Seeds of American Industry: Economic Geography and Agriculture

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April 2, 2019

Abstract

This article examines the degree to which a large potential market influences the location of new industries using the case of the 19th century United States' agricultural implements industry. This industry was highly innovative at the time, and it is also distinguished by having linkages with both the agricultural and manufacturing sectors. Its output is sold primarily in rural areas, which creates exceptional product-level spatial variation in demand. Proximity to demand and spillovers are both found to have strongly significant effects, with the impact of proximity to demand being larger by about half. The most complex implements are also associated with higher concentration of skilled labor. Together, these results show that agriculture provided a foundation for the development of advanced manufacturing in the United States.

1 Introduction

During the late 19th century, the United States experienced a major shift in the composition of its production and exports that culminated in overtaking the European powers as the world's leading industrial economy. Previously an exporter mainly of agricultural goods and semi-manufactures, the United States began to be known as a market leader in several industries with high innovation content. What drove this change to occur? A variety of explanations have been considered, ranging from availability of natural resources (Wright 1990; Irwin 2003) to geographical considerations such as market size and transportation infrastructure (Klein and Crafts 2011; Atack et al 2008) to changes in returns to innovation (Sokoloff and Khan 1990).

To address the question of how the United States went from a primarily agrarian nation and supplier of primary goods to other industrial nations to being a market leader in several industries, selling manufactures of American design, I focus on an example of the new innovation-intensive industries that grew rapidly in the post-Civil War period: manufacturing of agricultural implements[1]. Historical data in this industry is highly disaggregate in product space and is associated with a great deal of geographical variation which can be exploited to separate potential causes for location decisions from each other. The geography of the agricultural implements industry is found to be distinct from that of other manufacturing, which had a different geography of demand. There were also coagglomerative forces in

[1] The industry covers both traditional farm tools such as hoes and grain cradles, and mechanized tools like the mechanical reaper.

the industry, but only among manufacturers of the same category of implement, which suggests that manufacturers were able to make improvements by observing each other. Furthermore, by one measure of skill content, manufacture of the most complex implements was associated with higher human capital use by the industry.

The empirical setting of this paper is the Second Industrial Revolution of the late 19th century. Prior to this, the United States was best known internationally for its agricultural exports. As late as 1880, over half the labor force was still employed in agriculture.[2] Changes in technology during this time period are associated with a rapid increase in manufacturing and trade employment, but also with large improvements in farm labor productivity, due in considerable part to the mechanization of agriculture. Due to the sheer size of the agricultural sector, these changes contributed significantly to overall economic performance.

In this period, the agricultural implements industry thus served a dual role: as a productivity booster for the largest sector of the economy, and also by contributing to rapid growth in the manufacturing sector. From the perspective of economic development, the industry's distinguishing traits were rapid growth in size, international competitiveness, a high rate of innovation, and high demand for skilled labor. More US patents were filed in the 19th century for implements than either textiles or engines. In addition, the composition of its workforce implies a higher level of skill content than most other industries, with a near-absence of child labor and an exceptionally high number of salaried employees, both per firm and compared to the number of wage workers.[3] Considering also the leading international

[2] Though this was already a considerable decline from earlier in the century; cf. Lebergott 1966.

[3] In 1900, the industry employed 14.0 salaried employees per firm, with one per 4.6 wage-

position that it established by the turn of the century, the implements industry can therefore be said to be one of the earliest examples of American technological leadership.

Because the agricultural implements were a cutting edge technology at the time, and because in the American case, an industry in a country behind the technological frontier overtook its competitors in frontier countries, location decisions in the American implements industry are illustrative of the processes behind innovation- or skill-promoting industrialization. From the empirical perspective, the industry was subject to exceptional geographical variation. Though it is a manufacturing industry, it serves the agricultural sector: firms faced geographically distinct market access patterns for downstream and upstream transactions. The agricultural sector which they supplied provides an additional form of geographical variation: exogenous climate and soil differences between regions result in differences in crop suitability which in turn require different tools. Figure 1 illustrates one example: the clear North/South split between corn and cotton planter production.

The geographical variation in both intended market and technology can be used to identify the impact of geography through three channels which are considered important in the literature. First, proximity to demand: climate-driven differences in crop growing regions allow for identification by subjecting different implements to different geographies of demand access. Second, proximity to other firms, which might lead to quality improvements or decreases in production costs by access to inputs or by innovation- or infrastructure-related spillovers: since many im-

earners. Compare to iron and steel with 13.8 per firm and one per 24.2 wage-earners, or textiles with 3.9 per firm and one per 39.3 respectively. (U.S. Census Office 1902) plements are designed to solve similar problems, solutions might be transferable between manufacturers. Third, factor endowments: of specific interest to a high-tech industry is whether skilled labor played a role in industry location decisions, but other factors may have effects on the comparative advantages of different locations.

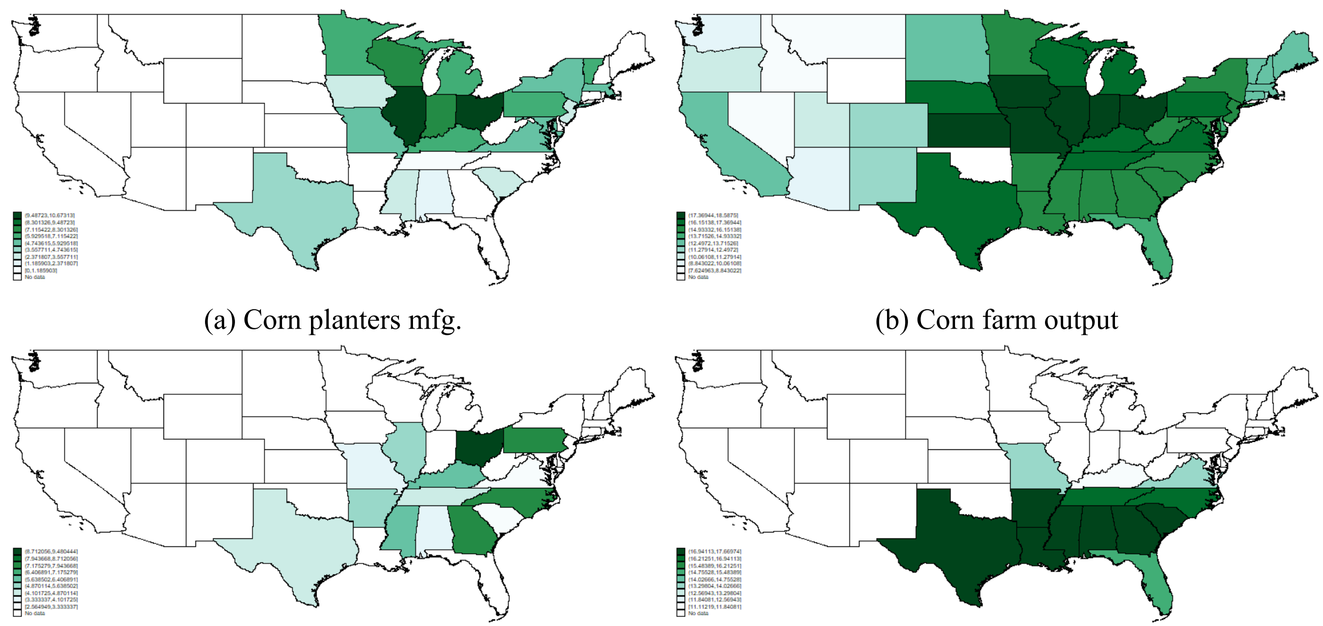
To address the question of impact of the three channels, I use a specification inspired by the model used by Midelfart-Knarvik et al (2001) to test the strength of interactions between state characteristics (or endowments) and product traits (input requirements or otherwise access to desirable conditions). Applied to the agricultural implements industry data for Census years from 1870 to 1900, which is highly disaggregate in product space, proximity is found to affect an implement's manufacturing location only for those crops in its target market, and implements which are of the same type. Other kinds of agriculture and manufacturing are found to have no residual influence.

Taken together, the two geographical effects emphasize the role of industry-specific linkages in promoting the growth of the agricultural implements industry. The positive impact of proximity only to related crops confirms the prediction that sufficient access to demand markets is a primary driver of industry growth. Similarly, the impact of proximity only to manufacturers of products with similar function suggests that manufacturers produce positive spillovers, but these benefits accrue mainly to closely-allied industry. Estimates of effects from factor endowments are not significant for most products. However, higher output of the most complex implements is associated with higher pay for wage-earners, yet not professionals or salaried employees. This could indicate higher skill content in the production process for these tools.

The case of the agricultural implements industry thus connects the usually separate literature on innovation with that on the geography of industrialization. While it is generally one of the goals of development for industrializing countries to move labor from agriculture to activities with higher labor productivity, as a practical matter, many development plans devote major efforts to increasing agricultural productivity, both in the present (World Bank 2007) and historically.[4] This is only natural since agriculture is frequently the largest sector by employment; an increase in incomes for the majority agricultural labor force can provide an indispensable demand boost for expanding industries. To generalize, the evidence for the importance of inter-industry linkages reinforces the case for well-planned dirigiste development policy as a means of both improving the productivity of a major existing industry and developing new industries capable of driving still further productivity innovations. Successful policies will effectively reproduce the structural change that American industry underwent organically.

