Economic History and Cliometrics Lab

Working Paper # 15

More Hands, More Power?

Estimating the Impact of Immigration on Output and Technology Choices Using Early 20th Century US Agriculture

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JEL classification: J43, J61, N51

Key words: Immigration, Agriculture, Output mix, Technological change

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Can shifts in output mix or technologies attenuate the impact of immigration on wages? We explore this using immigration-induced changes in relative labor supply at the county level in US Censuses of Agriculture in early 20th century. An increase in labor supply induced a shift away from capital-intensive crops and a reduction in farm size. Crop mix adjustments were more likely in counties less specialized in a given crop while adjustments in technological and organization changes were more marked in the rest. Suggestive evidence indicates that crop mix adjustments, but not organizational changes, were sufficient to limit wage impacts.

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1 Introduction

How do productive sectors and labor markets adjust to an inflow of new workers? This question has been one of the basic motivations of the literature (and the policy debate) regarding the impact of immigration to the United States and elsewhere in the world. As part of the discussion about the precise estimates of the effects of immigration on the labor market outcomes of natives, several authors have suggested a number of channels to explain the relatively small estimates presented from the literature. Some authors have suggested that native workers, even those with skill levels similar to those of migrants, are not perfect substitutes for immigrant labor (see for example, Cortés 2008 and Peri 2009). Other authors have argued that adjustments in technology or output mix occur in response to changes in the skill-mix, and those endogenous adjustments attenuate the wage and employment effects of the inflow of workers. For example, in response to an inflow of low-skill labor in the economy firms may increase the production of goods that are more labor intensive, generating a shift in the labor demand that allows the local economy to absorb the inflow of workers at the existing wages (see Hanson and Slaughter 2002 for a study along this dimension).[1] Also, new labor intensive technologies could be endogenously generated or adopted in response to a labor inflow as in the theory of directed technological change of Acemoglu (2002).[2]

This paper examines how firms, or farms in this specific case, adapted to increases in labor supply that were generated by inflows of immigrants during the years between 1910 and 1940. It focuses on contrasting three potential mechanisms through which responses to immigration may be occurring: changes in output mix, changes in "techniques", and input adjustments. Up to this point, the literature has found mixed support for the first mechanism as a way to absorb changes in factor availability (not always related to immigration), for example Hanson and Slaughter (2002), Lewis (2004a), Lewis (2004b), Bernard, Redding and Schott (2005) and Saad-Lessler (2005). We explore this further by arguing that factor-specificity will make the first channel difficult for some areas, forcing them to use either the second or third mechanisms (changes in techniques and input adjustments), which looking at the aggregate level, may mask much of the heterogeneity. The paper most related to our study, Lewis 2011, looks within narrow industries using data from the Survey of Manufactures for the late 1980s and early 1990s and finds that immigration-induced increments in the relative supply of low-skilled labor made firms less likely to adopt automation machinery. His evidence appears to be congruent only with the third hypothesized channel but does not measure how many adjustments may have occurred across four-digit industries versus the change along a given isoquant within the industry.[3]

[1] This mechanism corresponds to the Rybczynski theorem, the standard adjustment mechanism to changes in relative endowments in Heckscher-Ohlin trade models.

[2] See Lewis (2011) for an additional perspective on this line of work but motivated in the context of capital-skill complementarity.

[3] See Lewis (2013) for a review of work on the relation between immigration and production technology, including

The early decades of the twentieth century provide an interesting setting for several reasons, in which this analysis can be conducted. First, immigration flows over this period were large (e.g., in the early decades of the century, the fraction of the population that was foreign was larger than during the most recent decades in the United States) and had important variation across time and geographical areas, making this relevant context from which applicable lessons may be potentially used for today's markets. Second, agriculture was more important for the US economy at that time than it is today, it received a large number of immigrants and and it is also a sector in which capital and technologies can be easily measured in the Census. Indeed, during this period a large number of immigrants were working in the agricultural sector (although an even larger number of immigrants worked in manufacturing): 17 percent of all migrants arriving were farmers in their country of origin, and more than 10 percent of the immigrants in the United States reported to be farm workers.[4] Observing how these inflows may have fostered changes in technologies or crop choice is facilitated by the availability of relevant data in the United States Agricultural Census and by a large number of contemporaneous studies that describe in detail the production processes of various crops. Contrastingly, in today's economy most immigrants work in the services sector where techniques and capital are difficult to measure. Third, the period from 1910 to 1940 is particularly appealing because the "frontier" was almost completely established, limiting the incorporation of new land as a mechanism to absorb the inflow of immigrant workers. Finally, 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.

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. Our approach to this question follows a simple motivating framework. We start by thinking of local labor markets as small open economies with access to a similar set of production technologies which use land, capital and labor. These can be combined to produce two different outputs, one of which may be obtained through a labor-intensive technology and the other through a capital-intensive technology. Local economies, however, differ in the specificity of some of their land which can be re-assigned to a different output. If local economies are capable of changing their production mix, we would expect capital to reallocate across sectors and production technique 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. However, if the economy is restricted by the specificity of its land, then it will need to resort to changing technologies instead of output and if it's unable to fully absorb the inflow of labor, factor prices may be affected.

the channels we study in this paper.

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

We then search for evidence of these patterns in the adjustment of US agriculture to immigration-induced labor supply shifts over the period 1910 to 1940. Specifically, we estimate the impact that an increase in the number of farmers or low skill workers per acre of farmland has on agricultural outcomes. These outcomes are selected in accordance with the theoretical framework and include: scale of production, crop choice, draft power choice and direct measures of capital, output and land allocation. Such variables were obtained from the Census of Agriculture, some of which were digitalized for the purpose of this study. Data on the number of immigrants, farmers and low skill workers in each county were built using the Population Census of the United States.

We exploit the panel dimension of the dataset to control for national trends and other confounding factors using county and state-by-year fixed effects. To obtain causal estimates of the responses of capital, output mix and technology to changes in labor supply, we use immigration inflows such 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.

Our results suggest that the increases in the relative endowment of labor due to immigration influenced the production and organization of agriculture in the United States during 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 amount of labor per acre reduced the share of land allocated to wheat and raised the share of land allocated to hay and corn as well as the share of land in which no crops were produced. There is no observed response in terms of crop prices or productivity, suggesting that factor availability is the likely channel of this response.

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 result that is mostly driven by the fact that very large farms (more than 175 acres) become less common at the benefit of medium sized farms (50 to 100 acres). There is also evidence of a decline in the share of land managed by owners rather than tenants or managers, although this result is more noisy. We also look at measures of draft power that proxy for the adoption of mechanized technologies and fail to find strong evidence of changes in the number of tractors, mules or horses for the overall sample of counties. The estimated coefficients of the effects on the number of tractors are negative, which is consistent with the theoretical framework, but are not sufficiently precise. Aggregate capital appears to have fallen in response to the arrival of one percent more workers, leading the capital-labor ratio to fall by more than one percent.

