Industrial Spillovers from Agricultural Processing: Evidence from the Beet Sugar Industry

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June 2024

Abstract

This paper investigates the role of agricultural processing as a bridge between agricultural productivity growth and local industrial development through the U.S. beet sugar industry, which processes a heavy and perishable crop requiring large-scale local facilities near farmlands. To address the endogenous location choice of plant openings, I use a trade journal that lists potential sites for beet sugar plants. By comparing counties where factories were established with those not ultimately selected, I find that plant openings had long-lasting effects on both manufacturing and agricultural activities over one hundred years. These effects stem from local spillovers through input-output linkages rather than from improvements in public goods or amenities.

*Baek: New York University, syb262@stern.nyu.edu. I thank Diva Astinova, David Atkin, Jie Bai, Bruno Caprettini, Ciprian Domnisoru, Dave Donaldson, Bill Easterly, James Feigenbaum, Raquel Fernandez, Jacob French, Michael Gilraine, Walker Hanlon, Stephan Heblich, Jake Kantor, Gianandrea Lanzara, Danial Lashkari, Pepita Miquel-Florensa, Jacob Moscona, Petra Moser, Michael Peters, Stephen Redding, Martin Rotemberg, Vasily Rusanov, Cory Smith, Sharon Triaberman, Venky Venkateswaran, Tianyi Wang, Alex Whalley, Larry White, Stanley Zin, and participants at NYU student applied micro lunch, Yale econoimc history graduate student conference, and Urban Economics Association conference for helpful comments and feedback. I thank Michael Boland for sharing data on beet sugar plants. All errors are mine. This paper was perviously circulated under the title "Beet sugar: Local multiplier in rural America"

1. Introduction

Whether agricultural productivity growth leads to industrial expansion is a long-standing question in economic development (Lewis, 1954; Kuznets, 1957; Rostow, 1990; Matsuyama, 1992). Increased income from agricultural productivity growth in rural areas could potentially be invested in urban areas, resulting in mixed evidence on its effects on local industrial growth (Bustos et al., 2020).

This paper examines the role of the agricultural processing in local industrial expansion. When the agricultural processing of crops is done close to agricultural communities, it can spur industrial growth in local economies not only due to the presence of processing plants themselves but also because such factories can attract other related industries through agglomeration spillovers. This suggests that agricultural processing could serve as a bridge between agriculture and manufacturing, encouraging local economies to move up their value chains in the product space from existing industries to new ones (Hausmann and Klinger, 2006). However, evidence remains limited on whether and how the agricultural processing can have positive externalities on local industrial growth.

I investigate this question by examining the sugar beet industry in the United States. This empirical setting is particularly suitable for studying the role of agricultural processing in local industrial development, as it estimates the impact of large manufacturing plant openings in fundamentally rural areas. Sugar beets are heavy, perishable crops that require processing plants to be located close to farmlands. Holmes and Stevens (2004) characterized the sugar beet industry as a classic example of a ’weight-losing industry,’ where seven tons of beets are required to produce one ton of sugar. According to Holmes and Stevens (2004), sugar beet factories are generally larger than typical manufacturing plants, and these factories and farms are likely to be co-located due to the need for local processing.

The transformative effects of the beet sugar industry on local economies also received significant attention from observers in the distant past. The beet sugar industry in the northern United States was considered to be distinctive in its ability to combine agriculture and manufacturing (Michigan Bureau of Labor and Industrial Statistics, 1902). Government officials and academics of the era described the beet sugar industry as a great decentralizing power that promoted significant rural development (Child, 1840; Blakey, 1913; Mapes, 2010).