Section 2 provides additional historical background for the agricultural implements industry and discusses this paper's position relative to the literature. Sections 3 and 4 describe the empirical model and the available data respectively; section 5 presents the analysis and considers alternative explanations. Section 6 concludes with discussion in historical and development contexts, and of possibilities for related research.

[4]For example, World Bank 2007 for a modern case, and Arimoto 2012 is a historical one.



(a) Corn planters mfg. (b) Corn farm output

(c) Cotton planters mfg. (d) Cotton farm output

Figure 1: Geographical distribution of manufacture of corn and cotton planters in 1880. The difference in manufacturing locations between planting implements targeted at different crops is readily apparent in panels (a) and (c). For comparison, the distribution of farm output corresponding to the implement is shown in (b) and (d).
Source: U.S. Census of Manufactures 1880.

2 Background

For less-developed countries in the post-World War 2 era, the first stage in rapid economic growth is typically to move labor out of agriculture into more productive activities by encouraging investment in manufacturing. By focusing on the export market, this method makes use of the large gap relative to wages in more developed countries. At the same time, both present (World Bank 2007) and historical (e.g. Arimoto 2012, for Depression-era Japan) development plans often devote major efforts to increasing agricultural productivity. This is only natural, since agriculture is frequently the largest sector by employment. An increase in incomes for the mostly agricultural labor force can provide an indispensable demand boost for expanding industries and can also accelerate the process of labor reallocation, since rural migrants may face liquidity constraints (e.g. McKenzie and Rapoport 2007, Cai 2018).

However, because export-led manufacturing relies on low labor costs to make the country an attractive trading partner, growth in incomes can itself cause growth to slow, a situation commonly referred to as "the middle-income trap." The question of how to sustain growth through this income range is thus a major going concern in development. After achieving middle-income status, different growth strategies may be necessary to avoid slowdowns, such as a greater emphasis on skill- and capital-intensity and increased investment in education.[5] It follows that cases of nascent innovation-based industries might yield useful observations of transitions in growth strategy.

[5] e.g. Eichengreen et al 2013 find that involvement in high-tech exports and greater secondary and post-secondary education reduces the likelihood of slowdowns.

Though to call it a "middle-income country" would be inaccurate, it is possible to see a number of parallels between its experience in the 19th century and the story above. To whatever degree that high pre-industrial American incomes are products of greater physical and human capital endowments, those traits are not reflected in the skill intensity of early American factories, which employed skill-substituting technologies (e.g. ring spinning). The main exports were agricultural goods and semimanufactures of agricultural goods,[6] with lower-end manufactures mostly for the domestic market. The United States of the early postbellum period thus occupies a middle-income niche in global trade: it is an exporter of raw materials and lower value-added goods, with less skill-intensive industry and less sophisticated technology.

The conventional account of American emergence as an industrial power takes the position that it did so by reallocating factors away from agriculture (e.g. Broadberry 1998). But the agricultural sector was by no means stagnant during the 19th century, and mechanization had much to do with this.[7] Together with the size of the agricultural sector, this fact suggests that a strong backward linkage with agriculture could have been a powerful lever to encourage the growth of the industry.

In the final decades of the 19th century, the United States began to acquire competitiveness in complex manufactures, particularly machinery, rather than only raw and semi-manufactured goods. This stands in contrast to its position in older world manufactures markets such as textiles (cf. Harley 1992). Agricultural implements

[6]In 1878, cotton and cereals contributed over 50 percent of U.S. exports. This share rises to nearly 70 percent if manufactured food products are included (U.S. Census Bureau et al. 1878).

[7]Even Olmstead and Rhode (2002), who emphasize that higher productivity in agriculture was in significant part a result of biological innovations, still attribute about half the increase to mechanical innovations–an increase of over 100 percent between 1839 and 1909.

were one example of an industry in which American manufacturers came to out-compete others, a fact acknowledged by their contemporaries (Clark 1916). In the case of the Australian market, the province of Victoria went from purchasing 93 percent of its farm machinery from Britain in 1870 to importing 62 percent from the United States and Canada in 1900.[8] Industry trade numbers reinforce this story: though exports first exceed 2 million dollars annually in 1873 and consistently increase thereafter, imports are negligible until 1910 (US Department of Commerce, 1919). By 1905, exports were 21 million dollars of 113 million produced, or 18.6 percent, a higher proportion than any manufactures other than sewing machines (23 percent) and refined mineral oil (56 percent). Though international data on production of agricultural tools is sparse, making it difficult to draw firm conclusions about implement use, the rapidly growing rate at which major agricultural producers such as Argentina imported implements implies that the same general pattern of demand as for the US applies, with some delay. Exports from other countries (e.g. Argentina to Uruguay) appear to be anticorrelated with American and British exports, suggesting that the strength of the industry leaders inhibited growth of domestic implement production by other agricultural nations.

The agricultural implements industry's unusual position–connecting agriculture and manufacturing, and expanding rapidly in the transition between the agriculture-focused antebellum American economy and the mechanized and increasingly innovative, manufacturing-focused economy of the 20th century–gives it several uncommon advantages in terms of the ability to distinguish between explanations for American economic growth and industrial transformation.

[8] This preference for American machinery may have been the result of a greater willingness of American producers to adapt and market their products to the specific market (McLean 1976).

One explanation, well-represented in the literature, is geography: in this view, access to the United States' large internal market was key to the rise of industry, dictating both how much manufacturing would grow, and where it would locate. Economists have recognized the potential for trade costs and market access to influence industry location since at least the time of Marshall (1920), but attempts to disentangle these forces run into a significant measurement problem: both forward and backward linkages (e.g. labor supply, consumer markets, intermediates markets, financial services) concentrate in cities, leading to similar geographical distributions. But due to its position between two unlike sectors, firms in the agricultural implements industry face distinct upstream and downstream market access patterns, which must be balanced against each other in location choices. An additional form of geographical variation comes from the agricultural demand market: exogenous climate and soil differences between regions result in differences in suitability for crops–each of which require different tools. Thus, market access and endowments are characterized by different spatial distributions, allowing their effects to be identified more readily.

Many works use some variation on the Harris's (1954) market potential formulation to measure market access; it has been used to explain the location of the American manufacturing belt (Klein and Crafts 2011), the relocation of Polish industry after reunification in the interwar period (Wolf 2007), and the location of Japanese investment in the EU (Head and Mayer 2004). Since effective market size is not just a function of distance but the cost of trading over that distance, railroad access is a closely related topic; Atack et al. (2008) is but one example which finds that market size influences industry size through railroad access. Donaldson and Hornbeck (2016) reinforce this point with very fine transportation cost estimates and find that the rail network had a very large impact on land values and population. The outcomes in the historical case, access to markets[9] and capital accumulation,[10] can be seen as parallels to the measures usually taken as part of dirigiste plans for initial industrialization.

For the Census years 1870-1900, data is available at the state level for the output of individual implements, which is a similar level of disaggregation to the 5-digit SIC level. This data also divides implements into four categories according to their function, which dictates which manufactures are grouped together when testing for potential spillover benefits. The differences in geographic distribution can be large (see, for example, Figure 2). This is an indication of how different the location problem of supplying to agricultural producers is from that of supplying finished consumption goods. If it were the case that market potential based on GDP were the key driver for firm location (as Klein and Crafts 2011 find for consumer goods), then we would expect to find the majority of implements manufacturing in New York and Pennsylvania, as we do for manufacturing in general. Instead, while New York is still a major source of implements, it is third behind Ohio and Illinois; furthermore, less of its production is of newer mechanized implements. Nevertheless, the industry undergoes considerable consolidation during the 1880s and 1890s, and as with other American manufacturing, this process moves the industry towards the manufacturing belt.

If, as widely argued (e.g. Eichengreen et al 2013), a change in focus to high-tech industries is eventually required for continued growth, it is natural to consider the

[9]Potentially by relocation, but also by selection on location.
[10]Including infrastructure investments such as railroads.

speed of innovation as another explanation for industrialization.[11] The American implements industry had a very high rate of invention; the 38,661 patents filed between 1836[12] and 1900 exceed the number filed in either textiles (32,330) or engines (23,616). In this case, the large agricultural sector's backward linkage to the implements industry allowed it to support innovation. Sokoloff and Khan (1990) argue that the state of technology at the time made it possible for a broad-based innovation boom to occur, where a large number of relatively unspecialized individuals each contributed a few patents. This suggests a potential mechanism for the support: close access to the agricultural sector gives would-be inventors access to information about industry needs. I also find evidence for spillover effects within the industry, which are suggestive of the potential for the industry to encourage further innovation within itself and in related developments.

Market potential measures of both access to demand and access to spillovers are found to be robust determinants of industrial location in the period 1870-1900, with access to demand being somewhat approximately one and a half times as influential. These two positive results provide observational evidence that the both a backward linkage from agriculture and mutual spillovers between different parts of the industry were significant factors supporting the growth and agglomeration of the agricultural implements industry. The leading edge of this industry, a major area of innovation in the 19th century, was associated with greater employment of skilled labor, increasing the growth potential for similar industries. These results provide observational evidence that there were linkages with agriculture capable

[11] Maloney and Valencia Caicedo (2014) argue that this is a major difference between the United States and Latin America.

