors as a new source of draft power.

**Overview.** In this paper we examine whether, between 1910 and 1940, immigration-induced shocks to the (relative) supply of low-skilled labor caused farms in the United States to modify their choice of crops and production technology. In our empirical section we consider a variety of adjustment mechanisms through which farms can respond to an increase in the relative availability of labor and try to assess the importance of crop choice and technology-related for understanding the mechanisms of adjustment.

We approach this question by thinking of local labor markets as small open economies with access to a similar set of production technologies. In this context, the effects of an increase in the endowment of labor depend on whether capital and technology can be adjusted. First, if neither capital nor technology can adjust, an increase in labor should lead to a fall in the capital/labor ratio, a decrease in wages and an increase in the overall production through a scale effect. The capital/output ratio would also fall as output would rise.

In the case in which capital is mobile but the production technology cannot be adjusted, the impact of an inflow of workers will greatly depend on whether labor is complementary or substitute to the other two factors: land and capital. When capital, land and labor are complementary, we would observe that as the number of workers per acre rise, the capital-labor ratio decreases and the capital-land ratio increases. The capital-output ratio may increase or decrease but the wage would certainly fall, and the magnitude of the wage decline will be greater in the case in which capital does not adjust. If local economies are capable of changing their production mix, we would expect capital to reallocate across sectors 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 in the relative factor prices. Finally, the economy could also respond to the immigrant flow by slowing the adoption of labor-saving technology.

[2]According to authors' calculations using Census micro samples for 1910 to 1940, and the Reports of the Commissioner for Immigration between 1900 and 1930.

This simple framework thus gives us the key elements to identify the sources of adjustments in the early 20th century US agriculture. With this framework in mind, we estimate the impact of an immigration-induced shock to labor supply on the organization of agricultural production in the United States from 1910 to 1940. We use the Census of Agriculture from 1910 to 1940 to measure county-level data on several outcomes: scale of production, crop choice, draft power choice and direct measures of capital, output and land allocation.[3] We match each county to the number of farmers and low skill workers in this region, measured from the Census of the United States. We estimate the impact of an increase in the number of farm or low skill workers per acre of farm land in a county on the agricultural outcomes to account for the possible response in terms of land use and also to match the elements of our theoretical model. 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 estimates of the responses of capital, output mix and technology to changes in 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 allocate immigrants following the location of past immigrants. Furthermore, to avoid potential problems arising because of persistent shocks to agricultural markets we use the location of all past immigrants, regardless of their occupation and their sector of employment. Our instrument appears to be fairly strong and robust over this period, when used to predict the location of immigrant farmers, all (migrants and native) farmers and low-skilled workers per acre at the county level.

**Preview of the Results.** Our results suggest that immigration influenced the organization of agriculture in rural sectors of the United States in the early 20th century. We first present evidence that the share of land allocated to specific crops was altered by the endowment of agricultural workers. By comparing counties within a given state, we find that an increase in the relative availability of labor reduces the share of land allocated to wheat and increases the share of land allocated to hay and corn. A decline in land allocated to cotton is also observed, although with marginal significance. The organization of agricultural production (which may be akin to a change in "techniques") also appears to have been altered in response to the inflow of new workers. First, higher labor availability appears to have led to farms becoming smaller. A one percent increase in the number of farm workers per acre increase the number of farms per acre by 0.4 percent. This is mostly driven by the fact that very large farms (more than 175 acres) become less common at the expense of medium farms (50 to 100 acres). There is weaker evidence that the land in farms managed by tenants rather than owners increased as a result of a greater availability of labor.

We also look at measures of draft power that proxy for the adoption of mechanized technolo-

[3]Part of the data from these sources was digitalized for the purpose of this study.

gies and find evidence that the adoption of tractors was altered in response to the immigration-induced labor supply shocks. Specifically, we find that a one percent increase in the farmers-land ratio reduced the number of tractors per acre by 3.4 percent. We also find evidence of a negative impact on the number of horses per acre and of a positive impact in the number of mules per acre.

Our theoretical framework suggests that, in an environment with no adjustments in technology or production mix, the responses in capital-labor and capital-land ratios to a change in the labor-land ratio indicate the degree of complementarity or substitutability between inputs. The empirical results suggest a large degree of complementarity between land and capital and indicate that capital and labor over this period were mildly substitutable or neutral. We complement these findings with a decomposition exercise, in which we try to assess how much of the effects of labor shocks on input mix can be attributed to shifts in the method of the production and find that such shifts cannot explain the estimated effect on the capital-land ratio. Thus, the part of the observed change in the ratio of inputs appears to stem from changes in input ratios within a given method of production. Moreover, we observe changes in output productivity per crop and find no evidence of significant effects. Such results are consistent with previous findings indicating complementarity between land and capital and mild substitutability between labor and capital.

We provide some evidence against an underlying causal channel behind in which immigrant farmers affect agricultural practices via a transmission of knowledge. We also study whether the estimated effects are heterogenous along several dimensions and find evidence suggesting that in counties where tenancy was more frequent there are larger responses to changes in labor supply. This may be explained by the fact that these agricultural economies were characterized by thin labor markets, making them more susceptible to shocks in labor supply.

The results in this paper taken altogether indicate that, while output and production changes were able to absorb part of the labor supply shock induced by the arrival of immigrant farmers over the period, these adjustments seemed to have insufficient to completely attenuate the impact on factor prices. Thus, it is unlikely that wages did not fall in response to the change in relative factor endowment brought about by immigration.

**Layout.** 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. 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 3 we present the empirical strategy and in section 5 we show the main results. Finally, in section 6 we present the conclusions.

## 2 Theoretical framework

### 2.1 An agricultural production function

We propose to conceive the agricultural production as a function that combines 3 inputs, labor (L), capital (K) and land (T), as $Y = F(L, K, T)$. Assume that the function $F(\cdot)$ displays constant returns to scale in its arguments. Since we will study the agricultural production of a county within the United States, we will assume that capital is supplied elastically to that market and that the interest rate is fixed at the national level. This implies that:

$$d \ln \left( \frac{\partial Y}{\partial K} \right) = 0 \tag{1}$$

Using the characteristics of the constant returns to scale function, this translates into:

$$d \ln K = \frac{L \frac{\partial^2 Y}{\partial K \partial L}}{T \frac{\partial^2 Y}{\partial K \partial T} + L \frac{\partial^2 Y}{\partial K \partial L}} d \ln L + \frac{T \frac{\partial^2 Y}{\partial K \partial T}}{T \frac{\partial^2 Y}{\partial K \partial T} + L \frac{\partial^2 Y}{\partial K \partial L}} d \ln T \tag{2}$$

We can then derive the following expressions, which describe the impact of a change in the endowment of labor per land on the capital-to-labor and the capital-to-land ratios:

$$d \ln K - d \ln L = - \frac{T \frac{\partial^2 Y}{\partial K \partial T}}{T \frac{\partial^2 Y}{\partial K \partial T} + L \frac{\partial^2 Y}{\partial K \partial L}} (d \ln L - d \ln T) \tag{3}$$

$$d \ln K - d \ln T = \frac{L \frac{\partial^2 Y}{\partial K \partial L}}{T \frac{\partial^2 Y}{\partial K \partial T} + L \frac{\partial^2 Y}{\partial K \partial L}} (d \ln L - d \ln T) \tag{4}$$

The denominators in equations (3) and (4) are positive if the production function displays decreasing returns to capital. Therefore, the signs of the numerators will indicate input complementarity and substitutability. Equation (3) shows that a decline in the capital to labor ratio in response to a shock to the labor per land endowment indicates q-complementarity between capital and land. Equation (4) shows that if the capital-land ratio increases in response to a rise in the labor-to-land ratio, then capital and labor are q-complementary. In this argument we are adapting from Lewis (2011) and extending the application to a more general production function and a different set of inputs.