More importantly, we find evidence supporting our hypothesis regarding factor specificity. We proxy this by using counties where more than 25 percent of farmland in 1900 were dedicated to one crop, arguing that this specialization appears to have been the product of climate and soil conditions and not because of availability of the other production factors. We find that in counties that had a lower degree of specialization in a given crop, greater adjustments in crop mix appear to have taken place. This may be because, as opposed to diversified counties, specialized counties may have been more constrained to make crop changes. On the contrary, in counties that were more specialized, adjustments in technology and organizational changes were observed in greater magnitudes.

We examine whether the results are driven by an alternative causal channel in which the shifts in agricultural outcomes are explained by a transmission of agricultural knowledge generated by immigration but find no evidence supporting this as counties with more immigration from a given ethnic group do not experience a significantly different impact for a variety of outcomes.

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. However, change in crop mixes appear to explain even more than the observed decrease in capital. Thus, contrary to Lewis 2011, we find suggestive evidence that shifts in output mix, where possible, may have fully absorbed the labor inflow with limited impact on local wages. Furthermore, these results are compatible with labor, land and capital all being complementary within the agricultural production function.

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

2 Theoretical framework

Consider an economy where all goods are produced combining three different inputs: labor (L), capital (K) and land (T), according to production functions $F_i(L, K, T)$, where subindex i indicates the good.[5] Throughout the paper we assume that all the functions $F_i(\cdot)$ display constant returns to scale in the three factors, thus implying that factor ratios are fully determined by factor

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

prices.

Furthermore, we assume that there are only 2 different agricultural goods, but in a manner similar to Beaudry and Green (2003), one of them can be produced using two different technologies. The first good can be produced with a single production function $Y_1 = F_1(K_1, L_1, T_1)$. The second good can be produced with two different technologies, in the language of Beaudry and Green (2003), a "modern" and relatively capital intensive one, or a "traditional" more labor intensive one. In particular we assume the modern technology, $F_2(K_2, L_2, T_2)$, and the traditional one, $F_3(K_3, L_3, T_3)$, to be such that, at any given factor prices, $\frac{K_3}{L_3} < \frac{K_1}{L_1} < \frac{K_2}{L_2}$.

There is free mobility of capital and labor across goods. However, land differs from them because a fraction of the available land is "specific", that is to say that it can only be used in the production of the second good. Specifically, total land used in factor i is given by $T_i = A_i + B_i$ where B captures the land that can be allocated to either crops and A, the land that is specific to the second good. Thus, the market clearing conditions for land are $A_2 + A_3 = \bar{A}$ and $B_1 + B_2 + B_3 = \bar{B}$.[6] The economy wide use of factors is determined by aggregate supply $(\bar{L}, \bar{K}, \bar{T})$ and factor prices are determined within the economy. We assume throughout this section that good prices are given (you can think that this is a small economy open to trade in goods.)

2.1 Sectoral adjustments and factor-specificity

When production of good 1 is not too large, the constraint imposed by land specificity does not bind, and all three technologies will be in use. In this situation we can think of this economy as a 3-good-3-factor economy. As long as the land specificity does not bind, the entry of new labor inputs can be absorbed through shifts in production techniques or outputs, as predicted by the Rybczynski Theorem, a core result of Heckscher-Ohlin (HO) trade theory (Rybczynski, 1955), and thus factor prices will remain unchanged. This also implies, that factor ratios within each method of production will remain intact. Using this result and the constraints on the supply of inputs, we can derive the following conditions:

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

where $k_i = \frac{K_i}{T_i}$ and $l_i = \frac{L_i}{T_i}$, $i = 1, 2, 3$.

How the economy will adjust to the inflow in terms of land allocation will depend entirely

[6] The assumption that the good with two technologies also has access to some specific land help us build a limit to how much the economy can adjust simply by changing the product/technology mix.

on the capital-land ratios across sectors. It can be shown that in all cases, except the one where $k_3 > k_1 > k_2$, the increase in labor availability will lead to more land being used in the least capital intensive crop. The economy will also change the way it produces the good that is slightly more capital-intensive to use more labor in its production. The share of land used in the production function F_2 decreases almost certainly (except when $k_2 > k_1 > k_3$) and that devoted to F_1 increases where k_3 is largest than the other ratios or when $k_1 > k_2 > k_3$.

However, if B is very small, the crop-level adjustments will be limited. In this case, factor prices will be altered and the economy will have to resort to adjusting more within a sector across methods of production than across crops.

2.2 Shifts within a given production function

If the economy is unable, because of factor-specificity, to fully absorb the shift in labor supply by adjustments in the basket of goods being produced or the technologies being used, we should then observe shifts in factor intensity within a given production function. In order to see exactly how this case works, assume for simplicity that capital is supplied elastically and that the interest rate is fixed at the economy level.[7] 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

[7] This is a common assumption in papers exploring similar mechanisms and in immigration literature, see for example (Lewis, 2011).

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 α 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 α 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 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.

3 Empirical Strategy

3.1 Baseline equation

Using the simple framework explaining how immigration could impact output and technological choices of producers, we explore these relationships empirically in the context of agriculture in *local* economies in the US in the early 20th century. In the construction of our empirical model we take into account three other adjustment mechanisms that can affect our estimates of the responses of agriculture and which are different from those discussed in section 2. The first mechanism corresponds to the skating rink effect, i.e. an outflow of native workers that leaves total labor supply unchanged in response to the arrival of new immigrants. We address this issue by studying the impact of changes in *total* number of farmers regardless of their country of birth. Thus, our estimates take into consideration the fact that immigration does not lead to a one-to-one increase in the total availability of workers in a local economy (county).[8]

Second, in response to an inflow of immigrants, there may be an adjustment in the amount of cultivated land. In our empirical specifications we consider this potential change and divide all labor supply measures by the amount of land farmed.[9] We also adjust our instrumental variable strategy to control for this endogenous response of land farmed.

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

Our main estimation equation is:

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

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 farmland in each county. The term X_{ist} is a vector of county level time-varying controls. The terms ν_i and μ_t are, respectively, county and year specific fixed effects and υ_{st} is a vector of state-by-year fixed effects. Regressions are weighted by amount of farmland in

[8] 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, these displacement flows may not be large enough to fully offset the immigration inflows. In such case, immigration inflows may effectively translate into a higher labor supply, as seems to be the case in our sample.

[9] 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.