[12] The patent office records were destroyed by fire in December of 1836; records from before then could not be completely reconstructed.

of promoting the development of innovation-based industries, and by extension, full transformation of the economy.

3 Empirical Design

My specification is based on the model developed by Midelfart-Knarvik et al. (2001) (henceforth, MKOV), and subsequently used by Wolf (2007) and Klein and Crafts (2011), which derives from the usual CES demand system the following estimating equation:

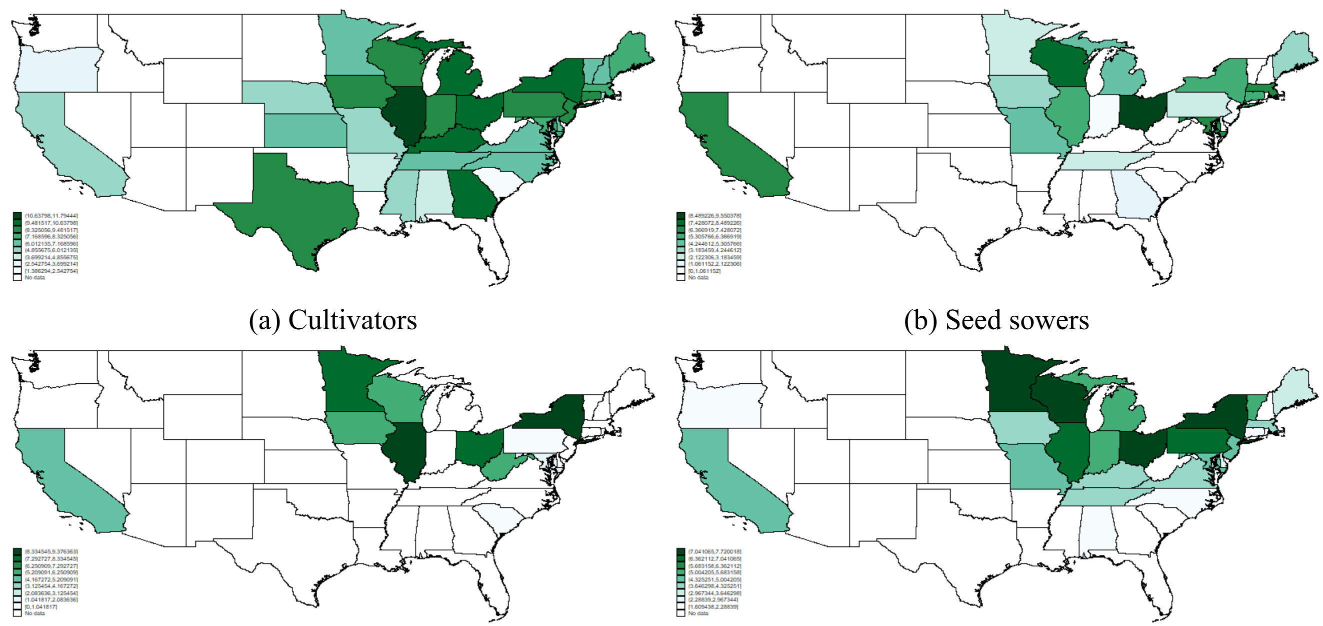
$$s_{it}^{k} = c(\nu_i : k,t)^{1-\eta} m(u^k : i,t) exp[\varepsilon_{it}^{k}] \tag{1}$$

Here, c is the unit cost function, m is market potential, and s_{it}^{k} is the share of domestic gross output by value for industry k in state i in period t. Log-linearizing this around a reference point captures many of the linkages of interest with the basic form

$$\ln(s_{it}^{k}) = \alpha + \sum_{j} \beta^{j} (y_{it}^{j} - \bar{y}^{j})(x_{t}^{jk} - \bar{x}^{j}) + \varepsilon_{it}^{k} \tag{2}$$

where j denotes a pairing of a location characteristic (values y) with an industry characteristic (values x), which are believed to jointly affect the desirability of a location for firms in the given industry. In this case, each value of k would denote a specific implement. The parameters $\bar{y}^{j}$ and $\bar{x}^{j}$ are thought of as reference values, since they denote values for which the share of output in a state or industry would be independent of the corresponding industry or location characteristic. This model can be written as:

$$\ln(s_{it}^{k}) = (\alpha + \sum_{j} \bar{y}^{j} \bar{x}^{j}) + \sum_{j} (\beta^{j} y_{it}^{j} x_{t}^{jk} - \beta^{j} \bar{y}^{j} x_{t}^{jk} - \beta^{j} \bar{x}^{j} y_{it}^{j}) + \varepsilon_{it}^{k} \tag{3}$$



(a) Cultivators

(b) Seed sowers

(c) Harvesters

(d) Threshers

Figure 2: Geographical distribution of manufacture of selected agricultural implements in 1880. Each of the four categories (in order: cultivator, seeder, harvester, thresher) is represented. Manufacture of cultivators (a) is widely distributed, while production of the larger, more expensive harvester is concentrated within the manufacturing belt (c).

Source: U.S. Census of Manufactures 1880.

which makes it clear that each linkage can be expressed in the form of an interaction between a state characteristic and industry characteristic, expanded about the reference point: the coefficients to be estimated in a regression analysis are β^j on the interactions and $-\beta^j\bar{y}^j$ and $-\beta^j\bar{x}^j$ on industry and state characteristics respectively.

One of the problems that this analysis must address is the fact that, at the roughly 5-digit SIC equivalent level of disaggregation obtained by considering each implement as a separate product, there will be many zeros in the production data. A log-linear model such as the original MKOV deals rather poorly with this feature of the data. OLS will not be consistent unless quite stringent criteria on the errors are fulfilled. Both of these problems can be overcome by applying the Poisson pseudo-maximum-likelihood (PPML) estimator (Santos Silva and Tenreyro 2006) with the estimating equation. This reduces the necessary assumption for consistency to the form of the conditional mean; that is, that $E[s_{it}^k|x] = exp(x_i\beta)$, which will be compatible with the definition given in equation 1.

The model can then be expressed in the form:

$$\begin{aligned} \ln s_{it}^k = & \sum_n \beta_n (\ln MARKETPOTENTIAL_{ikt}) \\ & + \sum_m \beta_m (\ln ENDOWMENT_{it} \times TECHGROUP_k) \\ & + \sum_i \gamma_i STATE_i + \sum_k \theta_k IMPLEMENT_k + \sum_t \delta_t YEAR_t + \varepsilon_{ikt} \end{aligned} \tag{4}$$

where $STATE$ and $IMPLEMENT$ are dummies for states and implements respectively, and $TECHGROUP$ is a category of dummy variables denoting groups of implements arranged by rough level of sophistication. It bears repeating that the dependent variable to be estimated is each state's share of production of a given implement in a given time period. This has the consequence that the impact of each of the interactions is scaled to the size of the market for the implement in question; differences in raw market scale can be included in the implement-specific θ (or alternatively, by normalizing the interaction terms directly).

The key feature of the MKOV model that I aim to preserve is the targeted interaction between industry needs and regional (state) endowments that predict different preferred locations for manufacturers of different goods, which is shown explicitly for endowments in Equation 4. For the market potential or geography interactions, the interaction is implicit in the implement-specific definition of each market potential. Since specific measures of labor and capital requirements are not available at the implement level, I substitute for them by categorizing implements into four groups and compare the impact of endowments on each category–more complex implements are expected to require more skilled labor and capital to manufacture. In category 1 are traditional hand tools such as hoes and scythes; category 2 consists of early mechanized implements (e.g. the reaper). Category 4 are complex "second generation" mechanized implements such as binding harvesters (a development of the reaper), whereas category 3 are implements introduced later in the sample period that don't fit the category 4 criteria. This categorization is necessarily somewhat ad hoc, but several alternative methods of building these categories will be discussed and the results summarized in Table 4. In any event, results on the other channels are robust to the inclusion or exclusion of this categorization.

My preferred specification, with the contents of the two major categories enumerated, is the following:

$$\begin{aligned}
\ln s_{it}^{k} = &\beta_1 (\ln CROPMARKETPOTENTIAL_{ikt}) \\
&+ \beta_2 (\ln MFRMARKETPOTENTIAL_{ikt}) \\
&+ \beta_3 (\ln SHAREPOPURBAN_{it} \times TECHGROUP_k) \\
&+ \beta_4 (\ln SHARELABORPRO_{it} \times TECHGROUP_k) \\
&+ \beta_5 (\ln INDUSTRYWAGE_{it} \times TECHGROUP_k) \\
&+ \beta_6 (\ln KLRATIO_{it} \times TECHGROUP_k) \\
&+ \sum_i \gamma_i STATE_i + \sum_k \theta_k IMPLEMENT_k + \sum_t \delta_t YEAR_t + \varepsilon_{ikt}
\end{aligned} \tag{5}$$

The third to sixth terms in my specification, which feature the technology group dummy, are interactions intended to represent the effect of factor endowments on location by group: three are for different measures of labor accessibility, these being $SHAREPOPURBAN$, the proportion of labor in urban areas[13]; $SHARELABORPRO$, the proportion of trained professionals, used as a measure of the availability of white collar or professional workers (e.g. inventors and engineers); and wage level $INDUSTRYWAGE$, which I use here as a proxy for the productivity (or skill content) of production workers. The fourth ($KLRATIO$) is capital-labor ratio.