This paper estimates the long-run effects of beet sugar plant openings between

1901 and 1912 on local economies in the United States. Local economic outcomes could be driven by a variety of county characteristics that favor plant openings other than the entry of manufacturing plants itself. To overcome this identification challenge, I use unique data on plant site selection. The *American Beet Sugar Gazette*, a trade journal, provided a list of cities or towns that were deemed suitable or were attempting to build beet sugar factories during this period. By comparing counties that established beet sugar factories to those included in the gazette that did not eventually construct a factory, this paper assesses the effects of sugar beet plant openings. Given that the aggregate demand for sugar is finite, the total number of beet sugar plants are limited and they must choose one city over another. Yet, this does not necessarily mean that the runner-up location is inherently disadvantaged in terms of industrial growth. In fact, I find that the treated and control counties exhibit similarities in various economic characteristics and demonstrated comparable trends in a wide range of outcome variables prior to the introduction of beet sugar factories.

The comparison between treated and control counties suggests that the openings of the plants led to a 40 percent increase in the value of farmland and buildings, a 348 percent increase in manufacturing employment, and an 86 percent increase in population over one hundred years. The overall effects were much stronger in Western states than in Eastern states, suggesting that the low initial population density, particularly in the West, during this period accounts for the large effects.

If the manufacturing employment increase is mainly due to the beet sugar industry expansion, it restricts room for externalities from beet sugar plants. To confirm that observed effects on manufacturing are not solely from beet sugar industry alone, I exclude confectionery industry employment using individual-level census data. Similar results emerge for overall manufacturing employment. I also provide direct evidence of local economic spillovers by weighting manufacturing employment based on its upstream and downstream connections to the confectionery industry. Findings highlight pronounced effects on downstream industries, such as food industry.

To further pinpoint mechanisms and rule out alternatives, I examine a cross-section of counties in 2000. I find that treated counties are more likely to have industries related to the beet sugar industry, such as animal food, cut stone, plastics, or fertilizers, whereas there were no pre-existing differences in similar industries in

1880. There is no strong evidence that treated and control counties differ in terms of local amenities or the share of college graduates. Therefore, the results of this paper highlight the role of the agricultural processing industry in creating long-lasting economic benefits through agglomeration spillovers.

This paper contributes to the literature on the impact of agricultural productivity growth on structural transformation (Lewis, 1954; Kuznets, 1957; Rostow, 1990; Matsuyama, 1992; Bustos et al., 2016; Gollin et al., 2021; Fiszbein, 2022). At the subnational level, several studies document that the effect of agriculture on industrial development is negative or null, as specialization in agriculture can deter industrial development or raise the opportunity costs of education (Foster and Rosenzweig, 2004; Hornbeck and Keskin, 2015; Moscona, 2019; Uribe-Castro, 2019; Jung, 2020). This paper highlights the role of the agricultural processing in spurring localized economic spillovers, presenting a novel channel for understanding these dynamics.

Unlike previous findings, such as Bustos et al. (2016), who find that labor-saving technological change in agriculture can spur industrial growth by releasing labor to the manufacturing sector, this study focuses on the sugar beet industry, which is labor-intensive.[1] Therefore, the industrial expansion observed from beet sugar factory openings cannot be attributed to labor-saving technological change.

This study also differs from Dell and Olken (2020), Carillo (2021), or Schmidt et al. (2018) who document the role of political institutions or human capital during structural change. The setting of this paper provides a more suitable ground for understanding the role of agricultural processing industry itself rather than other byproducts that followed agricultural development.

This study also contributes to the literature on local economic spillovers (Glaeser et al., 1992; Greenstone et al., 2010; Hanlon and Miscio, 2017; Allcott and Keniston, 2018; Kantor and Whalley, 2019; Andrews, 2020; Abebe et al., 2022; Fiszbein, 2022; Smith and Kulka, 2023) by examining the unique case of the beet sugar industry, an agriculture-based manufacturing activity that transformed rural economies. The establishment of beet sugar factories not only boosted local manufacturing employment but also stimulated related industries, creating a broader economic base. This highlights the role of existing advantages in local communities in diversifying their industrial mix into more complex activities (Hausmann and Klinger,

[1]Fiszbein et al. (2022) find that sugar beet is the second most labor-intensive crop in the US, followed by tobacco.