1900 and standard errors are clustered at the county-level to adjust for heteroscedasticity and within-county correlation over time.[10]

The coefficient of interest is θ, which we interpret as the effect on agricultural decisions of a change in the endowment of labor per area of farmland. Estimates of θ based on OLS regressions are unlikely to be informative of the causal effect of labor supply since workers potentially select their location based on unobserved determinants of agricultural outcomes. Moreover, the many shocks that hit the agricultural sector over this period may have simultaneously affected the allocation of labor supply. In the next subsection we discuss the possible sources of these confounding factors and explain our strategy to deal with these issues.

3.2 Confounding factors and identification strategy

During the early 20th century, major transformations took place in the agricultural sector, some of which were fostered by international shocks or environmental phenomena. These transformations affected regions differently, to the extent that natural and institutional conditions led to regional specialization in farming practices. Indeed, regional specialization in the production of crops characterized early 20th century agriculture. 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 in corn. Given that many of the transformations that affected agriculture over the period likely affected the location and the 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.

One of the events that had a major impact on agricultural production was the onset of the First World War which boosted international demand for US agricultural products. This 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 hard. 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.[11]. Moreover, there was

[10] 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.

[11] 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)

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.

Identification Strategy. Thus, international events such as the First World War and policy measures such as the AAA constitute factors likely affected agricultural production and employment decisions and should be taken into account in our identification strategy. We first consider shocks that generate a co-movement of agricultural labor supply and agricultural production decisions in a way that was not differential across regions. We deal with these shocks by including a set of year fixed effects, μ_t and 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. We also control for time-invariant county-specific characteristics that determine the location patterns of agricultural workers with county level fixed effects, ν_i. Along these lines, 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 partialed out.

Nonetheless, the numerous transformations affecting the agricultural sector over this period constitute sources of unobservable time-varying shocks that may have affected agricultural outcomes and labor outcomes in a differential manner across regions. Moreover, farmers and low skilled workers may have selected their location based on such time-varying unobserved determinants of agricultural outcomes. We use several approaches to deal with these issues.

First, we include state-year fixed effects in the regression v_{st}. This means that we will only be exploiting within state 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. There may be, however, policies implemented at the county level and other confounding shocks that could be associated with the within-state location decision of workers and agricultural county level outcomes. To deal with this issues, which brings us to our second approach, we implement an instrumental variable strategy that exploits 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 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-skilled 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 of immigrants across counties to allocate the national stock of farmers or low-skill workers in each decade. It should be noted that the location shares, $\frac{N_{jsi,1900}}{N_{j,1900}}$, are obtained from Census tabulates, as opposed to micro-samples. This makes their measurement more reliable and thereby attenuates concerns of measurement-error bias.

The identification strategy that combines the instrumental variable with year, county and state-by-year fixed effects has two requirements 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. Regarding this second condition, the stock of farmers/low-skilled workers will be predicted using the 1900 ethnic group distribution of *all immigrants* as opposed to the ethnic distribution of *immigrant farmers*. This is preferred because the location choices of *farmers* in 1900 may be more related to anticipated changes in agricultural practices than the location choices of *all immigrants* and, therefore, ameliorates concerns of identification.

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

Finally, we explore the possibility that the Dust Bowl, a major regional shock affecting the agriculture sector, may have led to large variations in the results. We therefore test whether our results are sensitive to the exclusion of Oklahoma, Kansas and Nebraska, which were the states most affected by the Dust Bowl.[12]

4 Data and Descriptive Statistics

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

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

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 for 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 or as low-skilled workers. Farmers are defined as individuals whose primary occupation, as reported in the Census, is being a farmer or a farm laborer. Low-skilled workers are also defined using occupational categories in the census and include farmers as well as laborers, servants, fishermen, housekeepers and other low-skill trades. Immigrants are defined as individuals who are registered in the US Census and were born outside the US, as is traditional in the literature. 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. However, we can obtain the national flows necessary to build our instrument, L_{jt} in equation (9), from that source.

The shares of immigrants located in each county that are used to compute the instrument, $\frac{N_{jsi,1900}}{N_{j,1900}}$ in equation (9), are built using data on the number of immigrants in every county by country of birth. This data is available in the 1900 Census county level tables that are available in digital format at the National Historical Geographic Information System (NHGIS; see Center 2011).

4.2 Agriculture data

We use data from the 1910, 1920, 1930 and 1940 Censuses of Agriculture to construct a wide variety of agricultural variables at the county level. [13] 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.[14]

Our framework suggests that, in response to changes in labor supply due to immigration, the first type of adjustment that one could expect is a change in output towards a more labor intensive mix. In the context of a local agricultural economy, such changes in output mix corresponds to shifts in crop production. We therefore obtain measures of physical output, value and area planted for the four most important crops during this period: corn, wheat, hay and cotton. [15]

[13]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.

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

[15]During 1910-1940, these crops ranked highest in terms of area farmed. Their combined area amounted to the

We also include a measure of non-crop land to capture the extensive adjustment. 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.[16] Finally, we 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.

Using agricultural studies of the period, we assess the relative labor-intensity and degree of mechanization of each of these crops. Specifically, we use the result of studies conducted by the National Research Project during the 1930s that determine the trends in the amount of labor used to produce corn, cotton, wheat and oats between 1909 and 1936 (Elwood, 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.[17] 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. The studies also show how these crops differed in their ability to integrate new technologies. Wheat stood out as the crop with fewer labor requirements and whose production suffered the greatest transformations in technology, as threshers, reapers, combiners and tractors were rapidly introduced (Olmstead and Rhode, 2008). 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 et al. (1939); Holley and Lloyd (1938); Macy et al. (1938)). On the contrary, cotton stood out as the crop that mostly "resisted the tendency to mechanization in agriculture". The literature has attributed this lag in cotton mechanization to the relative complexity of the operations associated with its production, the small scale of farms and the uneven terrain. It has also been argued that the long-term share tenancy contracts in cotton production may have reduced the incentives to adopt the existing technologies, which mechanized only specific stages of production leaving peaks in the labor requirements (for a discussion, see Whatley (1987)). Finally, the labor requirements of hay and corn were in between those of cotton and wheat (Elwood et al., 1939; Holley and Lloyd, 1938;

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.

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

[17]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.

Macy et al., 1938). We also obtain direct estimates of the average L/T and K/T for each of these crops by using the fact that within each county, the following relationship must hold:

$$J/T = \sum_i (t_i/T) * (j_i/t_i) \qquad \text{for } J = K, L \tag{10}$$

By combining the data on all counties, we obtain an estimate of the factor intensities relative to land within each crop as the parameter $\hat{\delta}_i$ in the linear regression below.

$$J/T = \sum_i \delta_i (t_i/T) \qquad \text{for } J = K, L \tag{11}$$

The results are very much aligned with the historical studies detailed above but allow us to obtain values for land not used for crops as well as for that used in other crops.