Furthermore, this setting implies that if both capital and labor and capital and land are q-complements, the output per labor ratio would fall and the output per land would increase in response to a shock to the labor per land endowment, since:

$$d\ln Y - d\ln L = \frac{(\alpha+\beta-1)L\frac{\partial^2 Y}{\partial K \partial L} + (\alpha-1)T\frac{\partial^2 Y}{\partial K \partial T}}{T\frac{\partial^2 Y}{\partial K \partial T} + L\frac{\partial^2 Y}{\partial K \partial L}}(d\ln L - d\ln T) \tag{5}$$

and

$$d\ln Y - d\ln T = \frac{(\alpha+\beta)L\frac{\partial^2 Y}{\partial K \partial L} + \alpha T\frac{\partial^2 Y}{\partial K \partial T}}{T\frac{\partial^2 Y}{\partial K \partial T} + L\frac{\partial^2 Y}{\partial K \partial L}}(d\ln L - d\ln T) \tag{6}$$

where $\alpha = \frac{L\frac{\partial Y}{\partial L}}{Y}$ and $\beta = \frac{K\frac{\partial Y}{\partial K}}{Y}$.

The sign of the capital to output ratio depends on the relative size of the two cross-derivatives. If capital and land are much more complementary than capital and labor, then capital-to-output ratio should fall.

Finally, in this setting, the wage response would depend on the relative level of capital and labor complementarity. Formally,

$$d\ln w = \left(\epsilon_{\alpha,L} + \frac{L\frac{\partial^2 Y}{\partial K \partial L}}{T\frac{\partial^2 Y}{\partial K \partial T} + L\frac{\partial^2 Y}{\partial K \partial L}}\epsilon_{\alpha,K}\right)(d\ln L - d\ln T) \tag{7}$$

where $\epsilon_{\alpha,x}$ represents the elasticity of $\alpha$ with respect to $x$. It is easy to show that $\epsilon_{\alpha,L} < 0$ and that the sign of $\epsilon_{\alpha,K}$ depends on whether capital and labor are substitutes or complements in the production function. If capital and labor are neither complements nor substitutes in the production function, the wage would decrease by a factor depending of the elasticity of $\alpha$ with respect to L, that is, on how large are the decreasing returns to labor. If capital and labor are either strong substitutes or strong complements, the wage effect of a change in endowments will be greatly attenuated. When capital and labor are great substitutes, capital can adjust and thus diminish the impact of the inflow of workers on the wage. If capital and labor are great complements, the inflow of workers will lead to a strong positive response of capital and this will raise the productivity of each worker, thus diminishing the wage effect of the change in endowments.

## 2.2 Additional Considerations

The model put forth in the previous section considers a single good economy (or alternatively an economy where we can use an aggregate production function). However, in the standard trade models we need to take into account the possibility of having multiple goods being produced in each of the local economies. Thus, to interpret our empirical results we need to allow the inflow of labor to be absorbed into the economy by increasing the share of the production devoted to more labor intensive outputs or more labor intensive technologies. Such adjustments are predicted by the Rybczynski Theorem, a core result of Heckscher-Ohlin (HO) trade theory (Rybczynski, 1955). The present study provides suggestive evidence of whether such adjustments took place.

In this environment, capital and land within each industry would change in response to the inflow of workers, in a way such that the input ratios are fixed within an industry. Thus, as exogenous immigration shocks would not affect the capital labor ratios within each sector, wage and other input prices would remain fixed. Counties receiving more immigrants may absorb the extra labor by changing the output mix, mobilizing factors in favor of those crops that are labor intensive. There will be an expansion in the production of labor intensive crops (e.g., cotton) and a contraction in the production of capital intensive crops (e.g., wheat). These disproportionate changes in the output mix will be absorbed by imports and exports across regions. However, this result hinges on the assumption that technology does not change in response to the relative abundance of labor. It also assumes that each sector, or crop, cannot be produced using a different technique (or organizational structure) with a different input mix. If this option was available, counties may be able to hire the extra labor at the existing wage by increasing the relative use of labor intensive technologies. We now look for evidence of these patterns in the data.

## 3 Empirical Strategy

Having elaborated a simple framework that explains how immigration could impact output and technological choices of producers, we explore this relationship empirically in the context of agricultural local economies in the US in the early 20th century.

In the construction of our empirical model we should take into account the fact that natives may reallocate in response to an immigration inflow by leaving or slowing their migration to regions where immigrants are less concentrated. We address this issue by studying the impact of changes in *total* labor endowments, rather than on the endowments of immigrant labor. In this way, we take into consideration the effect of changes in labor endowment net of the reallocation of native workers.[4] Furthermore, since a easy adjustment mechanism would simply to change the amount of the fixed input (land) placed under cultivation, we will also account for the potential change in the size of the area farmed.[5] Finally, immigration could also induce a phenomena of outmigration to different economic activities, we will also, in some specifications, consider the

[4]In studies of contemporary immigration to the US, Borjas, Freeman, and Katz (1997) and Cortés (2008) provide evidence that immigration leads to a displacement of natives. However, if the displacement is less perfect then immigration inflows effectively translate into higher labor supply, as it appears to be the case in our sample.

[5]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.

full stock of low-skill workers to account for the potential change in occupations generated by the immigration.

Our main estimation equations is:

$$y_{ist} = \theta \log \frac{L_{ist}}{T_{ist}} + \beta' \log X_{ist} + \nu_i + \mu_t + \upsilon_{st} + \epsilon_{ist} \quad (8)$$

where the left hand side variable is an agricultural outcome observed in year $t$, state $s$ and county $i$. $L_{ist}$ represents the corresponding measure of labor supply which can either be the stock of all farmers or the stock of low skilled workers in county $i$. The variable $T_{ist}$ measures the area devoted to farmlands in each county. The term $X_{ist}$ is a vector of county level time-varying controls. The terms $\nu_i$ and $\mu_t$ are, respectively, county and year specific fixed effects and $\upsilon_{st}$ is a vector of state-by-year fixed effects. Regressions are weighted by the size of the farmland in 1900 and standard errors are clustered at the county-level to adjust for heteroscedasticity and within-county correlation over time.[6]

The coefficient of interest is $\theta$, which we interpret as the effect on agricultural decisions of a change in the endowment of labor per area of farmland generated by a shock from immigration. Estimates of $\theta$ based on OLS regressions are unlikely to be informative of the causal effect of labor supply since workers potentially select their location based on unobserved determinants of agricultural outcomes. In addition, agricultural production over this period was hit by a variety of shocks which we need to account for. We first explain our strategy for the first problem and then detail our handling of the second.

### 3.1 Instrumentation

The main issue with the estimation of (8) is that immigrants may very well select their location based on time-varying demand determinants that influence agricultural outcomes at the county level. To deal with this, we exploit exogenous variation in the county-level stock of immigrants and use it to predict the relative level of agricultural labor in each county. 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), and Lewis (2011).

Formally, the instrument for the logarithm of the stock per acre of all farmers or low-skill

[6]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.

workers per acre in county $i$ and year $t$ is:

$$\log\left(\sum_j \frac{N_{jsi,1900}}{N_{j,1900}} L_{jt} / T_{i,1900}\right) \tag{9}$$

where $N_{jsi,1900}$ is the stock of immigrants from ethnic group $j$ in state $s$ and county $i$ in 1900; $\frac{N_{jsi,1900}}{N_{j,1900}}$ is the fraction of immigrants from ethnic group $j$ that were located in county $i$ in 1900; and, $L_{jt}$ is the stock of farmers or low-skill workers from ethnic group $j$ in the United States in decade $t$ and $T_{i,1900}$ is the acres farmed in 1900. Thus, the instrument uses the 1900 distribution across counties to allocate the national stock of immigrants in each decade. Note that with this instrument, the stock of farmers/low-skill workers will be predicted using the 1900 ethnic group distribution of *all immigrants* as opposed to the ethnic distribution of *immigrant farmers*. This is done because we may suspect that the location choice of immigrant farmers in 1900 could be more related to anticipated changes in agricultural practices than that of all immigrants. Furthermore, it assumes away land allocation responses to the change in labor input, because those may very well be a response to the labor flow.