The market potentials used here follow the form introduced by Harris (1954):

$$MP_i = \sum_j Y_j / d_{ij}$$

with d_{ij} being the effective distance between regions i and j.[14] Unlike the other four, endowment-related terms, the first two terms in the specification are not ex-

[13] Urban areas are defined to be towns and cities exceeding 2500 residents. An alternative figure using cutoff of 25,000 residents is nearly perfectly correlated and thus produces the same results.

[14] In principle, as derived in Krugman (1992), firms in central areas should experience greater

plicitly defined as interactions between a state characteristic and an implement characteristic. However, the market potential terms are specific to the implement being observed: in effect, they are the part of the whole crop or manufacture market potential interacted with a function which describes the state's relative suitability for the implement at hand. For example: cotton planters are in the category of seeding implements and are used on cotton only. The crop market potential would then be equivalent to the total market potential for all crops interacted with a function that multiplied the contribution of each state by the fraction of the crop which is cotton. For an arbitrary implement K:

$$CROPMARKETPOTENTIAL_{iKt} = \sum_j \left[\left(\frac{Y^A_{jt}}{d_{ij}} \right) \times \left(\sum_c \frac{\delta_{cK} Y_{cjt}}{Y^A_{jt}} \right) \right] \qquad (6)$$

where Y_{cjt} is the output of crop c in state j in period t, $Y^A_{jt} = \sum_c Y_{cjt}$ is the total agricultural output of state j, and δ_{cK} is a binary variable which is equal to 1 if implement K is useful in producing crop c, and 0 otherwise. Correspondingly, the manufacture market potential for cotton planters would be the total market potential of implements manufacturers multiplied by the fraction of manufacturing value in each state that was of seeders:

$$MFRMARKETPOTENTIAL_{iKt} = \sum_j \left[\left(\frac{Y^M_{jt}}{d_{ij}} \right) \times \left(\sum_k \frac{\delta_{kK} Y_{jkt}}{Y^M_{jt}} \right) \right] \qquad (7)$$

where Y_{jkt} is the output of implement k in state j in period t, $Y^M_{jt} = \sum_k Y_{jkt}$ is the total implement manufacturing output of state j, and δ_{kK} is a binary variable which is equal to 1 if implement k is the same type of implement as K and 0 otherwise.

price competition, which offsets the advantage of higher market access. However, lack of data on regional trade prevents the straightforward implementation of the full price-adjusted market potential. In any event, previous literature such as Head and Mayer (2004) suggest that either definition is supportable, and that the measure derived by Krugman does not necessarily outperform Harris's ad hoc measure.

In effect, the proportion of the crop or manufacturing output that is associated with the given manufacture functions as the state endowment portion of the interaction. The first term is a measure of the impact of downstream market potential. It is natural to predict that implements manufacturers will locate nearer to large concentrations of farms producing crops that the implements in question are useful for (see Figure 2) because of the direct impact on transport costs, but this term will also absorb any other effect stemming from close proximity to customers, e.g. better feedback leading to reduced development costs. The second term, "manufacture market potential," addresses the potential for spillovers by measuring the effect of proximity to manufacturers producing implements with similar functionality. The underlying mechanism would be that implements designed to perform similar tasks (even if on different crops) are likely to share features that can be copied or adapted between manufacturers, e.g., mowers are for harvesting hay. Developments in reapers or binding harvesters might be transferable to mowers,[15] since they have some common mechanisms: both are machines for cutting tall grasses, they can be horse- or (later) tractor-drawn, and certain features, such as the ability to seat the operator and to neatly arrange or bind the cut stalks are considered desirable for both implements.

Besides the interactions in the preferred specification, I also examine a variety of other market potentials:

Total (or GDP) market potential is of the type used in previous articles in the literature; this is calculated from state-level total personal income figures (Klein

[15]This is perhaps best demonstrated by the fact that later harvesters combine the functionality of both into one implement.

Table 1: Market Potentials

Potential	Function
Crop MP	Agricultural potential × Crop-implement suitability
Non-assoc. Crop MP	Agricultural potential of unsuitable crops
Manufacture MP	Total industry potential × Common implement type
Non-assoc. Mfr. MP	Total industry potential of other implement types
Total (GDP) MP	Total state personal income potential
Mfg Sector MP	Total state manufacturing potential, all industries

Sources: Census 1870-1900, Klein (2009), Haines (2004).

2009) and is included to account for proximity to economic activity not specifically related to agriculture or implements. If it were the case that the agricultural implements industry has no special connection to either farmers or related manufacturers but only to manufacturing activity in general (if, for example, industrial location were driven primarily by input or intermediate prices, which is predicted by theory to be a channel for market potential effects), this interaction would have high explanatory power. Manufacturing sector potential is the corresponding potential for overall manufacturing activity: it can be expected to be significant in the case that implements manufacturing locations are driven by the same factors as manufacturing on the whole.[16]

When constructing market potentials it is necessary to address the issue of how

[16] I should like very much to be able to include a market potential for intermediates or other material inputs here; unfortunately, the lack of product-specific data about the composition of inputs limits the ability of the study to measure any such effects.

distance is to be assessed, particularly as regards the impact of transportation infrastructure. A variety of approaches to this problem have been used, ranging from simple great circle distances based on an assumption of largely complete transportation networks (e.g. Klein and Crafts 2011) to comprehensive calculations of minimum route lengths with GIS (Donaldson and Hornbeck 2016). While the GIS method is very accurate in principle, it requires two assumptions about route efficiency: first, that the estimate of wagon route distance (which cannot easily be found using GIS in the absence of local road maps) is correct, and second, that the shortest route is also the cheapest and most practical route. On this second point, farmers in several states were upset enough by perceived rate discrimination to lobby for regulations to force railroads to charge more favorable rates. In the present situation, manufacturing output data is at the state level, so lack of geographical disaggregation also precludes making full use of the GIS method. However, because relevant market potentials for agricultural implements can be driven by locations with low population and poor railroad access to a greater degree than most final consumer goods, I elect to adjust the distance over the inter-state distance estimates based on the cost of road wagon transportation. Effective distance between two states is therefore the interstate distance between centers of states by railroad (assuming states are roughly circular, the mean distance to points within a state will be $d = \frac{2}{3}\sqrt{\frac{A}{\pi}}$.[17]), plus an estimate of the average distance traveled within the destination state by wagon. This wagon distance is estimated based on the density of track in miles of track per square mile of land area; the distance is then added to the railroad at a penalty rate based on the ratio of cost per ton-mile to the railroad freight cost. This ratio ranges from a low of 4.84 in 1870 to 20.5 in

[17] States are, of course, not actually circular. But for most states this is likely a lesser source of inaccuracy than the assumption of uniformly distributed activity within the state.

1900, reflecting a steep decline in railroad freight rates; wagon costs per ton-mile are largely stagnant over the period (Carter et al 2006). More details can be found in the associated appendix, section 8.1.

4 Data

The majority of the data used come either directly or indirectly from the United States Census. Data on the scale of agricultural implements manufacturing are found in the Census of Manufactures industry special reports at the state-implement level gathered as part of the decennial Census from 1870 to 1900. Variables include number of establishments, total workers, capital, total wages, and value of inputs and outputs. Worker counts are broken into men, women and children; however, adult men comprise over 96 percent of the industry workforce in all periods, so significant heterogeneity stemming from worker demographics is unlikely. I therefore refer only to the total number of hands in each period. The outstanding feature of the special reports is the tabulation of state-level output for each implement. Studies of late 19th century industrial location usually cannot disaggregate to finer than a 2- or 3-digit level; the individual products in the special reports are comparable to a 5-digit level of disaggregation.

The Census of Agriculture (also decennial 1870-1900) provides data on the crop output for the purpose of calculating market potential for the backward linkages. Data on harvests are detailed and include the yields of several dozen farm products, and their acreage. For categorizable implements, crops are organized into

13 groups[18] which I use to construct the demand or crop market potentials[19]. Reported occupations in the (population) Census are used to obtain the share of professionals in the labor forces of each state. Haines's (2004) digitization of the Census data, includes population and manufacturing data by state.

Table 2 summarizes the size and output of the industry in the period covered by the study. The industry undergoes a notable consolidation during the 1880s. While growing considerably in size, the industry experiences its main growth in labor productivity during that decade, but employment increases very little as the number of active firms falls, in contrast to the decades before and after.

Table 2: Industry Size and Output

	Establishments	Hands	Output (1900 dollars)
1870	2076	25249	$52,066,875
1880	1943	39580	$68,640,486
1890	910	42544	$81,271,651
1900	715	56628	$98,010,506

Source: Census of Manufactures 1870-1900.