Changes in labor supply due to immigration can also be absorbed via adjustments in the methods and organization of agricultural production. To measure these margins we collect county-level data on the scale and organization of farms as well as the use of inputs in production. To measure scale, 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.[18] 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.[19] Measures of scale and tenancy are likely correlated with the use of technologies since large farms and farms cultivated by their owner were more likely to be capital-intensive than smaller and tenant-operated farms.

To proxy for changes in input choices, we measure draft power using 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 (see, for instance, Cochrane 1993 and Olmstead and Rhode 2001). The period we study saw a rapid adoption of tractors that has been documented as one of the most important technological innovations in modern agriculture.[20]. The diffusion of tractors was very rapid, although there

[18] 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."

[19] 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".

[20] 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

was a significant variation in the pace of the adoption across regions.[21] 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).[22] Thus, we explore how the substitution of animal traction by tractors was affected by an increase in the amount of labor, since this shift in draft power represents capital upgrading or technology adoption. County level data on the number of tractors are available in the Census of 1925, 1930 and 1940. In 1920, the information is only available by state and not by county. We assume that the fraction of tractors in the state by county was constant between 1920 and 1925 and generate a proxy for the number of tractors in each county in 1920. Finally, since the national number of tractors is very low in 1910, we use zeroes as a proxy of the number of tractors in every county in 1910.

Finally, we exploit additional data from the Agricultural Census to obtain measures of capital. In all the relevant years, the Census of Agriculture reports values for four categories of farm assets: land, buildings, livestock and implements and machinery. We 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, like the value of crop production, were deflated using the CPI.

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 528 immigrant farmers in each county, a number that corresponds to approximately 11 percent of the total stock of farmers per county. Farmers represent about 47 percent of all low-skilled workers in a given county and the county-level stock of low-skilled workers is, on average, 10,306.

Counties have on average 2,917 farms and 592 thousand acres in farmland. Note, however, that not all of the farmland was devoted to crop production, as areas used in livestock, woodlands or unimproved forests and 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 29% of the total farmland, as is shown in Table 1. Table 1 also reports productivity measures. While an average of 21 bushels of corn were produced per acre, in the case of wheat, 14 bushels per acre were produced. An average acre of land produced 1.3 ton of hay (about 0.4 bales) and 1 ton

Rhode, 2008).

[21]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).

[22]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).

of cotton. Data for crops is missing for several states in which no cotton or wheat production was reported. It is also worth noting that there is a large variation in the measures of land allocation and productivity by county.

Farms over this period were very large. More than 50 percent of all farms had an area greater than 100 acres. 64 percent of farms were farmed by their owner and 30 percent by their tenants.

The value of implements and machinery in 1910 dollars was 420 per worker and 3.58 per acre. Horses, over this period, were still the major source of draft power with close to 8,500 on average in a county. In contrast, a typical county had approximately 2,400 mules and 300 tractors. Large variations in these input mix and draft power measures are observed across counties.

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. Unlike Panels B and C, Panel A reports regressions that only include observations for the years 1910-1930, since 1940 measures of immigrant farmers per county are not available. Although the log number of immigrant farmers will not be used as an endogenous regressor, we present its first stage in Panel A to show that the relevance of the instrument is due to the fact that it predicts the location of immigrant farmers, as opposed to the natives. Panel B presents the results of the first stage in which the left-hand side variable is the log number of all farmers, (both native and foreign) and Panel C presents the results of the first-stage when the left-hand side variable consists of the log of all low-skilled workers. The construction of a measure of labor supply in terms of the availability of low-skilled workers is motivated by the possibility that farmers and low-skilled 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.[23] These controls in column (2) are included to test whether the predictive power of the instrument is driven by the fact that in the computation of the 1900 location distribution of immigrants, non-farmers and high-skilled workers were included. Column (3) includes the set of time varying county level controls built from interactions of decade dummies and the 1900 value of agricultural variables. Finally, column (4) is estimated after excluding all counties in states which were affected greatly by the Dust Bowl.

[23] 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.

Panel A 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 those involved in agriculture. Furthermore, 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 immigrants per acre of 0.4 to 0.5 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 most affected by the Dust Bowl. The fact that the first stage estimate is relatively insensitive to the inclusion of proxy measures of county-level agricultural trends is reassuring. This 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 per acre seems to be significantly driven by the immigrant flows. An increase of 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. The reduction in the significance level of coefficients with respect to Panel A is not surprising, as it 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 of non immigrant farmers and the set of time-varying country level controls are included.

The last panel presents the result of an analogous regression to that in Panel B, but the instrument allocates the national stock of low-skilled immigrants 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 workers control is included. This may be due to the fact that few immigrants over this period were high-skilled workers and thus this specification is highly demanding on the data. Reassuringly, the point estimate does not change very much, but the precision of the estimate falls significantly.

Thus, the first stage provides 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 while that devoted to labor intensive crops increases.

Table 3 presents the results of the estimates in which the outcome variable is the area planted for four types of crops- corn, wheat, hay and cotton-, as well as the area planted with no crops. For each outcome, the first column presents the regressions with the extensive set of fixed effects (i.e., year, county and state-by year). The second column adds the time-varying controls and the last excludes observations of the Dust Bowl states. Panel A presents the estimates from an OLS regression. The results show that the correlation between the number of 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-skilled workers of 1 percent results in a decline in the share of land allocated to wheat of 0.05 to 0.08 percent. There is also an increase in the share of land devoted to corn and hay as well as the share of land in which no crops are produced. The land allocated to cotton appears to decline, but the results are not statistically significant. The impacts of changes in the relative availability of low-skilled workers presented in Panel C are less precise. However, the magnitude and signs are very similar to those in Panel B. In general, all results are insensitive to the inclusion of time varying county level controls and to the exclusion of the states most affected by the Dust Bowl.

The findings in Table 3 showing a decline in the area allocated to wheat are consistent with our framework. As discussed in section 4, wheat is by far the less labor intensive crop in the study. Shifting production from wheat to corn and hay is therefore consistent with an environment in which the local agricultural economy absorbs an increase in labor supply by moving away from a more capital-intensive output mix. On the other hand, a decline in the production of cotton would not be consistent since this is the most labor intensive good. While the coefficients in Panels B and C are not statistically different from zero, their negative signs persist even if we restrict the sample to counties with a strictly positive production. Increases in the share of land with no crop production may be consistent with our framework if this farm area were mostly devoted to livestock and the labor requirements in this activity exceeds those of wheat. Unfortunately, we don't have studies on the labor requirement of this type of activity to confirm this hypothesis. Our own estimates from (11) suggest that land with no crop production displayed the lowest capital per worker ratio of all types of crops within our analysis.