2006; Neffke et al., 2011). When certain types of agricultural processing industries have positive external effects on local industrialization, these externalities are typically not considered by individual farmers. The findings highlight the importance of strategic investments in these industries. This study provides empirical evidence supporting policies that encourage the development of complementary industries in rural areas, which can lead to long-term regional development.

The next section of this paper provides a review of the institutional background surrounding beet sugar. Section 3 estimates the causal effect of beet sugar plant openings. Section 4 explores agglomeration effects behind the main results. Section 5 rules out alternantive explanations. Section 6 concludes.

2. Institutional background

Invention and diffusion of beet sugar Sugar, once a luxury item for the wealthy, has become a staple of modern diets (Mintz, 1986). Sugar consumption in the United States increased dramatically between 1865 and 1914, with annual per capita consumption rising from 18.17 pounds to 89.14 pounds (Federal Trade Commission, 1917, p.17). While sugarcane is the most commonly used raw material for sugar production, sugar beets also play a significant role in the sugar industry. In fact, beet sugar accounts for between 55 and 60 percent of domestic sugar production in the United States since the mid-2000s (US Department of Agriculture, 2018), and 30 percent of global sugar supply (Dohm et al., 2014).

The technology to extract sugar from beets was first invented and commercialized in Europe.[2] Attempts to establish a sugar beet plant in the United States date all the way back to the nineteenth century. By 1880, the United States consumed more sugar than any other major advanced economies, excluding Britain (Bannister, 1890). David Lee Child, an abolitionist, had a trip to France, Belgium, and Germany in 1836 to examine the sugar beet industry in the hopes of finding an alternative for slave-produced cane sugar. Due to the expanding slave emancipation movement, it was anticipated that the production of sugar from the colonies would decrease in the face of an ever increasing demand for sugar. Child (1840) compared the productivity of Louisiana's cane sugar industry to that of France's beet sugar industry, concluding that the sugar beet sector is more efficient in terms

[2] Appendix E provides a more detailed account of this process.

of labor intensity, soil fertilization, and economic benefit to local economies. It was believed in France at the time that the rise in employment brought on by the beet sugar production had reduced urban migration because it boosted employment in rural areas and encouraged farmers to have better education to comprehend the sugar beet growing process. In 1838 Northampton, Massachusetts, Child himself established a sugar beet factory, but it stopped operating in 1841.

The quest for a viable sugar beet industry in the United States drew interest not only from abolitionists but also from members of the Church of Jesus Christ of Latter-day Saints, who proposed building a sugar beet plant in Salt Lake City. With ample funds at their disposal, they invested in heavy English equipment and expensive French beet seedlings. However, their plans were thwarted by the unsuitable soil, which was too saline to produce sugar of high quality. They built a sugar beet plant in 1853, only to see it grind to a halt in 1855 (Kaufman, 2009). Over the next few decades, fourteen sugar beet factories sprouted up in Massachusetts, Utah, California, Illinois, Wisconsin, Maine, and Delaware. Yet, with the exception of the one in Alvarado, California, none of these factories managed to last more than a decade, let alone achieve commercial success (War Food Administration, 1946).

These failures stood in stark contrast to the enthusiasm and optimism that characterized early nineteenth-century American sugar beet promoters. James Pedder of the Philadelphia Beet Sugar Society, after visiting France to study beet sugar, confidently declared that “America is destined to take the lead in the production of silk and sugar, as she has already done in cotton, rice and tobacco.” (Pedder, 1836, p. 40) Similarly, Grant (1867) argued that "beet sugar could be successfully transplanted from France to the United States."

One of the main reasons for the failures was a lack of understanding regarding the suitable regions for growing sugar beets in the US. Harvey Wiley, later the first commissioner of the US Food and Drug Administration, was appointed chief chemist at the US Department of Agriculture (USDA hereafter) after studying sugar chemistry during his time in Germany from 1878 to 1881. In his 1890 publication, where he discusses the optimal soil and climate conditions for sugar beet cultivation, he warns against the dangers of constructing large and expensive sugar beet factories without first studying the local climatic and soil conditions (Wiley, 1890, p. 6). While German immigrants brought considerable knowledge to the

US, they often failed to choose the best regions for growing high-quality beets (Ballinger, 1978, p. 9). The knowledge of where to cultivate them was deeply ingrained throughout Europe and had to be rediscovered through trial and error in the United States. Due to the high cost of constructing sugar beet plants, there was a high level of investment uncertainty, making it more difficult for farmers and businesses to enter this new industry.