Two requirements should hold for our identification strategy to be valid. First, the total national stock of immigrant farmers 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 over the next decade. Note that the 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 distribution of 1900 immigrants within each state affect county-level agricultural outcomes at time $t$. As was discussed above, the instrument uses the past location choices of immigrants of all occupations, not only of those involved in agriculture. This reduces the concern that farmers in the past may have selected their location within each state anticipating changes in agricultural conditions. Furthermore, the location shares are obtained from Census tabulates, as opposed to micro-samples, making their measurement more reliable and thereby attenuating concerns of measurement-error bias.

### 3.2 Other confounding changes

Agricultural production over this period was subject to a number of shocks. The first two decades of the 20th century were characterized by agricultural prosperity, boosted by international demand for US agricultural products during the First World War. The period of prosperity in agriculture came to a precipitous stop in 1920 when agricultural prices suddenly dropped, in part due to a post-war decline in exports. The high level of farm mortgages accumulated during the previous decades led many farmers to bankruptcy. There was an increase in tenancy, since farmers who were forced from ownership had to rent land in order to continue farming. The agricultural south, the corn belt and the agricultural mountain states were particularly hit. By the end of the 1920s the low agricultural prices had not recovered and in fact were subject to greater downward pressure as the shift from horses to tractors increased supply. The onset of the Great Depression dramatically worsened the situation. Farm prices declined further, lowering the farmers' terms of trade by 37 percent 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). Moreover, there was great agricultural damage in the Great Plains region due to a major environmental catastrophe that became widely known as the "Dust Bowl" . Due to a severe drought and erosion, the soil was blown off from the fields in huge dust storms that, in some areas, removed almost 75 percent of the soil (Hornbeck, 2012).

In the 1920s the government responded to the difficulties in the agricultural sector with a series of policies aimed at increasing farm prices, such as subsidized loans to cooperatives that would buy and store agricultural produce. This proved insufficient, and a more aggressive supply intervention was implemented in 1933 as part of the New Deal. 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. 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.

Thus, this was a period of major transformations in the agricultural sector, some of which were fostered by international shocks or environmental phenomena. Moreover, these transformations affected regions differently, to the extent that natural and institutional conditions led to regional specialization in farming practices. To the extent that many of these events likely affected the location and production decisions made by farmers, they should be taken into account in our identification strategy, in which we make an effort to isolate the causal effect on agriculture of immigration-induced labor supply shocks from potential confounding factors.

First, we use a set of year fixed effects, $\mu_t$, to control for shocks that generate a co-movement of agricultural labor supply and agricultural patterns at the national level. In this way we attempt to isolate the impact of events such as the onset of World War I, which increased the price of US crops and affected the availability of labor at a national level. Second, time-invariant county-specific characteristics that determine the location patterns of agricultural workers are controlled for with county level fixed effects, $\nu_i$. In this way, confounding factors such as the geographic conditions that jointly influence agricultural practices and the location choices of farmers (e.g., rivers, weather, distance to the coast) are controlled for.

Since one can consider several sources of unobservable regional time-varying shocks that might have simultaneously determined agricultural outcomes and the location of farmers, we include state-year fixed effects in the regression $v_{st}$. This means that we will only be exploiting cross-regional variation *between counties within a given state*. Our identification strategy will therefore not be affected by, say, state level policies such as the AAA that simultaneously affected crop choice and agricultural employment. It would be, however, if specific programs were implemented at the county level but we found no indication of this by looking at the historical literature.

Nevertheless, there may still be confounding shocks associated with the within-state location decision of farmers in 1900 and with the relative agricultural performance of counties within a state over the following decades. To account for these confounding factors, 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. Below 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 suggests a threat to the validity of the identification assumption.

Finally, we also explore whether our results are sensitive to the exclusion of the states most affected by the Dust Bowl (Oklahoma, Kansas and Nebraska).[7]

## 4 Data and Descriptive Statistics

The above empirical strategy will be conducted using county data of all US states except for Hawaii, Alaska and the District of Columbia between 1910 and 1940. However, county boundaries changed over this period, with some counties merging or ceasing to exist. We therefore

[7] Hornbeck (2012) details that counties with the highest erosion levels were located in these three states.

tracked all the boundary changes and grouped the counties whenever it was necessary to keep the unit of observation constant over time. We also exclude any county for which the number of predicted farmers (based on our instrument described below) was less than 0.1 (and any county where the number of low-skill was predicted to be less than 0.6 in regressions where that variable is used). This generated a balanced panel of 2,697 counties. The average number of counties by state is 58 with the smallest including only 3 counties (Delaware) and the largest, 235 (Texas).

### 4.1 Labor supply and immigration data

We use county level aggregate tables from the United States Decennial Population Census (100% summary tables) to record the number of farmers and low skilled workers in each county in the period 1910-1940. Since we are also interested in the stock of immigrant farmers in each county, we use the one percent micro samples of the 1910-1940 Integrated Public Use Microdata Series (IPUMS; see Ruggles, Sobek, Alexander, Fitch, Goeken, Hall, King, and Ronnander 2008) to identify immigrants who work as farmers. As is traditional in the literature, we define immigrants as individuals who are registered in the US Census and were born outside the US. Farmers are defined as individuals whose primary occupation, as reported in the Census, is being a farmer or a farm laborer. Unfortunately, we are only able to compute county level stocks of immigrant farmers for the period 1910-1930 because the county identification variable is unavailable for 1940 but we can obtain the national flows necessary to build our instrument from that source.

To construct the shares employed in the construction of the instrument, we obtain data on the number of immigrants in every county by country of birth. This data is available in the 1900 Census county level tables, which are available in digital format at the National Historical Geographic Information System (NHGIS).

### 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. [8] 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.[9]

Our framework suggest that the first type of adjustment that one could expect is a change

[8] 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 in their digitalization for the purpose of this study.

[9] Expenses for labor is available but not in a digitalized format and the definition appears to have changed too many times over the period to make the comparison meaningful.

in output mix, which here corresponds to 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. [10] 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.[11] Finally, we can obtain a proxy for the price of each output in the county by dividing the value of the crop reported by the physical output of that crop.

Agricultural studies of the period help us understand the relative labor-intensity of each of these crops. The National Research Project conducted a series of studies during the 1930s to determine the trends in the amount of labor used to produce corn, cotton, wheat and oats between 1909 and 1936 (Elwood, Lloyd, Schmuts, and McKibben, 1939; Holley and Lloyd, 1938; Macy, Lloyd, and McKibben, 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. 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. 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 hours in 1907-1911 to 88 hours in the period 1933-1936. Production and harvesting of an acre of wheat required an average of 12.7 hours of work in 1909-1913 and just 6.1 hours in 1934-1936. Furthermore, these crops differed in their ability to integrate the 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). The accounts from contemporary researchers and economic historians state that, 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 (Olmstead and Rhode (2001) and Elwood, Lloyd, Schmuts, and McKibben (1939); Holley and Lloyd (1938); Macy, Lloyd, and McKibben (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

[10] 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.

[11] We use the historic CPI series provided by the Minneapolis Fed in http://www.minneapolisfed.org/

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, Lloyd, Schmuts, and McKibben, 1939; Holley and Lloyd, 1938; Macy, Lloyd, and McKibben, 1938).

Regional specialization in the production of crops also characterized early 20th century agriculture, driven in part by the suitability of the agricultural land in each region for a given type of production. While the South concentrated in cotton, the region spanning from North Dakota to Texas constituted the Wheat Belt and the region spanning from eastern Nebraska to Ohio specialized mostly on corn.