Nonetheless, aside from this shift in crops being driven causally by a change in input availability, the results presented above could be driven by two alternative mechanisms. First, if the market for crops is relatively local, immigrants may demand a different basket of consumption goods and thus influence the price of different crops. To explore this further, we constructed a proxy for the log of output price by dividing the value of crops by their physical output and regressed this proxy price on county and state-decade fixed effects. Overall, this suggests that about 40 to 70 percent of price variation can be explained by these fixed effects (more in the case of hay prices, less in the case of wheat prices). 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 therefore test whether the price of the output responded to the inflow of immigrants and present the results in Panel A of table 4. The format of this table replicates that of table 3 except that it presents only IV results using the log of all farmers as the endogenous variable. In neither case we observe that the price of output responded significantly to a change in the labor input at the county level. This evidence suggests that either the immigrants did not change crop allocation through a demand mechanism or that the crop allocation change was not large enough to alter the local prices of the crop.

In another possible causal channel, an inflow of immigrants may change the crop mix within a county if it changes the productivity of the production function of a given crop. This may happen because the labor of immigrants is not a perfect substitute for the labor of natives or immigrants bring from their countries of origin innovative knowledge about agricultural production techniques. By estimating the models in Panel B of table 4 we explore this hypothesis. In these models we estimate 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 results reveal little evidence in favor of an alternative causal mechanism. Instead, the evidence favors the hypothesis that the shifts in the crop mix observed in each county can be explained by differences in the labor requirements of some of these crops.

5.3 Adjustments in the organization of production

Shifts in crop mix as those described in subsection 5.2, are just one possible adjustment mechanism to changes in labor supply. Agricultural economies may also 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 of the number of farms per acre (i.e., the inverse of the average size of a farm). Columns (3) through (12) show estimates of models of the share of all farms by the following 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. Panels B and C show IV estimates of the effects on farm scale of an increase in the per-acre supply of farmers and low-skilled workers, respectively.

Results in the first two columns of Panel A show that, when comparing counties within the same state, an increase in the number of farmers per acre in a county is associated with smaller farms. These OLS estimates are smaller than the IV coefficients in Panel B, suggesting that immigrant farmers are disproportionately located in counties that have small farms. As shown in the first two columns of Panel B, the causal impact of a 1 percent increase in the number of workers per acre is an increase of 0.4 percent in the number of farms per acre. Subsequent columns in Panel B suggests that this decline in the average size of a farm 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. [24] Similar conclusions are reached from the results in Panel C, which show estimates of the effects of changes in the supply of low-skilled workers per acre. This appears to have occurred within each crop as the changes in crops detailed in the previous section would have, based on the 1900 distribution of crop production by farm size, increased the proportion of very large farms.

We look for more evidence of changes in the organization of production by studying the impact on tenancy given changes in labor supply. The results are presented in Table 6. Panels in this table are organized in the same way as in Table 5. IV estimates in the first three columns of Panels B and C show the effects on the fraction of farms operated by owners are negative, but not statistically different from zero. The effects on the fraction of farms operated by managers and tenants in the remaining columns are not significant either, but have a positive sign. 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. While the lack of

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

significant IV estimates of the effects may indicate the absence of adjustments in these margins, it may also be due to lack of precision in the estimation. In such case, the signs of the estimated coefficients would constitute weak evidence of shifts away from ownership, which is consistent with our theoretical framework. As discussed in section 4, farms cultivated by owners tended to be more capital-intensive than tenant-operated farms. Also, agricultural economies where land was frequently farmed by tenants were characterized by thin labor markets. As discussed by Whatley (1987), given the seasonal nature of agricultural production, thin labor markets were very costly for farmers. Tenant contracts were implemented to reduce the costs of fluctuations in labor requirements. In such an environment, immigration-induced labor inflows may have had an effect.

Overall, these results suggest that changes in the relative availability of agricultural labor changed the organization of agricultural production. In particular, in response to an increase in the number of farmers per acre, there was a shift to smaller farms. This result is consistent with a scenario in which farms adjusted to an immigration-induced change in the relative endowment of agricultural labor elected ways to arrange production that was more labor-saving. Shifts from ownership to tenancy arrangements would also be consistent with such a scenario, but the evidence we provide of adjustments in this margin is much weaker than the evidence we provide of shifts in the scale of production. Nonetheless, in section 5.5 we present results showing that a relative decline in ownership consistent with our theoretical framework did take place, but only for a sample of counties.

5.4 Adjustments to Input Mix

We then turn to adjustments in terms of input mixes. The interpretation of these results is more difficult than the ones presented above as adjustments across or within crop mixes or production methods would both impact aggregate input mixes. We start by looking for adjustments in measures of draft power. Table 7 reports the estimates of models of the effects of changes in labor supply on the county-level given the number of horses, mules and tractors.

Panel A shows results from OLS regressions that indicate that agricultural workers tend to locate in counties where there is a large number of horses and mules per acre. In contrast, the IV estimates in Panels B and C show that a larger endowment of agricultural or low-skilled workers per acre has no statistically significant effect on draft power measures. While the estimates are not significantly different from zero, the signs of the coefficients suggest a slowdown in the adoption of tractors and horses and an increase in the use of mules. These shifts would be consistent with a scenario in which farms adjusted to an immigration-induced labor shock by slowing the adoption of labor saving technologies, such as tractors.

We then turn to a more direct measure of capital (i.e., the real value of implements and machinery used in agriculture) to examine adjustments to the input mix. In a model where the only adjustments that would have occurred would have been by changing the output mix, we should observe that the aggregate capital-to-labor ratio would fall by one in response to an increase of one more worker and the capital-to-land ratio would remain unchanged. If adjustments within each output are also used, the aggregate impact will depend on whether inputs are q-complements or q-substitutes as presented above in our framework.

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-skilled 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 approximately one percent. We cannot reject the hypothesis that our estimates are equal to one. Such a shift is consistent with a scenario in which farms move to more capital-intensive technologies or output mixes. Contrastingly, in columns (4)-(6) we see that a change in the relative supply of labor has no significant effect on capital-land ratios. Overall, these results are consistent with a situation where the supply of capital within each local economy was unable to adjust in the short-term.

5.5 Heterogeneity by specialization

Our theoretical framework argues that adjustments in terms of output mixes were more likely when a larger fraction of land could be allocated to various types of production while changes in terms of technology uses would be preferred for counties that were unable to reallocate their land to more labor-intensive outputs. We explore whether there is any evidence of this by classifying counties by high or low producers of a specific crop in 1900.[25] This is first explored in Panel A of Table 9, which presents models in which the outcome variable is the share of land allocated to each crop. The results appear to match the framework we provided: larger adjustments in the production of a given crop are observed in counties that had a *low production* of such crop in 1900. In the case of corn and hay, we strongly reject the equality of the two coefficients.