All market potentials are constructed using Harris's (1954) method of inverse distance-weighted sums. The Harris measure neglects the price index, which in the theory acts as a countervailing effect on agglomerative forces, but as noted by Klein and Crafts (2011), the internal trade flows data necessary to construct

[18] Wheat, rye, barley and oats are grouped together as "small grains" because they can use the same equipment; likewise, potatoes and sweet potatoes are grouped.

[19] It is in some cases necessary to calculate the values of crops themselves; the appendix contains further details.

the index are unavailable before 1949. A separate market potential is calculated for each crop and implement category (of which there are four: seeders, cultivators, harvesters, and separators). If an implement is capable of serving more than one crop type, the crop market potential will be the sum of individual crops' market potentials (see equation 6). State level total income estimates are drawn from Klein (2009) and state manufacturing outputs from Haines (2004); average education and experience figures for alternate specifications are based on estimates by Turner et al (2006). As mentioned briefly above, I handle distances by estimating interstate distances as being on a railroad with distance between the centers of each state in a pair, and the intrastate distance as the approximate distance from a railroad based on railroad density. Therefore, a railroad map is necessary to correctly estimate the transport costs needed to find market potential. For this purpose, I use U.S. state maps for 1870 to 1900 (Siczewicz 2011) to calculate the distances between states and area of states. The length of track in state is drawn from the Statistical Abstract of the United States; this number and the land area of the state are used to estimate the track density and the distance traveled.

The combination of the above data sources yields a data set on 53 implements in four categories in 40 states and four census periods, with five state characteristics and two industry-state characteristics (the crop and manufacture market potentials)[20].

Because exports come to form a considerable (if still minority) part of industry revenues from the late 1880s onward, it's worth considering whether or not for-

[20]Market potentials are normalized to a mean of 1. Different implements vary widely in size of market; this allows state shares in their production to be compared to each other.

eign markets affect location decisions within the industry. Though agricultural surveys are in many cases either not comprehensive or absent altogether, the majority of countries that import agricultural implements from the United States[21] have at least some output data available for the period 1870-1900. Thus, it is possible to construct a crude measure of international market potential which covers the destinations for over 90 percent of the value of US exports for each year in the sample except 1870, for which only 53 percent coverage is possible due to the absence of British and Brazilian data. This part draws upon the agricultural and railroad track statistics in International Historical Statistics, 1750-2005[22] and uses the ocean freight rates collected by Harley (2008) to estimate the weighted shipping distance.

5 Results

In this section I discuss the results of Poisson estimation on the specification defined in section 3. Due to the disaggregation of the implements and the geographical concentration of many examples thereof, there are many zeros in the data, so the log-linear MKOV model is contraindicated. A similar problem is frequently faced in gravity estimation; the Poisson pseudo-maximum likelihood estimator (Santos Silva and Tenreyro 2006) is able to retain most of these observations while correcting for certain biases. The downside is that the possible endogeneity of market potentials must still be addressed and the use of a non-linear model will complicate the use of instruments.

[21] As listed in Foreign Commerce and Navigation of the United States, 1870-1900.

[22] In some cases, it is necessary to interpolate or use data from close years; as ignoring a missing country is tantamount to entering a zero, this was deemed less inaccurate.

Table 3 reports the results of estimation on equation 5, with standard errors clustered by state[23]. The values of the market potentials are scaled so that the mean for each implement is equal to 1; under the PPML model the estimated coefficients can be interpreted as elasticities. I present the Poisson regression results both considering the sample in aggregate and with interaction terms separating the groups by according to the year of the observation and according to the technology categories defined in section 3. The key results are that both downstream market access (Crop MP) and proximity to similar manufacturers (Manufacture MP) are statistically significant at the 0.1 percent level, with the estimated elasticity of downstream market access being in the range of 1.5 to 2 times as large as for proximity to manufacturers. Specifications 2 and 4 include interactions between the market potentials and year fixed effects using 1890 as the base year[24]. Though there are not enough periods to observe any clear time trend in the effect of the market potentials, it is possible that the estimate on crop market potential is lower in 1880 than in 1900. If this is the case, a period in which an anti-agglomerative force (attraction to a geographically scattered customer base) was weak coincides with the period of heaviest consolidation in the industry–with the number of operating manufacturers declining by more than half, from 1943 plants to just 910, between the 1880 and 1890 censuses.

In general, the directly observable factor endowment measures appear to have little impact on implement manufacturers' location decisions. However, it is important to note that state and implement dummies have a large impact on the estimation–

[23]For reasons of space, interaction categories which return no significant estimates are not displayed, but they are included in the appropriate columns as described in the table.

[24]The choice of base year is due to the number of observations

Table 3: Clustered Poisson regression for manufacturing share, overall and separated by period and technology categories.

	(1) Output share	(2) Year*MP	(3) Tech*Labor	(4) Both
Crop MP	2.815***	2.954***	2.875***	2.931***
	(8.17)	(5.55)	(8.27)	(5.88)
Manufacture MP	1.745***	1.815***	1.750***	1.894***
	(5.82)	(4.45)	(5.80)	(4.82)
Share Labor Professional	0.866	0.614	1.609	1.318
	(0.68)	(0.47)	(1.44)	(1.16)
K/L Ratio	-0.167	-0.0354	-0.0527	0.0609
	(-0.38)	(-0.06)	(-0.09)	(0.08)
Share Pop. Urban	-0.794	-1.005	-0.716	-0.886
	(-0.73)	(-0.74)	(-0.69)	(-0.68)
Industry Wage	-0.183	0.290	-0.898	-0.453
	(-0.34)	(0.51)	(-1.48)	(-0.73)
Crop MP × 1870		-0.186		-0.118
		(-0.29)		(-0.18)
Crop MP × 1880		-0.837		-0.821
		(-1.18)		(-1.19)
Crop MP × 1900		0.507		0.608
		(0.96)		(1.20)
Share Pop. Urban × Tech Group 2			0.570*	0.549*
			(2.09)	(2.02)
Share Pop. Urban × Tech Group 3			1.412	1.360
			(1.85)	(1.71)
Share Pop. Urban × Tech Group 4			0.795	0.777
			(1.48)	(1.43)
Industry Wage × Tech Group 2			1.011	0.986
			(1.68)	(1.65)
Industry Wage × Tech Group 3			2.642	2.480
			(1.46)	(1.29)
Industry Wage × Tech Group 4			1.798***	1.948***
			(3.63)	(3.90)
Time Interactions	NO	YES	NO	YES
Tech Group Interactions	NO	NO	YES	YES
Observations	4951	4951	4951	4951

Notes: *t* statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Columns: (1) No interactions (2) Market potentials by period, base year 1890 (3) Implements are roughly categorized by sophistication; the choice of categorization is covered in Table 4 (4) Both interactions from (2) and (3) are included. State and product fixed effects are included in all specifications, market potentials are normalized; interactions with no significant results are omitted for space.

since they may represent a wide variety of unobserved state characteristics, factor endowments should not be ruled out as an important influence on industry geography. There is no statistically significant influence for the industry capital-labor ratio. The interactions on urban population share and industry wages included in columns 3 and 4 find positive and significant impacts for groups 2 and 4 respectively. These categories contain heavy equipment such as reapers and their more advanced developments.

As discussed previously, the urban population share is taken to be a proxy for the available manufacturing labor. This result is therefore consistent with the idea that a larger pool of labor is desirable: while a significant effect is only observed for group 2, the much lower power of the estimates on groups 3 and 4 means that a similar-sized effect cannot be ruled out. The impact of industry wages, by contrast, is likely only on group 4, which are the largest and most complex implements. If industry wage can be taken as a proxy for labor productivity–an interpretation made more plausible by the dramatic rise in real wages coinciding with the consolidation between 1880 and 1890–this estimate shows that the most sophisticated products in the industry are associated with the most skilled, highest-paid production workers.

Taken together, the estimates on the elasticities of production share with respect to market potential suggest that market potential with respect to crops is around half again as influential as market potential with respect to similar manufactures. Manufacture market potential is slightly more variable (standard deviation of 0.51 as compared to 0.40 for crop market potential), which partly offsets the difference in elasticity with respect to overall impact. Using the deviance R-squared method of Cameron and Windmeijer (1996) gives an overall share of variation explained of 0.496 compared to the null model and 0.160 compared to a model with everything but the market potentials, under the specification of column 1 of Table 3. Inclusion or exclusion of the factor endowment variables does not meaningfully change these numbers.

Table 4 reports the results of using a variety of different technology categorizations. Since the choice of categorization in the main specification was made manually, it is worth considering whether that choice reflects a useful division of the implements in the sample. The first three columns are different variations on the same theme–the second column retreating from the categorization of post-1890 small implements as a separate category (and thus having only three categories) and the third only distinguishing "traditional" tools of types in use before industrialization from later machinery, though it should be noted that all tools benefit from improved materials and designs stemming from industry developments. These specifications yield qualitatively the same result, of a somewhat higher output share for higher categories in more urban states with higher wages. For comparison I also show two alternative categorizations: one based on regression estimates of how desirable professionals in the labor force were to individual implements and one categorized by date observed in the sample. The main result on the market potentials is not sensitive to any of the tested changes in the categorization.