We are also interested in measures of the scale and the organization of agricultural production as they may also be a way of changing the way a given output is produced. 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.[12]. We also use data on the number of farms by type of operator; this is, the number of farms per county that are operated by owners, tenants or managers.[13] Evidence suggests that large farms and farms cultivated by their owner are likely to be more 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.

To proxy for changes in input choices, we measure draft power that are built from data on the number of horses, mules and tractors in each county. 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. From 1920 onwards there was a dramatic transformation in the use of combustion engine draft power. While only 4 percent of farms in 1920 had a tractor, by 1940 this fraction had increased to 23 percent. 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). This shift from animal draft to tractors has been documented as one of the most important technological innovations in modern agriculture (see, for instance, Cochrane 1993 and

[12]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.”

[13]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".

Olmstead and Rhode 2001). 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).[14] The diffusion of tractors was very rapid, although there was a significant variation in the pace of the adoption across regions. The Pacific and West North Central regions were leaders in the 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). Thus, we explore how the substitution of animal draft power by tractors was affected by an increase in the amount of labor, since this shift represents capital upgrading or technology adoption. County level data on the number of tractors started being reported in the Census of 1930 and 1940. There is, however, information on the total number of tractors in the United States in 1920, which amounted only to 200 tractors. Since the national number of tractors is very low, we use zeroes as a proxy of the number of tractors in every county in 1920.

Finally, we exploit additional data in 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 choose the value of implements and machinery to measure the stock of capital in the farms. County level measures of this outcome were available in digital format and were also deflated as explained before.

### 4.3 Summary Statistics

Table 1 gives main summary statistics for the population characteristics and agricultural outcomes in the 1910-1940 sample of counties. On average, there was a stock of 451 immigrant farmers in each county, a number that corresponds to approximately 10 percent of the total stock of farmers per county. Farmers represent about 45 percent of all low-skill workers in a given county and the county-level stock of low-skill workers is, on average, 9418.

Counties have on average 2566 farms and 473 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 brushland are also included in the Census. Thus, even though the land devoted to the four main crops amounts to 82% of the total crop area, it only constitutes 30% of the total farmland, as is shown in Table 1. There is a large variation in these measures by county. An average of 21 bushels of corn per acre was produced while wheat offers an average of 13 bushels per acre. An average acre of hay produced 1.3 ton and one of cotton, about 0.4 bales. Data for crops is missing for several states in which no cotton or wheat production was reported.

[14] 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 percent 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).

Farms over this period were very large. More than 50 percent of all farms had an area greater than 100 acres. Sixty-four percent of farms were farmed by their owner and 31 percent by tenants.

The value of implements and machinery in 1910 dollars was 426 per worker and 3.66 per acre. Horses, over this period, were still the major source of draft power with close to 7,000 on average in a county for only 1,900 mules and 400 tractors. Large variations are observed across states.

# 5 Results

## 5.1 First stage

Estimation of the first stage of equation (8) 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 where the left-hand side variable is the log number of immigrant farmers. This panel has fewer observations than the subsequent ones because it only includes 1910-1930, since in 1940, we are unable to identify immigrant farmers within each county. Although this variable will not be used as an endogenous regressor, we wanted to show that the strength of our first stage comes naturally from the fact that we can predict the location of immigrants using our instrument (and less so of natives). Panel B presents the results of a first stage in which the left-hand side variable is the log number of all farmers, (both native and foreign) and Panel C presents the first-stage results when the left-hand side variable consists 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 farmers and low-skill workers are substitutable. All specifications include decade, county and state-by-county fixed effects. Column (2) adds, as an additional control, the predicted stock of either non-farmers or high-skill immigrants.[15] These controls are included to verify if the predictive power of the instrument is driven by the fact that in the computation of the 1900 location distribution of immigrants, non-farmers and high-skill 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 mostly affected by the Dust Bowl.

The first panel indicates that the first stage relationship between the instrument and the stock of immigrant farmers is strong, even though the instrument was constructed using the 1900 location choices of immigrants of all occupations, not only of those involved in agriculture, and that we only exploit labor input variation and ignore land adjustments. A predicted change of 1 percent in the stock of immigrant farmers translates into a change in the actual number of

[15]Predicted stocks of non-farmers (high-skill workers) are constructed using the formula in (2) were $L_{jt}$ is the stock of non-farmers (high-skill workers) from ethnic group $j$ in decade $t$.

immigrants per acre of 0.3 to 0.4 percent. This result is robust to the inclusion of the predicted location of non-farmers, the inclusion of time varying county variables and the exclusion of the states more 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 favors 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 farmers (both immigrants and natives). Although immigrants represent just 10 percent of all farmers in our sample period, the change in the stock of all farmers seems to be significantly driven by the immigrant flows. The magnitudes of the coefficients are smaller, indicating that an increase in 1 percent in the predicted number of farmers in a county translates into an increase of about 0.2 percent in the number of total farmers 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. Immigration is associated with a change in the labor supply per acre farmed within each county. The reduction in the significance level of coefficients with respect to Panel A can be explained by the inclusion of native farmers in the dependent variable. Finally, the instrument does not lose its predictive power when a control for the predicted stock or the set of time-varying country level controls are included.

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

Thus, the first stage provides some evidence in favor of the identification assumption. The fact that the instrumental variables are relatively insensitive to an observed set of time-varying covariates, supports the assumption of exogeneity to unobserved time-varying factors. 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 have transformed agricultural outcomes by importing knowledge on agricultural practices from foreign countries, then our interpretation of the results would be inaccurate. In section 5.5, we provide an assessment of the importance of this alternative causal channel.

## 5.2 Adjustments in Crop Choice

As we discussed in section 2, the US agricultural economy may have absorbed the labor supply shock generated by immigrant inflows by shifting production towards goods that employ labor more intensively. In this case, we would expect that in response to an immigration-driven increase in labor supply, the acreage devoted to capital intensive crops decreases and that devoted to labor intensive crops declines.

Table 3 presents the results on the area planted for our four types of crops: corn, wheat, hay and cotton. For each crop, the first column presents the regressions with only our extensive set of fixed effects, the second adds the controls and the last excludes the Dust Bowl states. The first panel suggests that the correlation between the number of farmers 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 farmers per acre. We find that, within each state, an exogenous increase in the relative availability of farmers or low skill workers results in a decline in the share of land allocated to wheat and, marginally, to cotton. There is also an increase in the share of land devoted to corn and hay. The impacts of changes in the relative availability of low skilled workers is less precise but the magnitudes are very similar between the bottom two panels. 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.

The decline in wheat in response to the labor supply shock is consistent with our framework, since wheat is by far the less labor intensive crop in the study. The same cannot be said about the negative impact of labor supply in cotton, as this is the crop with the greatest labor requirements. The results remain the same if we restrict the sample to counties with strictly positive shares of any of the crops.

Aside from the channel we suggest, these results could be driven by two alternative mechanisms. First, immigrants may desire a different basket of consumption goods and thus influence the price of the different crops (if the market for crops is relatively local). To explore that, we used our proxy for the log of output price (constructed by dividing value by physical output) and regressed it on fixed effects by county and state-decade. Overall, this suggests that about 60-70 percent of price variation can be explained by these fixed effects (more so for hay, less so for cotton). This suggests that the assumption in our framework that prices are exogenously given and that the output market is not local may not be entirely accurate. We then test whether the price of the output responded to the inflow of immigrants in Panel A of table 4. The format of this table replicates that of the previous one except that it presents only IV results using the log of all farmers as the endogenous variable. In only one case do we observe that the price of output responded significantly (and marginally so) to a change in the labor input at the county level. This suggests that there is little evidence that the immigrants change crop allocation through a price mechanism or that the crop allocation change was large enough to alter the local prices of the crop.