In contrast, Panel B shows that the greater adjustments in productivity took place in countries that had *a high production*. This may be because, as opposed to shifting their output mix, counties

[25]Counties that devote more than 25% of the farmland to the production of a given crop are defined as "high producers" of this crop.

that were specialized adjusted their technologies in response to an increase in the relative endowment of labor. We explore this issue in greater detail in Table 10. We analyze whether counties that were more specialized (and, therefore, were unable to adjust as much through output mix changes), made greater adjustments in technologies than counties that diversified. A specialized county is defined as one that had in 1900 more than 25% of its production devoted to a given crop. The results of this analysis are presented in Table 10 and are consistent with our hypothesis: counties that were more specialized in 1900 responded to the labor supply shock by altering the technologies and organization of their production to a greater extent than counties that were diversified. These counties had greater declines in their ownership shares and in the capital-labor ratios. They also saw greater declines in the average farm size, although the differences are not statistically different when compared with the diversified counties. Finally, they experienced greater adjustments in the use of mules. Coefficients suggesting a decline in the use of tractors are also larger in the case of the specialized counties, but are not statistically significant.

To confirm that the categorization between “high producing" and “low producing" counties is not artificial, we replicate the exercise but, instead, we separate counties by those that had, on average, larger and smaller farms in 1900. We find no evidence of similar patterns as those displayed in Table 10. We also separate the counties by those that had high or low tenancy rates in 1990 and by those located in the South or non-South states, since tenancy incidence and region may be correlated with the degree of specialization. Again, we don't find a pattern that replicates the results obtained from deriving separate estimates according to the degree of specialization. [26]

5.6 An alternative causal channel

Thus far, we have interpreted our estimates in light of a framework in which an immigration shock impacts agricultural production decisions by changing the relative endowment of labor inputs. However, one can consider 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 of 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 played a critical role in the successful spread of wheat cultivation to Kansas, Nebraska, Oklahoma and the surrounding region.

[26] The results of these estimations are not presented due to space restrictions, but are available upon request.

In Table 11 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 whether the major ethnic group migrating to the region is of German or British origin.[27] Thus, with these interactions we test if the impact of immigration-induced labor supply shocks 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.

The results in Table 11 show that differences between the two major ethnic groups are not statistically significant, with the exception of the share of cotton, a margin that appears to have been subject to larger adjustments in counties located in states with a high concentration of German immigrants. In the case of all other outcomes, adjustments in mostly German counties are not statistically different from adjustments in mostly English counties. We interpret this as evidence against the hypothesis according to which the observed adjustments in output and technologies are explained by an inflow of agricultural knowledge brought by immigration.

5.7 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, akin to a Oaxaca decomposition (Oaxaca, 1973). 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

$$(K/T) = \sum_i \omega_i \frac{k_i}{t_i} \tag{12}$$

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 ω_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

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

importance of each method:

$$\Delta(K/T) = \sum_i [\Delta\omega_i * (k_i/t_i)] + \sum_i [\omega_i * \Delta(k_i/t_i)] \tag{13}$$

We can obtain an analogous version of (13) in which we decompose the elasticity of (K/T) with respect to (L/T):

$$\frac{\Delta(K/T)}{(K/T)\Delta ln(L/T)} = \frac{\sum_i \Delta\omega_i(k_i/t_i)}{(K/T) * \Delta ln(L/T)} + \frac{\sum_i \omega_i \Delta(k_i/t_i)}{(K/T)\Delta ln(L/T)} \tag{14}$$

With simple algebra we obtain:

$$\beta = \underbrace{\frac{\sum_i \theta_i (k_i/t_i)}{(K/T)}}_{\text{Shifts in methods of production}} + \underbrace{\Psi}_{\text{Shifts within methods of production}} \tag{15}$$

where β is the elasticity of (K/T) with respect to L/T; Ψ is the second term at the right hand side of (3)); and θ_i is the change in the of ω_i in response to a change in log of L/T.[28]. We can obtain estimates of the parameter β from the results in table 8 and can also make an estimation of the first term to the right hand side of 15, which captures the component of β 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 θ_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 -0.041 in the model with controls although it is not significant. This would correspond to the total effect as measured on the left hand side of equation 15. When we evaluate 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 the decreased farm sizes would have lead to an increase in the K/T ratio of about 10 to 15 percent. This is consistent with the "inverse relationship" between farm size and productivity observed in almost all contexts. Therefore, 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 for their land in 1900. If we take the non statistically significant estimates on shifts in tenure patterns as valid point estimates, we could

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

generate almost all of the change in K/T in Panel B by changes across tenure patterns although we only explain 1/3 of the shift detailed in Panel C. More interestingly, we also computed the K/T that would have been generated by the change in crop choices, keeping the crop-specific input ratios to their 1910 levels. The results in this case suggest that we should have observed an even more marked decrease in the capital-to-land ratio (between 30 and 40 percent instead of 4 to 15) had the input ratio within each crop not risen. Based on (4) and (3), this is consistent with capital, labor and land all being q-complements and with the aggregate impact on wages being very muted.

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. When comparing counties within a state, we find that increases in the labor supply of farmers in a county (relative to farmland) led to land reallocation away from capital intensive crops and towards labor intensive ones, to a reduction in average farm size and to a decline in the aggregate capital-labor ratio.

We also provide some evidence indicating that, compared to counties with a high degree of specialization in a given crop, diversified counties were more likely to respond to a labor supply shock by shifting their output mix. In contrast, counties that were more specialized and, therefore, were more constrained to shift their crop mix, were more likely to adjust the organization and technology of production.

Thus, our results highlight the role of changes in output mix and production techniques as mechanisms to adjust to an influx of labor inputs. Furthermore, suggestive evidence conveys that, where possible, output mix adjustments were probably sufficient to fully absorb the inflow of workers, leading to limited impact on local wages.

Our results differ from those of Lewis (2011) in that he finds that manufacturing firms changed their labor-capital ratio and lowered wages in response to the immigration inflow. We highlight that this is happening in our context when factor specificity (here land) is high. More research is likely warranted in considering whether manufacturing capital may be highly specific in the short term and whether long-term effects may differ from the ones documented. Further study of other sectors during this same historical period can also shed light on the role of other mechanisms in the incorporation of immigrants and the adoption of new techniques.