In 1890, the USDA began collaborating with state agricultural experiment stations to conduct systematic experiments to evaluate the suitability of sugar beets in various regions of the United States. The USDA plant scientists' experiments formed the foundation of the industry (US Department of Agriculture, 1902, p. 596). The USDA distributed sugar beet seeds with written instructions, gathered sugar beets at the end of the year, and assessed the sugar quality of each sample. Based on the experiment results, the USDA issued a map drawing the beet belt with their new data, showing the areas that were thought to be especially favorable for growing sugar beets (see Figure F.2a and Figure F.2b). The experiment records show the grower's name, location, sugar beet crop variety, and quality of sugar. The sucrose in beet or purity coefficients are plotted in Figure F.9a and Figure F.9b, respectively, with the figures showing the county-level mean of beet sugar quality surveyed by the USDA. Higher purity or higher sucrose indicates sweeter sugar. The experiments that began in 1890 allowed them to "determine with some degree of accuracy the localities where sugar-beet is destined to be most successful." (US Department of Agriculture, 1899b, p. 6).

Between 1888 and 1897, the research and development phase saw the import of improved sugar beet seeds from Europe, the adaptation of labor-intensive European cultivation methods to the labor-scarce environment of the United States, the expansion of US factory scales, and the on-the-job training of sugar beet factory workers by European immigrants or those who studied in Europe. Federal and state governments offered bounties to entice additional investment, tariffs on imported sugar, tariff reductions on sugar beet machinery equipment in 1890, conducted systematic experiments to examine the suitability, and sent agents to encourage farmers and businessmen to promote beet sugar industry, all of which contributed to the industry's growth[3] (Arrington, 1967).

[3]It is difficult to pinpoint the primary factors that contributed to the growth of the beet sugar industry. Economists at the time raised doubt about the importance of sugar tariffs (Blakey, 1912; Magnuson, 1918; Taussig, 1912).

Economic impact of beet sugar plant openings Although the industry was a relatively small-scale industry in 1890, producing a total of 2,467 tons, the sugar beet industry experienced remarkable growth in subsequent years, reaching 722,054 tons of production in 1915 (Federal Trade Commission, 1917, p.12). During the early stages of industrialization, they played a crucial role in linking agriculture to the burgeoning industrial sector by training agricultural labor, attracting manufacturing workers, and fostering local economic growth.

Historical records show that the establishment of beet sugar factories resulted in the transformation of rural areas into thriving cities. In Sugar City, Colorado, the population increased by 40 percent after the construction of a sugar beet plant, despite there not being "a single house, barn, or even shack in sight in any direction." Similarly, the sugar beet factory in Rocky Ford, Colorado, led to the construction of hundreds of new buildings and increased the Santa Fe Road's freight income sevenfold (Palmer, 1908). At the time, it was widely accepted that the sugar beet plant brought benefits to various segments of society, including "business and professional men, mechanics, and laborers" (Palmer, 1913). Earlier proponents of the sugar beet industry also recognized its significant economic benefits.

There were multiple avenues for economic spillovers resulting from the establishment of sugar beet factories. Since suitable temperate areas for sugar beet cultivation had high land values, the sugar companies could not vertically integrate large farmlands (Mapes, 2010, p.53). Instead, smallholders rotated sugar beets with other crops and received training from agriculturalists employed by the companies on how to cultivate the beets. This training also led to discussions on how to improve the cultivation of other crops, such as wheat, rye, barley, and maize. Blakey (1913) claims that every sugar beet factory is "a sort of local agricultural college", enhancing the agricultural efficiency of almost every community it entered.