In addition, an inflow of immigrants could change the crop mix within a county if they change the productivity of the production function of a given crop either because they are not perfect substitutes with natives as workers or because they also bring with them knowledge about production techniques that they knew from their own country. Panel B of table 4 explore this hypothesis by estimating the causal effect of a change in the labor input with the land productivity (measured as physical output per acre) for each crop. Once more the table reveals little evidence of a pattern. This reinforces our argument that it is probably because some crops were more able to absorb the inflow of labor than others that we observe such a change in the crop mix in each county.

### 5.3 Adjustments in the organization of production

Agricultural economies may absorb an immigration-induced labor supply shock through adjustments in the organization of production. In this section we examine whether such adjustments took place using as outcome variables farm size and tenancy. As discussed above, economic historians have documented that a larger farm size facilitated the adoption of mechanized farming technologies, such as tractors. Moreover, tenancy arrangements have been shown to have an influence on mechanization, to the extent that long-term tenancy contracts reduced the incentives for labor-saving technological investments.

We start by studying the impact of labor supply shocks on farm size. The first two columns of Table 5 present the results of models on the number of farms per acre (the inverse of the average size of a farm). Columns (3) through (12) show estimates of models of the share of all farms by size category: very small (less than 20 acres), small (between 20 and 50), medium (between 50 and 100), large (between 100 and 175) and very large (more than 175 acres). Panel A presents OLS estimates of the correlation between farm scale and the stock of farmers per acre while Panel B shows IV estimates of the effects. Finally, Panel C presents the IV estimates of the effect of low-skill workers.

Results in Panel A show that, for comparisons within the same state, an increase in the number of workers per acre in a county is associated with smaller farms. These OLS estimates are smaller than the IV coefficients, suggesting that immigrants are disproportionately located in counties that have small farms. The causal impact of a change of 1 percent in the number of workers per acre is a change in 0.4 percent in the number of farms per acre, as can be seen in the first two columns. Subsequent columns suggests that this shift is driven by a decline in the number of very large farms and an increase in the number of medium sized farms. Once more, we find the results not to be altered by the inclusion of time-varying county level controls. [16]

More evidence of changes in the organization of production is presented in Table 6 where we now look at tenancy decisions. Panels in this table are organized in the same way as in Table 5. IV estimates in Panel B indicate that an increase of one percent in the stock of farmers per acre lead to an increase of 0.07 percent in the share of land tenanted and a decrease of approximately 0.2 percent in the share of land farmed by the owner. The effects on the fraction of farms operated by managers are not statistically different from zero but are also positive. The effects of changes in the endowment of low skilled workers in Panel C have similar magnitudes but much less statistical power. Comparisons with the OLS correlations in Panel A are an indication that immigrant farmers are more likely to be located in counties where more farmland is operated by tenanted farms.

Overall, these results indicate a change in the way the agricultural production was organized. In response to an increase in the number of farmers per acre, farms shrunk and more farmland was operated by tenants rather than by owners. This evidence of changes in scale and tenancy is consistent with a scenario in which farms adjusted to an immigration-induced change in the relative endowment of agricultural labor by electing ways to arrange production that was more labor-saving.

### 5.4 Adjustments to Input Mix

In this section we directly test whether there is evidence that farms responded to the inflow of labor by also changing their input mix. Table 7 reports the estimates of regressions of the use of horses, mules and tractors. The number of observations in the tractors models is significantly lower because there are no observations for 1910.

The first panel reports OLS results indicating that agricultural workers tend to locate in counties where there is a large number of horses and mules per acre. However, the IV estimates in Panels B and C show that a larger endowment of agricultural or low skilled workers per acre leads to a decline in the relative number of tractors and an increase in the number of mules. While the estimates of the model of horses are negative, they are not significantly different from zero. Overall, the results in table 7 are consistent with a framework in which farms adjusted to an immigration-induced labor shock by slowing the adoption of labor saving technologies. In this case, they appear to have slowed down the shift from mules to tractors.[17] These results are

[16] The exclusion of counties in Dust Bowl states also has no impact on the estimation. These results are not presented in the table for space constraints but are available upon request.

[17] Mules were most common in the south, where their prevalence increased over time reflecting a substitution away from horses and oxen. Mules were stronger and more durable than horses, and were typically sold by higher prices(Olmstead and Rhode, 2008).

not robust to the addition of controls or to the exclusion of Dust Bowl States.

We now use a general measure of capital (i.e., the real value of implements and machinery used in agriculture) to examine adjustments in capital intensity. Table 8 presents the results of estimates of changes in the capital-labor and capital-land ratios in response to changes in the labor-land ratio. The first panel shows the OLS results while Panel B presents IV estimates of the causal impact of having more farmers per acre. Panel C shows IV estimates of an analogous model in which the endogenous variable is the number of low-skill workers per unit of land. 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.

IV estimates in columns (1)-(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 about 1.1 to 1.3 percent and has no significant effect on the capital-land ratio.

### 5.5 Further explorations

Thus far, we have interpreted our estimates in light of a framework in which an immigration shock affects agricultural production decisions by changing the relative endowment of labor inputs. However, one can consider an alternative causal path, aside from this labor supply mechanism, that explains our results. In particular, changes in the availability of workers due to immigration may affect agricultural outcomes if immigration involves a transfer of knowledge on agricultural practices. Indeed, economic historians have provided some anecdotal evidence that suggests 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 was critical in the successful spread of wheat cultivation in Kansas, Nebraska, Oklahoma and the surrounding region.

In Table 9 we provide auxiliary evidence to assess the importance of this alternative causal channel. We re-estimate the main results in this paper but modify the baseline equation 8 by introducing interactions between the measure of agricultural labor $\log \frac{L_{ist}}{T_{ist}}$ and dummy variables that indicate if the major ethnic group migrating to the region is of German or British origin.[18] Thus, with these interactions we test if the impact of immigration-induced labor supply shocks

[18]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 only since they represented the main ethnic group in the majority of states during our reference period.

varies by 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 on different practices, the regional impacts should depend on the origin of the immigrant groups. There is no evidence of a difference between counties that had a high concentration of either ethnic group.

At a theoretical level we can think that the capacity of adjustment through output mix depends on how productive a county is in the production of a given crop. We explore whether there is any evidence of this by classifying counties by high or low producers of a given crop in 1900.[19] The intuition is that, if a county was particularly well suited for a crop, their capacity to change their output mix may be much more limited. This is explored in Table 10 where two outcomes (land shares and land productivity) are explored. The results appear to match the intuition we provided: all counties that were particularly specialized in a given crop in 1900 increased the land allocated to that particular crop when faced with a larger number of farmers per acre. In the cases of crops where we found an increase in shares in the overall set of counties, counties that were high producers increased the share of land devoted to these crops more than counties that were less suitable for it. In the cases of crops where, in aggregate, land shares fell, that is only observed among low producing counties. We strongly reject the equality of the two sets of coefficients for all crops.

We explore whether this also translates into a larger use of changes in technology for specialized (who cannot adjust as much through output mix changes) than for diversified counties. A specialized county is defined as one who had, in 1900, more than TC% of its production in a given crop. The results are presented in Table 11. The results are overwhelmingly consistent with our hypothesis: counties that were more specialized in 1900 responded to the immigration shock by altering the organization of their production more than counties that were diversified. They increased the number of farms per acre more importantly, shifted more intensively from owner to tenants, turned away more from tractors and more towards mules. All these differences are highly statistically significant.

To confirm that this separation was not artificial, we repeated the exercise by separating counties between those that had, on average, larger and smaller farms in 1900. We found no evidence of the pattern presented above. We also separated the counties between high and low tenancy and South and non-South, both which are somewhat correlated with specialized and diversified counties. The differences are much less stark than those presented in the previous table although for some outcomes, the difference is statistically significant.[20]

[19] Carolina, we need the definition of what is a high and low producing county here.
[20] Results not presented but available upon request.