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Table 1: Summary Statistis

Variable	Mean	SD	N
Labor supply measures			
Stock of immigrant farmers	528	1159	8,085
Stock of farmers	4,873	5,405	10,780
Stock of low skill workers	10,306	23,453	10,828
Predicted labor supply			
Predicted number of immigrant farmers	379	1,647	8,085
Predicted number of all farmers	2,575	13,347	10,780
Predicted number of low skill immigrants	1,649	8,509	10,828
Land allocation and crop choice			
Farms	2,917	2,890	10,828
Acres farmland	591,920	850,624	10,828
Share of total farm acres planted in corn	0.11	0.10	10,828
Share of total farm acres planted in wheat	0.06	0.09	10,828
Share of total farm acres planted in hay	0.08	0.07	10,828
Share of total farm acres planted in cotton	0.04	0.08	10,828
Crop productivity			
Bushels of corn per acre	21.22	12.50	10,513
Wheat productivity	14.14	7.60	9,230
Hay productivity	1.31	1.74	10,793
Cotton productivity	0.36	0.19	3,378
Land size and tenancy			
Share of very small farms (less than 20 acres)	0.05	0.06	10,828
Share of small farms (20 to 50)	0.22	0.18	10,828
Share of medium farms (50 to 100)	0.19	0.10	10,828
Share of large farms (100 to 175)	0.23	0.11	10,828
Share of very large farms (more than 175 acres)	0.30	0.24	10,828
Share of farms operated by owner	0.64	0.15	10,828
Share of farms operated by tenant	0.30	0.15	10,828
Share of farms operated by management	0.05	0.10	10,828
Capital intensity			
Capital-labor ratio	419.64	342.16	10,764
Capital-land ratio	3.58	3.34	10,828
Draft power			
Number of horses	8,484	10,753	10,828
Number of mules	2,345	4,599	10,828
Number of tractors	333	666	10,828

Table 2: First Stage

	(1)	(2)	(3)	(4)
	Panel A: Immigrant farmers			
Log predicted stock of immigrant farmers	0.387***	0.474***	0.398***	0.437***
	(0.137)	(0.174)	(0.129)	(0.134)
Log predicted stock of non immigrant farmers		-0.144		
		(0.219)		
R-squared	0.758	0.758	0.761	0.779
N	8085	8085	8085	7419
	Panel B: All farmers			
Log predicted stock of immigrant farmers	0.196***	0.243***	0.179***	0.193***
	(0.073)	(0.077)	(0.069)	(0.072)
Log predicted stock of non immigrant farmers		-0.086		
		(0.101)		
R-squared	0.907	0.907	0.910	0.908
N	10780	10780	10780	9892
	Panel C: All low skilled workers			
Log predicted stock of low skilled workers	0.188**	0.206	0.157**	0.184***
	(0.072)	(0.171)	(0.065)	(0.069)
Log predicted stock of high skilled workers		-0.023		
		(0.196)		
R-squared	0.941	0.941	0.944	0.943
N	10828	10828	10828	9940
1900 controls	No	No	Yes	Yes
Excluding dust bowl states	No	No	No	Yes

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

Standard errors are clustered at the county level.

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

Table 3: Effects on crop acreage share

		Corn			Wheat			Hay			Cotton			No crop	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Panel A: OLS															
Log(Farmers/T)	0.008***	0.007***	0.007***	0.004***	0.003**	0.002*	0.002**	0.003***	0.003***	0.017***	0.012***	0.012***	-0.040***	-0.035***	-0.035***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.006)	(0.006)	(0.006)
N	10780	10780	9892	10780	10780	9892	10780	10780	9892	10780	10780	9892	8085	8085	7419
Panel B: IV -farmers															
Log(Farmers/T)	0.057***	0.057***	0.062***	-0.054**	-0.077**	-0.067**	0.018**	0.013*	0.014*	-0.036	-0.046	-0.047	0.122*	0.143**	0.127*
	(0.019)	(0.020)	(0.021)	(0.025)	(0.033)	(0.029)	(0.009)	(0.008)	(0.008)	(0.030)	(0.032)	(0.031)	(0.066)	(0.073)	(0.067)
N	10780	10780	9892	10780	10780	9892	10780	10780	9892	10780	10780	9892	8085	8085	7419
Panel C: IV-low skilled workers															
Log(LowSkill/T)	0.059***	0.058**	0.063***	-0.065**	-0.102**	-0.087**	0.021**	0.019*	0.017*	-0.046	-0.050	-0.043	0.152*	0.195**	0.163**
	(0.022)	(0.025)	(0.024)	(0.029)	(0.044)	(0.035)	(0.010)	(0.011)	(0.009)	(0.039)	(0.043)	(0.038)	(0.078)	(0.097)	(0.082)
N	10828	10828	9940	10828	10828	9940	10828	10828	9940	10828	10828	9940	8121	8121	7455
1900 controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Excl. Dust Bowl st.	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

The dependent variable is the share of total farmland allocated to each crop. All regressions include fixed effects for county and time and fixed effects for each year*state. Regressions are weighted by the acres of farmland in 1900.
Standard errors are clustered at the county level.
*: 10% significance, **: 5% significance, ***: 1% significance

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)	-0.618	-0.736	-0.809	0.597	0.358	-0.018	-0.607	-0.922	-1.004	0.032	0.047	0.036
	(0.580)	(0.628)	(0.623)	(0.658)	(0.456)	(0.361)	(0.608)	(0.698)	(0.700)	(0.164)	(0.254)	(0.283)
N	7761	7761	7113	6279	6279	5644	10744	10744	9859	2417	2417	2338
Panel B: Effects on crop productivity												
Log(Farmers/T)	-0.145	-0.165	-0.013	-0.319	-0.330	-0.202	-0.166	-0.175	-0.098	-0.010	-0.318	-0.239
	(0.295)	(0.303)	(0.267)	(0.290)	(0.286)	(0.271)	(0.220)	(0.238)	(0.221)	(0.213)	(0.272)	(0.261)
N	10434	10434	9561	9049	9049	8187	10742	10742	9858	3283	3283	3176
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)	0.250***	0.233***	0.003	0.003	0.017***	0.013***	0.007***	0.006***	0.009***	0.011***	-0.036***	-0.033***
	(0.028)	(0.028)	(0.002)	(0.002)	(0.005)	(0.005)	(0.002)	(0.002)	(0.003)	(0.003)	(0.006)	(0.006)
N	10780	10780	10780	10780	10780	10780	10780	10780	10780	10780	10780	10780
Panel B: IV- Farmers												
Log (Farmers/T)	0.415**	0.416***	0.009	0.003	0.009	0.016	0.069***	0.072***	0.026	0.046**	-0.113**	-0.137**
	(0.143)	(0.150)	(0.015)	(0.015)	(0.030)	(0.032)	(0.024)	(0.027)	(0.020)	(0.021)	(0.053)	(0.062)
N	10780	10780	10780	10780	10780	10780	10780	10780	10780	10780	10780	10780
Panel C: IV-Low skilled workers												
Log (LowSkill/T)	0.471**	0.554**	0.005	-0.001	0.020	0.035	0.091***	0.101***	0.023	0.059**	-0.138**	-0.194**
	(0.193)	(0.215)	(0.019)	(0.021)	(0.041)	(0.048)	(0.029)	(0.036)	(0.022)	(0.026)	(0.065)	(0.085)
N	10828	10828	10828	10828	10828	10828	10828	10828	10828	10828	10828	10828
1900 controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