Table 5 shows the results of three tests designed to rule out alternate explanations for the observed pattern on crop- and implement-specific market potentials. After accounting for proximity to implement-specific geographical influences, I find no further impact of the total or GDP market potential. If the agricultural implements

Table 4: Comparison of different technology categorizations.

	(1) 4-category	(2) 3-category	(3) Traditional	(4) By Share Pro	(5) Tracked Date
Crop MP	2.875***	2.867***	2.874***	2.772***	2.829***
	(8.27)	(8.68)	(8.50)	(8.23)	(8.23)
Manufacture MP	1.750***	1.750***	1.772***	1.756***	1.745***
	(5.80)	(5.63)	(5.72)	(5.65)	(5.88)
Share Labor Professional	1.609	1.533	1.564		0.659
	(1.44)	(1.28)	(1.31)		(0.50)
K/L Ratio	-0.0527	0.0837	0.0655	0.0565	-0.463
	(-0.09)	(0.15)	(0.11)	(0.07)	(-1.00)
Share Pop. Urban	-0.716	-1.037	-1.079	-0.827	-0.573
	(-0.69)	(-0.93)	(-0.94)	(-0.72)	(-0.56)
Industry Wage	-0.898	-0.893	-0.903	-0.359	-0.199
	(-1.48)	(-1.58)	(-1.60)	(-0.45)	(-0.28)
Share Labor Pro × Tech Group 2	-1.180	-1.302	-1.083		0.405
	(-1.44)	(-1.57)	(-1.33)		(0.29)
Share Labor Pro × Tech Group 3	-2.584	1.557			-0.0628
	(-1.24)	(1.11)			(-0.07)
Share Labor Pro × Tech Group 4	1.522				-1.900
	(1.08)				(-1.06)
K/L Ratio × Tech Group 2	-0.362	-0.376	-0.431	-0.577	0.887
	(-0.84)	(-0.77)	(-0.92)	(-1.08)	(1.40)
K/L Ratio × Tech Group 3	-0.597	-1.348		-0.231	0.423
	(-0.49)	(-1.90)		(-0.24)	(0.43)
K/L Ratio × Tech Group 4	-1.334			0.167	-3.535**
	(-1.90)			(0.17)	(-3.11)
Share Pop. Urban × Tech Group 2	0.570*	0.703*	0.699*	0.290	-0.241
	(2.09)	(2.52)	(2.43)	(1.16)	(-0.54)
Share Pop. Urban × Tech Group 3	1.412	0.759		0.431	0.285
	(1.85)	(1.47)		(1.36)	(0.79)
Share Pop. Urban × Tech Group 4	0.795			-0.392	-0.145
	(1.48)			(-0.98)	(-0.19)
Industry Wage × Tech Group 2	1.011	1.093	1.096*	0.725	-0.320
	(1.68)	(1.87)	(2.03)	(0.83)	(-0.23)
Industry Wage × Tech Group 3	2.642	1.809***		-0.0292	1.069
	(1.46)	(3.66)		(-0.03)	(0.84)
Industry Wage × Tech Group 4	1.798***			0.525	4.390
	(3.63)			(0.48)	(1.88)
Observations	4951	4951	4951	4951	4951

Notes: t statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Columns: (1) Primary 4-category specification, in order: hand tools, early large implements (e.g. reaper), small implements tracked 1890 or later, combined implements (e.g. binding harvester) (2) 3-category specification without separate category for 1890 and after (3) 2 categories, traditional hand tools and all others (4) quartile by regression coefficient on share professional (5) by date tracked in census.

industry were not particularly influenced by the location of growing regions, we should expect to find that it would behave similarly to the manufacturing sector as a whole and be positively associated with the general market potential (GDP MP). Since this is not observed, the key downstream influence is shown to be the location of agriculture, clearly distinguishing agricultural implements, an intermediate in the production of agricultural goods, from industries which sell primarily to end consumers. The third column is a robustness check on the accuracy of the assignment to each implement of associated crops and implements. For example, if agriculture in general attracts manufacturers, or if crops which are relevant to users of an implement have been miscategorized as unimportant, the residual market potential of the non-associated crops should have predictive value for the location of the manufacturers, and likewise for the implement category. However, these impacts, if they exist, are not statistically distinguishable from zero. To the reverse, if unimportant crops have been included as associated, they should bias the coefficients towards zero by diluting the market potential measure. The last test includes all market potentials including one based on the manufacturing sector's output by state as a check on the association of the implements with other manufacturing. The lack of an observed positive effect reinforces the conclusion that implements are geographically distinct from other manufacturing industries.

5.1 Foreign market potential

When considering the market potential implied by foreign agriculture, two of the main difficulties are the incompleteness of international data in the 19th century and judging how large of an effect trade barriers will have. Fortunately, there is a

Table 5: Alternative specifications testing total (or GDP) market potential and the validity of crop and implement categories.

	(1) Base+Tech	(2) GDP MP Test	(3) Assoc. Test	(4) All MP Test
Crop MP	2.875***	2.942***	2.831***	2.929***
	(8.27)	(5.06)	(7.79)	(7.51)
Non-associated Crop MP			0.0433	0.0448
			(0.60)	(0.79)
Manufacture MP	1.750***	1.525**	2.126***	2.305***
	(5.80)	(3.21)	(6.94)	(5.90)
Non-associated Manufacture MP			-0.640	-0.222
			(-1.81)	(-0.72)
Total (GDP) MP		-0.942		-2.195
		(-0.36)		(-0.49)
Mfg Sector MP		0.141		-2.503
		(0.09)		(-1.29)
Share Labor Pro × Tech Group 2	-1.180	-1.420*	-1.240	-1.147
	(-1.44)	(-2.01)	(-1.50)	(-1.43)
Share Labor Pro × Tech Group 3	-2.584	-3.240	-2.870	-2.635
	(-1.24)	(-1.79)	(-1.23)	(-1.22)
Share Labor Pro × Tech Group 4	1.522	1.759	1.451	1.372
	(1.08)	(1.23)	(0.97)	(0.91)
K/L Ratio × Tech Group 2	-0.362	-0.100	-0.435	-0.478
	(-0.84)	(-0.21)	(-0.88)	(-0.92)
K/L Ratio × Tech Group 3	-0.597	-0.749	-0.798	-0.655
	(-0.49)	(-0.63)	(-0.61)	(-0.48)
K/L Ratio × Tech Group 4	-1.334	-1.570*	-1.457*	-1.488*
	(-1.90)	(-2.23)	(-2.05)	(-1.97)
Share Pop. Urban × Tech Group 2	0.570*	0.620	0.741*	0.812*
	(2.09)	(1.78)	(2.49)	(2.55)
Share Pop. Urban × Tech Group 3	1.412	1.663*	1.649	1.561
	(1.85)	(2.45)	(1.89)	(1.91)
Share Pop. Urban × Tech Group 4	0.795	1.315	0.921	0.938
	(1.48)	(1.88)	(1.70)	(1.75)
Industry wage × Tech Group 2	1.011	0.721	0.886	0.869
	(1.68)	(1.84)	(1.50)	(1.56)
Industry wage × Tech Group 3	2.642	1.862	2.832	2.779
	(1.46)	(1.22)	(1.42)	(1.43)
Industry wage × Tech Group 4	1.798***	1.606**	1.855***	1.800***
	(3.63)	(3.00)	(3.71)	(3.81)
Observations	4951	4951	4951	4951

Notes: *t* statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Columns: (1) Baseline specification with tech group interaction (as in Table 3 col. 3) (2) Specification replacing state fixed effects with market potential constructed from state-level total personal income, this should be significant if end consumers or overall economy size are important determinants of location. (3) Specification with market potentials constructed from crop and implement outputs not associated with the dependent product. (4) Specification including all alternative market potentials.

high degree of overlap between countries for which useful agricultural production data exist and countries which imported agricultural implements. Calculating foreign market potential measures based only on importing countries is thus equivalent to an assumption that trade barriers were large enough for non-importing countries that their implicit market potential is not enough to make them a consideration in firm location decisions.

Table 6 shows estimates on the market potentials including an added foreign component– either all importers of US agricultural implements for which agricultural output figures are available, or those importing at least one percent of total US exports. In both cases, over 90 percent of US exports are accounted for except in 1870, and cutting slightly more or fewer small importers from the foreign crop market potential calculation does not make a statistically significant difference in the estimates (though not shown here, other, more restrictive cutoffs were also tested). Nor are the estimates for the foreign component itself significant. This regression was also performed on other criteria for country inclusion without meaningfully changing the results, so the absence of data for less integrated parts of the world is unlikely to be skewing the results. However, when individual year effects are allowed for, the effect of international market potential is estimated to be lower in the first half of the sample period than in the second half. This is consistent with the fact that international demand starts to play a much larger role in industry revenues after 1890.

Table 6: Alternative specifications including foreign markets for all recorded importers and importers of at least 1 percent of US exports.