The ripple effects extended beyond the agricultural sector to include numerous other industries. In addition to requiring various materials and equipment such as bags, thread, valves, pipes, and machinery, the plants also employed a wide range of workers, including chemists, engineers, machinists, carpenters, and blacksmiths. These factories attracted new businesses such as dairies, orchards, and feed yards, as well as professionals like merchants, bankers, and real estate agents, leading to the development of prosperous towns. According to historical records, sugar beet factories created prosperity among local businesses and residents (Grant, 1867; Wiley, 1898; Palmer, 1908; Browne, 1937).

This observation is echoed by Napoléon III, who claimed that the industry improved agricultural techniques, raised land value, increased employment and wages, and enhanced overall prosperity (Napoléon, 1843). Grant (1867) observes that, despite the government's efforts to prevent it, a significant number of agricultural workers had to move to urban areas in search of employment prior to the introduction of beet sugar in France. However, he notes that the introduction of the beet sugar industry provided employment opportunities with higher wages in rural areas and raised the educational level of the average farmer.

3. Estimating the impact of beet sugar plant openings

3.1 Research design and data

In this study, I investigate the local economic effects of sugar beet plant openings by using county-level data. A comprehensive list of sugar beet factories in the US is sourced from War Food Administration (1946), which includes all sugar beet factories constructed and removed in the US until 1945. If a city or a town that constructed a beet sugar plant shares boundaries with two different counties, both counties are considered to have sugar beet factories. Figure 1 shows the number of newly constructed beet sugar plants.

The study examines several outcome variables, including population, farm value, crop revenue, manufacturing workers, manufacturing wages, and manufacturing value-added.[4] Data on these variables are obtained from Haines (2005) and Haines et al. (2019). I impute crop revenue before 1910 by multiplying 0.376 with the farm revenue (Kantor and Whalley, 2019). Following Kline and Moretti (2014), I exclude non-production workers, who are often white-collar or highly skilled, from manufacturing employment. All dollar values are chained to the consumer price index in 1900.

Estimating the causal impact of plant openings faces a challenge: factories did not choose locations randomly. Factors like transportation networks, natural resources, local demand, amenities, and skilled labor influenced their decisions, many of which are unknown or unobservable. This study addresses this challenge by us-

[4] Manufacturing value-added is computed before 1920 by subtracting raw material input from manufacturing output.

ing the proposed sugar beet plant locations from the trade journal, *American Beet Sugar Gazette* (*Gazette* hereafter). Published by the American Beet Sugar Gazette Company, this journal served as a forum for the exchange of knowledge on the United States' beet sugar business and was first released in March 1899. Until December 1912, the publication disseminated information about communities striving to establish sugar beet industries (Beet Sugar Gazette Company, 1899). This section of the magazine was previously known as "New Factories" and "Projects for New Factories." Starting from 1911, it was renamed as "New Factory and Equipment" section, which offers comprehensive information on cities and towns that considered sugar beet enterprises, sometimes including the names of the entrepreneurs who invested their capital, planned factory size, and the circumstances that influenced the construction of beet sugar factories.

To construct counterfactual outcomes in which beet sugar plants were not established, I rely on counties that were initially deemed favorable for starting the business but were ultimately not chosen by the beet sugar firms. Springfield, Ohio, for example, appears on this list with the following remark: "There is no reason why the great state of Ohio should not have a sugar factory...The soil is eminently suited to the growing of this crop, the farmers are wide-awake and the capitalists enterprising and resourceful...The city of Springfield is at present making a great effort to secure it." However, Springfield had no sugar beet factories, according to War Food Administration (1946). If the early twentieth-century assessments made by sugar beet experts were credible, it is reasonable to assume that Springfield shared favorable characteristics for sugar beet plant construction, such as soil suitability, farmer expertise, and access to financing, in addition to various unknown or unobservable factors. These runner-up sites will presumably provide a reliable benchmark for what would have occurred if sugar beet factories had not been constructed.