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)	0.009	0.012	0.011	-0.020*	-0.020*	-0.020	0.011	0.008	0.009
	(0.009)	(0.009)	(0.009)	(0.012)	(0.012)	(0.013)	(0.008)	(0.008)	(0.009)
N	10780	10780	9892	10780	10780	9892	10780	10780	9892
					Panel B: IV- Farmers				
Log(Farmers/T)	-0.109	-0.150	-0.152	0.072	0.100	0.098	0.038	0.050	0.054
	(0.088)	(0.105)	(0.102)	(0.073)	(0.086)	(0.083)	(0.039)	(0.043)	(0.042)
N	10780	10780	9892	10780	10780	9892	10780	10780	9892
					Panel C: IV- Low skilled workers				
Log(Low Skilled/T)	-0.085	-0.133	-0.134	0.071	0.105	0.098	0.015	0.028	0.036
	(0.105)	(0.129)	(0.119)	(0.094)	(0.116)	(0.106)	(0.045)	(0.052)	(0.047)
N	10828	10828	9940	10828	10828	9940	10828	10828	9940
1900 controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Excl. Dust Bowl st.	No	No	Yes	No	No	Yes	No	No	Yes

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)	0.147***	0.141***	0.143***	0.197***	0.220***	0.225***	0.222***	0.235***	0.243***
	(0.023)	(0.024)	(0.026)	(0.041)	(0.040)	(0.042)	(0.075)	(0.066)	(0.069)
N	10780	10780	9892	10780	10780	9892	10780	10780	9892
				Panel B: IV-Farmers					
Log(Farmers/T)	-0.174	-0.177	-0.198	0.462*	0.460	0.388	-0.713	-0.764	-0.771
	(0.160)	(0.171)	(0.171)	(0.273)	(0.283)	(0.272)	(0.863)	(0.840)	(0.817)
N	10780	10780	9892	10780	10780	9892	10780	10780	9892
				Panel C: IV- Low skilled workers					
Log(LowSkill/T)	-0.206	-0.262	-0.318	0.472	0.469	0.300	-1.147	-1.336	-1.195
	(0.197)	(0.240)	(0.234)	(0.348)	(0.388)	(0.361)	(1.215)	(1.280)	(1.146)
N	10828	10828	9940	10828	10828	9940	10828	10828	9940
1900 controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Excl. Dust Bowl st.	No	No	Yes	No	No	Yes	No	No	Yes

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)	-0.730***	-0.754***	-0.748***	0.270***	0.246***	0.252***
	(0.030)	(0.030)	(0.031)	(0.030)	(0.030)	(0.031)
N	10780	10780	9892	10780	10780	9892
				Panel B: IV-Farmers		
Log(Farmers/T)	-0.920***	-1.041***	-1.052***	0.080	-0.041	-0.052
	(0.251)	(0.272)	(0.266)	(0.251)	(0.272)	(0.266)
N	10780	10780	9892	10780	10780	9892
				Panel C- IV low skilled workers		
Log(Low Skill/T)	-1.074***	-1.322***	-1.252***	-0.008	-0.151	-0.113
	(0.377)	(0.461)	(0.413)	(0.348)	(0.403)	(0.365)
N	10828	10828	9940	10828	10828	9940
1900 controls	No	Yes	Yes	No	Yes	Yes
Excluding dust bowl states	No	No	Yes	No	No	Yes

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

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

Standard errors are clustered at the county level.

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

Table 9: Heterogeneity by specific crop specialization

	Corn (1)	Wheat (2)	Hay (3)	Cotton (4)
	Panel A: Share of land allocated			
Log(Farmers /T)*High producers	-0.023	-0.052	0.-051*	0.060
	(0.032)	(0.107)	(0.028)	(0.274)
Log(Farmers /T)*Low producers	0.054**	-0.077**	0.013**	-0.177
	(0.020)	(0.033)	(0.008)	(0.238)
P-value difference	0.000***	0.788	0.020**	0.423
N	10780	10780	10780	10780
	Panel B: Land productivity			
Log(Farmers /T)*High producers	0.934**	-0.912	0.060	-0.926**
	(0.429)	(0.582)	(0.274)	(0.413)
Log(Farmers /T)*Low producers	-0.119	-0.341	-0.177	-0.334
	(0.298)	(0.291)	(0.238)	(0.277)
P-value difference	0.000***	0.146	0.247	0.019**
N	10434	9049	10742	3283

The dependent variable in the first panel is the share of total farmland allocated to each crop.
The dependent variable in the second panel is the log physical output per acre for each crop.
All regressions include fixed effects for county and time and fixed effects for each year*state.
Standard errors are clustered at the county level.
*: 10% significance, **: 5% significance, ***: 1% significance

Table 10: 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	0.416***	-0.155	0.052	-0.169	0.510*	-0.805	-1.082***
	(0.153)	(0.108)	(0.044)	(0.173)	(0.293)	(0.861)	(0.284)
Log(Farmers/T)*Specialized	0.421**	-0.222*	0.076	-0.063	1.181***	-1.357	-1.625***
	(0.196)	(0.132)	(0.058)	(0.236)	(0.422)	(1.055)	(0.358)
P-value difference	0.944	0.047**	0.263	0.285	0.001***	0.049**	0.000***

N=10780. The dependent variables are labeled in each column. All regressions include fixed effects for county and time, fixed effects for each year*state and interactions between 1900 characteristics and year dummies.

Standard errors are clustered at the county level.

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

Table 11: 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)	0.061**	-0.077**	0.016*	-0.055	0.370**
	(0.025)	(0.038)	(0.009)	(0.040)	(0.178)
Log(Farmers/T)*German	-0.047	0.002	-0.020	0.114*	0.367
	(0.047)	(0.070)	(0.029)	(0.062)	(0.333)
Log(Farmers/T)*Anglo	0.021	0.003	-0.016	-0.096	0.141
	(0.059)	(0.068)	(0.051)	(0.101)	(0.343)
N	10780	10780	10780	10780	10780
	Panel B: Effects on tenancy and draft power				
	Land by owners	Land by tenants	Horses	Mules	Tractors
Log(Farmers/T)	-0.19	0.059	-0.143	0.256	-0.911
	(0.136)	(0.051)	(0.180)	(0.313)	(1.034)
Log(Farmers/T)*German	0.261	-0.070	0.224	1.197	1.878
	(0.190)	(0.106)	(0.391)	(0.813)	(1.512)
Log(Farmers/T)*Anglo	0.301	-0.038	-1.502	1.628	-1.511
	(0.237)	(0.153)	(1.253)	(1.190)	(2.294)
N	10780	10780	10780	10780	8085

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

Standard errors are clustered at the county level.

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

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