	(1) Output share	(2) Output share	(3) Output share	(4) Output share
Output share				
Crop MP	2.899***	3.045***	3.060***	2.907***
	(6.03)	(3.44)	(6.31)	(3.68)
Foreign Crop MP	-0.192	0.377		
	(-0.42)	(0.38)		
Foreign Crop MP (1 pct)			-0.103	0.767
			(-0.61)	(1.30)
Manufacture MP	2.153***	2.981***	2.165***	2.867***
	(6.62)	(5.52)	(8.51)	(6.17)
Crop MP $\times$ 1870		1.022		1.213
		(1.25)		(1.11)
Crop MP $\times$ 1880		-0.578		0.304
		(-0.56)		(0.35)
Crop MP $\times$ 1900		0.448		0.473
		(0.61)		(0.76)
Manufacture MP $\times$ 1870		-1.517**		-1.654*
		(-2.66)		(-2.11)
Manufacture MP $\times$ 1880		-0.144		-0.465
		(-0.24)		(-1.00)
Manufacture MP $\times$ 1900		-0.234		-0.227
		(-0.54)		(-0.51)
Foreign Crop MP $\times$ 1870		-2.082*		
		(-2.06)		
Foreign Crop MP $\times$ 1880		-2.492**		
		(-2.66)		
Foreign Crop MP $\times$ 1900		0.427		
		(0.55)		
Foreign Crop MP (1 pct) $\times$ 1870				-1.097
				(-1.57)
Foreign Crop MP (1 pct) $\times$ 1880				-1.222
				(-1.34)
Foreign Crop MP (1 pct) $\times$ 1900				0.209
				(0.44)
Observations	3698	3698	3555	3555

Notes: t statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Columns: (1-2) Baseline specification with added foreign agricultural market potential, with and without year interactions (3-4) As columns 1-2 but with foreign market potential for only those importers with at least 1 percent of total US exports. As international data is not available for the same crops as for domestic data, only those implements for which relevant foreign data are available are included.

5.2 IV

Due to the danger of endogeneity in market potential measures, I use two instruments: the first, crop market potentials from the prior period (a 10-year shift). Both crop and manufacture market potential measures are strongly correlated over time–crop market potential extremely so, with correlations of over 0.9 between decades. While it is in principle possible that past market potentials could directly influence the current location of industry, this risk is reduced by the decade-long gap between observations. Though direct data on firm lifetimes is hard to find, the combination of continuous industry consolidation over the period of interest and the lack of clear impact on the capital channel in the preceding estimates indicate that non-leading firms are unlikely to survive long if they are in poor locations. Therefore, past crop market potential should only affect industry location through its impact on current market potential. As a check on this assumption, I also run the analysis with market potentials calculated as if crop outputs were equal to those in 1860, which further reduces the risk of failing the exclusion restriction. The second set of instruments for the geographical distribution of implement manufacturing by relating each state to fixed geographical locations. For each of the four years in the sample I construct instruments which are the inverse distance from the center point of the industry for each type of implement in those years; alternatively, I use the state distances relative to three cities chosen for their status as transport hubs: Atlanta, Chicago, and New York. These results are displayed in Table 7.

IV estimation is performed using two-step GMM on the Poisson model, however, including fixed effects in an instrumental variables regression on the Poisson model has not been shown to yield a consistent estimator. In order to address this issue I de-mean the control variables and also provide the result of Poisson estimates without instruments, dropping the fixed effects. Though the standard errors in the IV regression are naturally larger, the coefficients remain significant at the 5-percent level and are not statistically different. The overall similarity of the instrumented coefficients suggests that any endogeneity in the market potentials as regressors for share of manufacturing output should not alter the basic result. Columns 5 and 6 compare two additional instruments for manufacturing location: in column 5, the industry center for each year and type (this satisfies both the Hansen test and a Hausman test on a linear model containing the same variables as this specification). Column 6 constructs a crude estimate of predicted locations for each implement by backing out the relative importance of demand for each type of implement for the four most important crops (corn, cotton, wheat and hay). This is done by assuming that demand for each implement by each crop is proportional to the implement's value relative to the total value of all implements that can be used for that crop. A weighted average is calculated from these estimates using all non-Pacific states. Again, the coefficients are similar to each other and significant to at least the 5-percent level.

6 Conclusion

In this study, I have considered the impact of several forces that may have influenced industrial location decisions in the 19th century US agricultural implements industry. In total, the model is able to explain roughly half of the variation in output share between different states, with the market potential variables specifically

Table 7: Instrumental variables Poisson regression for manufacturing share.

	(1) Base Poisson	(2) Poisson, no FE	(3) IV Lag	(4) IV 1860	(5) IV Avg Mfg	(6) IV Predict
Crop MP	2.814***	2.561***	2.291***	2.968***	2.497***	2.498***
	(8.00)	(3.93)	(4.46)	(4.41)	(4.95)	(4.52)
Manufacture MP	2.038***	1.575***	1.538**	1.194*	1.538**	1.508**
	(4.75)	(3.65)	(3.04)	(2.17)	(2.79)	(2.67)
Total (GDP) MP	-5.353	-0.929	-0.626	-0.621	-0.800	-0.703
	(-1.20)	(-1.14)	(-0.99)	(-0.95)	(-1.25)	(-0.96)
Share Labor Professional	0.771	0.536	1.185	1.049	1.003	1.080
	(0.59)	(0.45)	(1.39)	(1.20)	(1.23)	(1.18)
K/L Ratio	-0.218	0.353	0.651	0.570	0.675	0.816
	(-0.51)	(0.48)	(1.14)	(1.03)	(1.19)	(1.47)
Share Pop. Urban	-0.457	0.881*	0.727*	0.779**	0.676*	0.605*
	(-0.42)	(2.17)	(2.51)	(2.66)	(2.30)	(2.31)
Industry Wage	-0.0372	0.267	0.492	0.544	0.559	0.671
	(-0.07)	(0.62)	(1.15)	(1.20)	(1.31)	(1.72)
Observations	4951	4951	4951	4951	4951	4951
Hansen's J (p=)			0.7032	0.7100	0.7072	0.4972

Notes: *t* statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. All IVs except column 6 instrument for crop market potential with the market potential from the prior period (10 years before). Columns: (1) Baseline Poisson with no period interactions and GDP MP added for comparison with no-FE case (2) Poisson with no fixed effects (3) IV Poisson, instruments are lagged crop market potential and inverse distance from Atlanta, Chicago and New York (4) IV Poisson, instruments are as in col. 3 with crop market potential replaced with 1860 crop outputs (5) IV Poisson, lagged crop market potential and implement type weighted industry center (6) IV Poisson, lagged crop market potential and predicted industry center by implement based on main crops as demand sources. Poisson IV regressions are not compatible with fixed effects; control variables have been de-meaned to compensate.

explaining roughly one-sixth. Lack of significant coefficients on market potentials based on general economic activity and on overall manufacturing sector output are evidence that the agricultural implements industry is subject to location forces that are distinct from the manufacturing sector as a whole. Rather, the location of the industry is driven foremost by access to demand from the agricultural sector. Crop market potential, which includes the direct influence on shipping costs of proximity to consumers as well as other potential benefits such as access to feedback, is the strongest factor influencing location choices, with a measured elasticity of around 3. This coefficient is a direct measurement of the impact of demand on industry location, separate from other possible channels such as access to inputs, and demonstrates that 19th century American agriculture had the ability to encourage the growth of related industries through demand.

The crop market potential effect is estimated to be 1.5 to 2 times as strong in determining manufacturing location as manufacture market potential, which is also strongly significant. A positive effect from proximity to manufacturers may measure benefits such as shared infrastructure, but the fact that the impact is found to stem primarily from manufacturers of implements with a shared function, rather than from proximity to the industry or to manufacturing in general, implies that technological spillovers are a strong component of this effect. The magnitude of the effect suggests that spillovers may have contributed to the exceptionally high rate of patenting observed in the implements industry. On the side of factor endowments, industry wages and to a lesser degree urban population share have a positive impact on concentration of larger, complex implements. The industry wage effect especially is evidence for an association between development of more sophisticated manufacturing and the accumulation of human capital in production workers. These trends towards greater innovation and higher skill content give the agricultural implements industry more and more of a 20th century character as it develops.

Strong geographical linkage effects are in agreement with much of the post-2000 work in the area of industrial location. Particularly, the strong impact of proximity to agricultural customers on the production of technologically advanced capital goods indicates that, for the United States, a large and commercialized agricultural sector could be a boon to entrepreneurs in related manufacturing industries and accelerated the transition to an innovation and manufacturing economy. The positive estimates connecting implements manufacturers to those working on similar equipment imply that existing manufacturers have the potential to accelerate the growth of industries with shared technology. In the context of historical US industrialization, these observation provide support to the hypothesis that the geography of American agriculture provided a base on which an advanced manufacturing sector was eventually built.

Subsequent export behavior in the early 20th century indicates that further work on the development of technologies relating to the location of agriculture may also bear fruit, as American manufacturers appear to lead where implement mechanisms (e.g. plow and reaper blades) are concerned, but lag behind in implements such as traction engines (Dennis 1909) where the technical hurdles to be overcome are not directly related to agriculture. Further examination of the related question of whether production of technologies that served the agricultural market impacted the growth of manufacturing in general is needed to decide the importance of this channel, but the combination of the results is suggestive: the possibility that certain “trail-breaking” industries might have had an impact on the location of American industry in excess of their size cannot be ruled out.