### 5.6 Impact on aggregate factor prices

The main limitation in the interpretation of the results is the assumption that we are observing shifts in input within a particular output or method of production. As an alternative, we perform a simple back-of-the-envelope exercise in which we try to assess how much of the observed change in the input ratio caused by shifts in the relative endowment of labor can be explained by changes in the method of production. Ideally, we would perform such exercise and decompose both the observed change in (K/T) as well as the change in (K/L). Unfortunately, with the information available we are only able to perform the analysis for the case of the capital-land ratio because we do not observe labor inputs by farm size and land ownership categories. Consider the following equation, in which we express the aggregate level capital-land ratio as the sum of the capital-land ratios within each method of production:

$$(K/T) = \sum_i \omega_i \frac{k_i}{t_i} \tag{10}$$

where $K/T$ is the aggregate-level capital-land ratio, $(k_i/t_i)$ is the ratio within a specific method of production $i$ and $\omega_i$ measures the relative importance of each method $i$ . We can decompose the aggregate change in capital-land ratio into two components: that accounted for by changes in the ratios *within each method of production i* and that accounted for by changes in the relative importance of each method:

$$\Delta(K/T) = \sum_i [\Delta\omega_i * (k_i/t_i)] + \sum_i [\omega_i * \Delta(k_i/t_i)] \tag{11}$$

We can obtain an analogous version of (11) in which we decompose the elasticity of $(K/T)$ with respect to $(L/T)$:

$$\frac{\Delta(K/T)}{(K/T)\Delta ln(L/T)} = \frac{\sum_i \Delta\omega_i (k_i/t_i)}{(K/T) * \Delta ln(L/T)} + \frac{\sum_i \omega_i \Delta(k_i/t_i)}{(K/T)\Delta ln(L/T)} \tag{12}$$

With simple algebra we obtain:

$$\beta = \underbrace{\frac{\sum_i \theta_i (k_i/t_i)}{(K/T)}}_{\text{Shifts in methods of production}} + \underbrace{\Psi}_{\text{Shifts within methods of production}} \tag{13}$$

where $\beta$ is the elasticity of $(K/T)$ with respect to $L/T$; $\Psi$ is the second term at the right hand side of (3)); and $\theta_i$ is the change in the of $\omega_i$ in response to a change in log of $L/T$.[21]. We can obtain estimates of the parameter $\beta$ from the results in table 8 and can also make an estimation of the

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

first term to the right hand side of 13, which captures the component of $\beta$ that is accounted for by shifts in the methods of production. If we use farm size and tenancy as proxy measures of each method of production, then an estimate of $\theta_i$ can be obtained from the estimated regressions in section 5.3 while the rest of the terms can be obtained from the Census reports of 1900.

As shown in column (5) of Table 8), the estimated elasticity of $(K/T)$ with respect to $(L/T)$ is -0.216 in the model with controls although it is not significant. This would correspond to the total effect as measured at the left hand side of equation 13. When we try how much of this adjustment can be explained by changes in farm size, we find that the documented effect of immigration on farm size cannot explain this pattern as very large farm sizes had the smallest amount of measured capital per acre in 1900 and thus that the shrinking of farm size would have lead to an increase in the $K/T$ ratio of 0.62. This is consistent with the "inverse relationship" between farm size and productivity observed in almost all contexts. Thus, this would suggest that the estimate obtained must be driven by the fact that within each farm size, increase in labor availability led to a large decrease in the capital to land ratio. When looking at the role of changes in tenure of the land, we observe that the shift away from land cultivated by owners to land cultivated by tenants would have led to a decrease in the capital to land ratio as tenants (and even more so managers) used less capital on their land in 1900. However, the fraction of the total effect that could be explained by this shift would be very small (-0.04 out of -0.216) suggesting that the estimated coefficient is not driven by changes in land tenure. These calculations suggest that, while shifts in crops and methods of production seem to have played an important role in absorbing changes in labor supply, the adjustments in input use within a given production method were also important.

This thus implies that the wage of workers would have fallen in response to the inflow of immigrants since the capital-labor ratio within each production/crop appears to have fallen.

## 6 Conclusions

We present evidence that an immigration-induced increase in the stock of workers per acre led to changes in crop choice and in the organization of production in agriculture during the first decades of the 20th century in the United States. We find that within a state counties in which immigration stocks per acre increased, there was a decline in the land allocated to wheat (which was the most easily mechanizable and less labor intensive crop) and an increase in land allocated to corn and hay. A negative adjustment in cotton was also observed at marginally significant levels. We also present evidence indicating that an increase in the relative availability of labor led to a reduction in the average farm size, a decline in the extent of farmland operated by owners, and an increase in the extent of farmland operated by tenants. Finally, we provide some evidence that a greater endowment of labor slowed down the adoption of tractors and increased the use of mules.

All these results are consistent with a framework in which a local agricultural economy responds to an increase in labor supply by shifting its crop mix and by slowing the adoption of labor saving methods of production. We explore an alternative causal channel in which the increase in labor supply is driven by a transfer of agricultural knowledge from immigrants and provide auxiliary evidence against this hypothesis. Thus, our results highlight the role of changes in output mix and production techniques as mechanisms to adjust to an influx of labor inputs. We also provide some evidence indicating that these responses to labor supply shock are larger in counties in which tenancy is a common institution, a finding that may be reflecting the thin labor markets that characterized these agricultural economies.

However, the negative impact of labor supply on the capital-labor ratio suggests that the shocks to the relative availability of labor were not entirely absorbed by changes in output mix and technological adjustments. Moreover, the results of the input-mix and the output-ratio regressions suggest that land and capital are complementary in production while labor and capital are mildly substitutable or neutral, which implies that the wage effects are not attenuated by adjustments in capital. However, these results are based on the assumption that each county can be represented by a unique aggregate production function, which is unlikely to be the case. We complement these findings with a decomposition exercise, in which we try to assess how much of the effects of labor shocks had on input mix can be attributed to shifts in the method of the production. Our findings provide suggestive evidence that these changes in the method of production do not fully explain the county-level changes we documented earlier. Overall, this set of findings suggests that wage effects from the immigration-induced labor supply shock were not completely attenuated by changes to the organization of production, a result that is relevant to academic and policy discussions about the labor markets effects of contemporary immigration.

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Table 1: Summary Statistis

| Variable | Mean | SD | N |
|---|---|---|---|
| **Labor supply measures** | | | |
| Stock of immigrant farmers | 451 | 966 | 8,108 |
| Stock of farmers | 4,258 | 3,689 | 10,786 |
| Stock of low skill workers | 9,418 | 23,021 | 10,786 |
| **Predicted labor supply** | | | |
| Predicted number of immigrant farmers | 348 | 1,588 | 8,027 |
| Predicted number of all farmers | 2,509 | 13,648 | 10,678 |
| Predicted number of low skill immigrants | 1,592 | 8,662 | 10,678 |
| **Land allocation and crop choice** | | | |
| Farms | 2,566 | 1,802 | 10,786 |
| Acres farmland | 473,034 | 481,474 | 10,786 |
| Share of total farm acres planted in corn | 0.11 | 0.10 | 10,764 |
| Share of total farm acres planted in wheat | 0.06 | 0.09 | 10,762 |
| Share of total farm acres planted in hay | 0.09 | 0.07 | 10,764 |
| Share of total farm acres planted in cotton | 0.04 | 0.08 | 10,764 |
| **Crop productivity** | | | |
| Bushels of corn per acre | 21.28 | 13.14 | 10,570 |
| Wheat productivity | 13.15 | 7.07 | 9,331 |
| Hay productivity | 1.28 | 1.77 | 10,722 |
| Cotton productivity | 0.36 | 0.20 | 3,349 |
| **Land size and tenancy** | | | |
| Share of very small farms (less than 20 acres) | 0.05 | 0.06 | 10,753 |
| Share of small farms (20 to 50) | 0.22 | 0.18 | 10,753 |
| Share of medium farms (50 to 100) | 0.19 | 0.10 | 10,753 |
| Share of large farms (100 to 175) | 0.24 | 0.11 | 10,753 |
| Share of very large farms (more than 175 acres) | 0.30 | 0.24 | 10,753 |
| Share of farms operated by owner | 0.64 | 0.15 | 10,753 |
| Share of farms operated by tenant | 0.31 | 0.15 | 10,753 |
| Share of farms operated by management | 0.05 | 0.10 | 10,753 |
| **Capital intensity** | | | |
| Capital-labor ratio | 425.74 | 356.81 | 10,698 |
| Capital-land ratio | 3.66 | 3.39 | 10,764 |
| **Draft power** | | | |
| Number of horses | 7,039 | 6.063 | 10,786 |
| Number of mules | 1,877 | 2,481 | 10,786 |
| Number of tractors | 396 | 606 | 8,080 |

Table 2: First Stage

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | **Panel A: Immigrant farmers** | | | |
| Log predicted stock of immigrant farmers | 0.338** | 0.450*** | 0.340*** | 0.386*** |
| | (0.133) | (0.167) | (0.127) | (0.131) |
| Log predicted stock of non immigrant farmers | | -0.189 | | |
| | | (0.214) | | |
| R-squared | 0.755 | 0.755 | 0.756 | 0.779 |
| N | 8108 | 8108 | 8102 | 7466 |
| | **Panel B: All farmers** | | | |
| Log predicted stock of immigrant farmers | 0.175*** | 0.235*** | 0.165*** | 0.181*** |
| | (0.065) | (0.075) | (0.063) | (0.067) |
| Log predicted stock of non immigrant farmers | | -0.112 | | |
| | | (0.099) | | |
| R-squared | 0.906 | 0.906 | 0.909 | 0.908 |
| N | 10786 | 10786 | 10778 | 9930 |
| | **Panel C: All low skilled workers** | | | |
| Log predicted stock of low skilled workers | 0.156** | 0.198 | 0.139** | 0.168** |
| | (0.065) | (0.177) | (0.062) | (0.067) |
| Log predicted stock of high skilled workers | | -0.052 | | |
| | | (0.189) | | |
| R-squared | 0.940 | 0.940 | 0.942 | 0.940 |
| N | 10786 | 10786 | 10778 | 9930 |
| 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

Table 3: Effects on crop acreage share

| | | Corn | | | Wheat | | | Hay | | | Cotton | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| **Panel A: OLS** | | | | | | | | | | | | |
| Log(Farmers/T) | 0.006*** | 0.006*** | 0.006*** | 0.005*** | 0.004*** | 0.002*** | 0.002** | 0.003*** | 0.003*** | 0.016*** | 0.011*** | 0.011*** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.002) | (0.002) |
| **Panel B: IV -farmers** | | | | | | | | | | | | |
| Log(Farmers/T) | 0.046** | 0.043** | 0.042*** | -0.061** | -0.089** | -0.076** | 0.025** | 0.019* | 0.018* | -0.060* | -0.062* | -0.060* |
| | (0.018) | (0.018) | (0.016) | (0.030) | (0.038) | (0.032) | (0.011) | (0.010) | (0.009) | (0.032) | (0.032) | (0.031) |
| **Panel C: IV-low skilled workers** | | | | | | | | | | | | |
| Log(LowSkill/T) | 0.052** | 0.043* | 0.042** | -0.075** | -0.122** | -0.093** | 0.026* | 0.023* | 0.020* | -0.075* | -0.071 | -0.064* |
| | (0.025) | (0.024) | (0.020) | (0.038) | (0.056) | (0.040) | (0.014) | (0.014) | (0.011) | (0.043) | (0.045) | (0.039) |
| 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 |
| N | 10764 | 10756 | 9908 | 10762 | 10754 | 9906 | 10764 | 10756 | 9908 | 10764 | 10756 | 9908 |

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

Table 4: Effects on crop prices and productivity

| | Corn | | | Wheat | | | Hay | | | Cotton | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| **Panel A: Effects on crop prices** | | | | | | | | | | | | |
| Log(Farmers/T) | 0.177 | 0.265 | 0.087 | -2.091 | -1.641 | -1.608* | -0.920 | -1.153 | -1.187 | -0.120 | 0.101 | 0.055 |
| | (0.465) | (0.413) | (0.391) | (1.403) | (1.020) | (0.886) | (0.692) | (0.774) | (0.753) | (0.506) | (0.532) | (0.528) |
| N | 7748 | 7778 | 7418 | 6457 | 6451 | 5842 | 10531 | 10523 | 9678 | 2430 | 2424 | 2373 |
| **Panel B: Effects on crop productivity** | | | | | | | | | | | | |
| Log (Farmers/T) | -0.225 | -0.192 | -0.080 | 0.166 | 0.072 | 0.201 | -0.189 | -0.191 | -0.127 | -0.109 | -0.331 | -0.300 |
| | (0.275) | (0.276) | (0.243) | (0.517) | (0.463) | (0.409) | (0.271) | (0.281) | (0.259) | (0.308) | (0.338) | (0.329) |
| N | 10470 | 10462 | 9620 | 9028 | 9020 | 8198 | 10526 | 10518 | 9674 | 3250 | 3242 | 3175 |
| 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 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

Table 5: Effects on scale of farms

| | Farms per acre | | Very small | | Small | | Medium | | Large | | Very large | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| **Panel A: OLS** | | | | | | | | | | | | |
| Log (Farmers/T) | 0.235*** | 0.220*** | 0.004 | 0.003 | 0.018*** | 0.014*** | 0.006*** | 0.006*** | 0.007*** | 0.010*** | -0.035*** | -0.033*** |
| | (0.027) | (0.027) | (0.002) | (0.002) | (0.004) | (0.004) | (0.002) | (0.002) | (0.003) | (0.003) | (0.006) | (0.006) |
| **Panel B: IV- Farmers** | | | | | | | | | | | | |
| Log (Farmers/T) | 0.368** | 0.375*** | 0.006 | 0.002 | 0.024 | 0.030 | 0.074*** | 0.072** | 0.029 | 0.052** | -0.134** | -0.156** |
| | (0.151) | (0.156) | (0.017) | (0.017) | (0.033) | (0.034) | (0.027) | (0.028) | (0.019) | (0.024) | (0.060) | (0.069) |
| **Panel C: IV-Low skilled workers** | | | | | | | | | | | | |
| Log (LowSkill/T) | 0.441** | 0.506** | 0.008 | 0.004 | 0.053 | 0.063 | 0.107*** | 0.112** | 0.022 | 0.061* | -0.191** | -0.240** |
| | (0.216) | (0.236) | (0.024) | (0.026) | (0.048) | (0.054) | (0.039) | (0.045) | (0.024) | (0.032) | (0.085) | (0.107) |
| 1900 controls | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes |
| N | 10753 | 10745 | 10753 | 10745 | 10753 | 10745 | 10753 | 10745 | 10753 | 10745 | 10753 | 10745 |

The dependent variable is the log number of farms in columns (1) and (2) and the share of total farms in each size category in columns (3) through (12). 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