In the development context, the question of linkages between industries continues to be relevant. Though dirigiste strategies have had a mixed record in recent decades, it should not be forgotten that many development successes in Asia were built on the back of such strategies. Findings of strong market access effects show that those outcomes were not flukes. Those successes featured improvement in agricultural productivity as a major component early in the transition. International comparisons on the relationship between agricultural productivity growth and the growth of manufacturing may be an interesting path for further research and shed further light on the mechanism. The east and southeast Asian industrialization cases may be more instructive from the perspective of initial industrialization, as their initial conditions will be more similar to present less-developed countries than that of the United States.

Yet even out of those countries ordinarily considered development successes, only a minority have progressed beyond the middle-income level. To address this problem, we must consider the experience of developed countries, the United States among them. If a transition to higher value-added innovation or R&D activities is the key to escaping the middle-income trap, then it is vital to understand what determines where those industries locate and grow. This study has found evidence for such a connection in the 19th century American agricultural implements industry, where location decisions were influenced by the geography of a pre-existing economy, but which also shows its influence on the economy through spillovers and signs of accumulation of human capital as it produces more technologically advanced goods.

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8 Appendix

8.1 Railroads and Distance Estimates

The construction of the distance variable consists of two main parts. The first is the distance either between the geographical centers of the two states in question, obtained using the GIS maps made by Siczewicz (2011). The distances themselves are calculated using Vincenty's formulae, which account for the oblate spheroid shape of the Earth. The second part of the distance variable is an estimate of the distance that must be traveled off the railroad by wagon once arriving in the destination state (defined to be the state to be summed over). I obtain my estimate from the railroad track density by finding the minimum average distance from the railroad within the state: effectively, if the state's area were a rectangle the length of all the track in the state, this would be one-quarter the width of that rectangle. For some states and territories with very poor railroad networks, this estimate exceeds the estimate of average distance between points within the state; in this case I cap the measure at that distance. Note that both of these distances are sure to be underestimates of the real distance traveled, but in the market potential calculation, distances are relative. Since both estimates are done on the same map, the underestimation of the two types of distance should mitigate the inaccuracy caused by either–any shared inaccuracy will, in effect, be a scaling factor which drops out when the market potential figures are normalized.

Table 8: Comparison of alternative distance specifications.

	(1) Baseline	(2) Vincenty	(3) Alt Distance
Crop MP	3.376***	2.926***	2.616***
	(10.82)	(11.06)	(12.72)
Manufacture MP	1.745***	1.683***	1.489***
	(4.05)	(5.29)	(3.70)
Share Labor Professional	1.257	1.155	0.937
	(1.10)	(1.07)	(0.82)
K/L Ratio	0.0827	0.0509	0.0947
	(0.12)	(0.07)	(0.13)
Share Pop. Urban	-0.865	-0.854	-0.873
	(-0.68)	(-0.78)	(-0.66)
Industry Wage	-0.489	-0.506	-0.502
	(-0.80)	(-0.88)	(-0.77)
Crop MP × 1870	-0.560	-0.501	-0.195
	(-0.80)	(-0.77)	(-0.37)
Crop MP × 1880	-1.278*	-1.074*	-1.125**
	(-2.27)	(-2.27)	(-2.64)
Crop MP × 1890	-0.487	-0.420	-0.178
	(-1.00)	(-0.99)	(-0.45)
Share Pop. Urban × Tech Group 2	0.555*	0.582*	0.499
	(2.03)	(2.16)	(1.75)
Share Pop. Urban × Tech Group 3	1.342	1.389	1.281
	(1.71)	(1.76)	(1.77)
Share Pop. Urban × Tech Group 4	0.761	0.735	0.752
	(1.39)	(1.36)	(1.36)
Industry wage × Tech Group 2	0.975	0.935	1.011
	(1.64)	(1.62)	(1.66)
Industry wage × Tech Group 3	2.450	2.290	2.393
	(1.28)	(1.23)	(1.29)
Industry wage × Tech Group 4	1.919***	1.888***	1.963***
	(3.86)	(3.94)	(3.76)
Observations	4951	4951	4951

Notes: *t* statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Columns: (1) Poisson with base (additive) distance specification (2) Poisson using only Vincenty inter-state distances (3) Poisson with alternate, multiplicative distance calculation. Column (1) likely underestimates the impact of low-infrastructure states, whereas column (2) overestimates.

In the base specification the effective distance is the sum of these two parts, with the second adjusted by the ratio between wagon freight rates and railroad freight rates:

$$d_{ij} = vincenty_{ij} + wagon_j * (wagonfreight_t / rrfreight_t)$$

This measure of distance is asymmetrical, an unusual choice for distance calculations, but which corresponds to the asymmetry in geography between the agricultural and manufacturing sectors. The decision to use this measure was made based on the fact that the relevant distances are between farm and factory; factories are assumed to be established considering access to railroads and so the adjustment for railroad infrastructure is only charged to the state where the potential purchaser is located. State level data are not disaggregate enough to know the distribution of activity within the state, but because whatever railroad access a state has is likely to be located near areas of major economic activity, this measure almost certainly overestimates the wagon travel distance for states with poorer railroad networks. For comparison purposes I also perform the analysis on market potentials calculated on the first (Vincenty) part alone. Since this measure underestimates the penalty associated with poor railroad networks (by ignoring it), it should serve as an opposite bound for the results of the analysis. As shown in the first two columns of Table 8, the changes in estimates are not particularly dramatic. The third column contains another alternate specification found by including the wagon distance adjustment multiplicatively (as if the two legs of the journey were separate transactions). This would overstate the adjustment against poor-infrastructure statements by still further and is thus not preferred, it is included for completeness.

8.2 Crop Prices

In earlier years in the sample, the Census reports quantities of crops grown and not values. In order to combine crop outputs for use with implements that can serve multiple categories, it is necessary to transform these quantities into values. Price data is obtained from several sources, notably Investigation Relative to Wages and Prices of Commodities, vol. 1, 1911 and the Historical Statistics of the United States (Carter et al 2006). Different sources may have different methods of obtaining the prices (e.g. time averaging of prices due to seasonality, different city of observation) which can introduce inaccuracy. However, this is mitigated by two features of the analysis: first, since market potentials are normalized, if two crops do not share any implements in common, then they can be from different sources without issue, as crop prices are only relevant for estimating the relative impact of their growing distribution on the same implement. Indeed, if implements designed for a crop are exclusively for that crop, lack of price data does not pose a problem. Second, the crops that have the least reliable price data are also the least economically important crops, so that even a large discrepancy in the price involved will not induce a big change in the market potential calculation.

8.3 List of Implements

Table 9: List of Implements

Implement	Data Availability				
	1870	1880	1890	1900	Total Periods
Seeders					
Bean planters			1	1	2

Continued on next page

Table 9 – *Continued from previous page*

Implement	1870	1880	1890	1900	Total Periods
Check rowers			1	1	2
Corn drills				1	1
Corn planters	1	1	1	1	4
Cotton planters	1	1	1	1	4
Grain drills	1	1	1	1	4
Grain sowers		1	1	1	3
Listers			1	1	2
Potato planters			1	1	2
Seed sowers	1	1	1	1	4
Cultivators					
Bean cultivators			1	1	2
Cotton choppers		1	1		2
Cotton scrapers			1	1	2
Cotton sweeps				1	1
Cultivators	1	1	1	1	4
Harrows	1	1	1	1	4
Hoes	1	1	1	1	4
Plows	1	1	1	1	4
Potato hillers				1	1
Rollers	1	1	1	1	4
Stalk cutters			1	1	2
Stalk pullers		1			1
Tobacco transplanters			1	1	2
Harvesters					
Bean harvesters			1	1	2
Bean pullers			1	1	2
Reaper-mowers	1	1	1	1	4
Corn harvesters			1	1	2
Fruit gatherers		1			1
Grain cradles	1	1	1	1	4
Hand rakes	1	1	1	1	4
Harvester-binders			1	1	2
Harvesters	1	1	1	1	4
Hayforks	1	1	1	1	4
Hay loaders		1	1	1	3
Hay stackers			1	1	2
Hay tedders		1	1	1	3

Continued on next page

Table 9 – *Continued from previous page*

Implement	1870	1880	1890	1900	Total Periods
Horse forks			1	1	2
Horse rakes	1	1	1	1	4
Mowers	1	1	1	1	4
Potato diggers		1	1	1	3
Potato hooks			1	1	2
Reapers	1	1	1	1	4
Scythes	1	1	1	1	4
Sickles	1	1	1	1	4
Snaths	1	1	1	1	4
Separators					
Bean separators			1	1	2
Thresher-separators			1	1	2
Corn huskers		1	1	1	3
Corn shellers	1	1	1	1	4
Fanning mills	1	1	1	1	4
Separators	1	1	1	1	4
Threshers	1	1	1	1	4
Clover hullers	1	1	1	1	4
Total per period	25	33	48	50	

53 implements total. *Sources:* Census 1870-1900.