Table 6: Effects on tenancy

| | Owner | | | Manager | | | Tenant | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| | | | | | **Panel A: OLS** | | | | |
| Log (Farmers/T) | 0.005 | 0.008 | 0.007 | -0.018 | -0.018 | -0.018 | 0.013* | 0.010 | 0.012 |
| | (0.008) | (0.008) | (0.008) | (0.012) | (0.012) | (0.013) | (0.008) | (0.008) | (0.009) |
| | | | | | **Panel B: IV- Farmers** | | | | |
| Log (Farmers/T) | -0.180* | -0.199* | -0.200* | 0.102 | 0.131 | 0.127 | 0.078* | 0.068* | 0.073* |
| | (0.100) | (0.111) | (0.108) | (0.085) | (0.098) | (0.093) | (0.042) | (0.040) | (0.039) |
| | | | | | **Panel C: IV- Low skilled workers** | | | | |
| Log (LowSkill/T) | -0.189 | -0.217 | -0.214 | 0.124 | 0.166 | 0.149 | 0.065 | 0.051 | 0.066 |
| | (0.126) | (0.146) | (0.131) | (0.119) | (0.143) | (0.126) | (0.051) | (0.050) | (0.046) |
| 1900 controls | No | Yes | Yes | No | Yes | Yes | No | Yes | Yes |
| Excl. Dust Bowl st. | No | No | Yes | No | No | Yes | No | No | Yes |
| N | 10753 | 10745 | 9897 | 10753 | 10745 | 9897 | 10753 | 10745 | 9897 |

The dependent variable is the log of the share of land farmed operated by each type of individual. 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

Table 7: Effects on draft power

| | Horses | | | Mules | | | Tractors | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| | | | | **Panel A: OLS** | | | | | |
| Log (Farmers/T) | 0.155*** | 0.147*** | 0.148*** | 0.192*** | 0.213*** | 0.215*** | 0.039 | 0.083 | 0.089 |
| | (0.026) | (0.026) | (0.028) | (0.041) | (0.040) | (0.042) | (0.122) | (0.114) | (0.120) |
| | | | | **Panel B: IV-Farmers** | | | | | |
| Log (Farmers/T) | -0.186 | -0.161 | -0.184 | 0.533* | 0.488 | 0.404 | -2.989* | -3.511 | -3.615 |
| | (0.181) | (0.184) | (0.182) | (0.322) | (0.312) | (0.291) | (1.595) | (2.165) | (2.241) |
| | | | | **Panel C: IV- Low skilled workers** | | | | | |
| Log (LowSkill/T) | -0.155 | -0.179 | -0.248 | 0.588 | 0.516 | 0.332 | -3.109* | -4.034 | -3.771 |
| | (0.241) | (0.275) | (0.260) | (0.437) | (0.444) | (0.386) | (1.691) | (3.207) | (2.980) |
| 1900 controls | No | Yes | Yes | No | Yes | Yes | No | Yes | Yes |
| Excl. Dust Bowl st. | No | No | Yes | No | No | Yes | No | No | Yes |
| N | 10785 | 10777 | 9929 | 10786 | 10778 | 9930 | 8070 | 8064 | 7428 |

The dependent variable is the log number of horses per acre (columns 1-3), the log number of mules per acre (columns 4-6), and the log number of tractors per acre (columns 7-9). All regressions include fixed effects for county and time as well as 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

Table 8: Effects on capital ratios

| | Capital-labor ratio | | | Capital-land ratio | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | | | **Panel A: OLS** | | | |
| Log (Farmers/T) | -0.747*** | -0.770*** | -0.763*** | 0.254*** | 0.231*** | 0.237*** |
| | (0.025) | (0.026) | (0.028) | (0.025) | (0.026) | (0.028) |
| | | | **Panel B: IV-Farmers** | | | |
| Log (Farmers/T) | -1.134*** | -1.247*** | -1.250*** | -0.134 | -0.247 | -0.250 |
| | (0.221) | (0.253) | (0.246) | (0.221) | (0.253) | (0.246) |
| | | | **Panel C- IV low skilled workers** | | | |
| Log (LowSkill/T) | -1.381*** | -1.620*** | -1.506*** | -0.294 | -0.457 | -0.390 |
| | (0.415) | (0.508) | (0.436) | (0.311) | (0.382) | (0.332) |
| 1900 controls | No | Yes | Yes | No | Yes | Yes |
| Excluding dust bowl states | No | No | Yes | No | No | Yes |
| N | 10781 | 10773 | 9925 | 10764 | 10756 | 9908 |

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

Table 9: Heterogeneity by main ethnic group

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | **Panel A: Effects on crop share and farm size** | | | | |
| | Corn | Wheat | Hay | Cotton | Farms per acre |
| Log(Farmers/T) | 0.040** | -0.063** | 0.020** | -0.058* | 0.350** |
| | (0.017) | (0.031) | (0.010) | (0.034) | (0.161) |
| Log(Farmers/T)*German | 0.031 | 0.030 | 0.031 | 0.004 | 0.106 |
| | (0.039) | (0.041) | (0.023) | (0.039) | (0.163) |
| Log(Farmers/T)*Anglo | 0.039 | -0.176 | 0.010 | -0.059 | 0.112 |
| | (0.049) | (0.207) | (0.050) | (0.074) | (0.308) |
| N | 10764 | 10764 | 10764 | 10764 | 10753 |
| | **Panel B: Effects on tenancy and draft power** | | | | |
| | Land by owners | Land by tenants | Horses | Mules | Tractors |
| Log(Farmers/T) | -0.202* | 0.079* | -0.127 | 0.358 | -3.610 |
| | (0.112) | (0.041) | (0.74) | (0.310) | (2.242) |
| Log(Farmers/T)*German | 0.081 | 0.014 | -0.002 | 0.863* | 1.897 |
| | (0.0102) | (0.088) | (0.250) | (0.489) | (1.764) |
| Log(Farmers/T)*Anglo | 0.283 | -0.065 | -1.520 | 1.490 | 0.200 |
| | (0.184) | (0.119) | (0.181) | (1.106) | (4.128) |
| N | 10753 | 10753 | 10669 | 10778 | 8070 |

The dependent variables are labeled in each column. 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

Table 10: Heterogeneity by specific crop specialization

| | Corn (1) | Wheat (2) | Hay (3) | Cotton (4) |
|---|---|---|---|---|
| | **Panel A: Share of land allocated** | | | |
| Log(Farmers /T)*High producers | 0.116*** | 0.123** | 0.093*** | 0.157*** |
| | (0.022) | (0.060) | (0.018) | (0.026) |
| Log(Farmers /T)*Low producers | 0.044** | -0.057** | 0.024** | -0.056* |
| | (0.018) | (0.029) | (0.011) | (0.030) |
| P-value difference | 0.000 | 0.000 | 0.000 | 0.000 |
| N | 10764 | 10762 | 10764 | 10764 |
| | **Panel B: Land productivity** | | | |
| Log(Farmers /T)*High producers | -0.771** | 0.116 | 0.084 | -0.631*** |
| | (0.347) | (0.792) | (0.238) | (0.245) |
| Log(Farmers /T)*Low producers | -0.206 | 0.163 | -0.194 | -0.138 |
| | (0.273) | (0.533) | (0.273) | (0.309) |
| P-value difference | 0.004 | 0.874 | 0.003 | 0.001 |
| N | 10470 | 9028 | 10526 | 3250 |

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

Table 11: Heterogeneity by overall crop specialization

| | Farms/acre (1) | Owners (2) | Tenants (3) | Horses (4) | Mules (5) | Tractors (6) | K-L ratio (7) |
|---|---|---|---|---|---|---|---|
| Log(Farmers /T)*Diversified | 0.369** | -0.180* | 0.079* | -0.185 | 0.535 | -2.882* | -1.134*** |
| | (0.151) | (0.100) | (0.042) | (0.180) | (0.326) | (1.588) | (0.221) |
| Log(Farmers /T)*Specialized | 0.528*** | -0.274*** | 0.192*** | -0.060 | 0.928*** | -4.426*** | -1.099*** |
| | (0.149) | (0.096) | (0.044) | (0.183) | (0.342) | (1.493) | (0.218) |
| P-value difference | 0.000 | 0.000 | 0.000 | 0.033 | 0.001 | 0.000 | 0.516 |
| N | 10753 | 10753 | 10753 | 10785 | 10786 | 8070 | 10781 |

The dependent variables are labeled in each column. 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