The *Gazette* highlights the importance of coordination between farmers and businessmen in the establishment of a sugar beet plant. Farmers were unwilling to produce sugar beets without the guarantee of compensation for their yields by sugar firms. Similarly, sugar corporations were hesitant to build a new facility without assurances that farmers would produce sugar beets. The establishment of sugar beet plants is more likely to reflect sugar beet-specific factors related to coordination between farmers and entrepreneurs, rather than favorable manufacturing conditions in general, at least among the counties mentioned in the *Gazette* as suitable locations.

The research design may be vulnerable to potential biases if sugar companies deliberately concealed their preferred locations to avoid driving up land values before they constructed plants. It is also possible that sugar beet companies did not disclose all of the potential locations for their factories, or named unappealing locations as their preferred destinations to mislead their competitors (Slattery and Zidar, 2020).

Thus it is worth noting how the list of potential locations is compiled in the *Gazette*. Rather than directly polling businesses about their preferred sites, the correspondents of the journal traveled around the country and conducted reconnaissance missions to identify communities that were seriously considering starting a sugar beet business. This could partly alleviate concerns about firms' strategic incentives to manipulate the announcement of preferred plant sites. In addition to beet sugar corporations, farmers and local government officials also provided input on the feasibility of establishing a beet sugar factory. If the correspondents and *Gazette* editors did not believe a town was suitable, it would not have been included on the list. Firms could not conceal favorable locations simply because they wished to do so. It is worth noting that all counties that established their first sugar beet plant between 1899 and 1912 were on the *Gazette*'s lists.

I create a panel of treated and control counties spanning from 1870 to 2000. I adjust county borders to follow the 1900 definitions (Hornbeck, 2010; Perlman, 2014). Control counties are places where beet sugar factories were considered but were never actually built until 2000. Control counties that established beet sugar factories after 1940 are excluded using sugar beet factory location data from Risch, Boland and Crespi (2014).[5] Counties that establish their first beet sugar factory before 1899 or after 1912 are not included in either the treated or the control group. I exclude counties without population estimates between 1870 and 2000 to construct a balanced panel. Out of 56 counties that establish their first beet sugar plants between 1899 and 1912, I exclude one county[6] from the treated group due to a lack of population data in 1870. I also drop two independent cities in Virginia from the control group as they lack agricultural outcome variables after 1940. The baseline specification will control for state-year fixed effects, and three singleton

[5]I thank Michael Boland for kindly sharing this data.

[6]Finney County, Kansas.

counties within their respective states are excluded from regressions.[7] Through this selection process, 263 counties were assigned to the control group and 56 counties were assigned to the treated group.

The spatial distribution of the treatment and control counties is shown in Figure 2. On average, the first beet sugar plant in these counties opened in 1904. It is worth noting that there is little geographical overlap between cane and beet sugar cultivation, as most cane sugar plantations are located in the South.

3.2 Balance test

Table 1 presents regression results of the variables regressed on the treatment indicator with or without state fixed effects, with all regressions weighted by county acres to estimate the effect on average land acres. Column (1) presents the mean values, while column (2) measures the unconditional differences between treated and control groups. Column (3) further refines these differences by controlling for state fixed effects. The significant difference in the share of lands used for sugar beet cultivation indicates the colocation of beet sugar factories and farms.

Overall, the treated and control counties exhibit a high degree of balance across most variables, such as population, number of farms, farm value, manufacturing workers, and manufacturing value added, after controlling for state fixed effects. Additionally, the share of literate farmers who can read and write, derived from individual-level census data, is well-balanced. Following Kantor and Whalley (2019), I calculate the distance from each county to the nearest federal agricultural experiment stations using data from US Department of Agriculture (1910). This distance to agricultural experiment stations is also balanced. The difference in the share of lands devoted to sugar beet cultivation indicate the colocation of sugar beet farms and factories.

I also examine agricultural potentials for beet sugar cultivation by digitizing USDA records from this period. The USDA experiment is an indicator variable that equals one for counties where the USDA measured sugar quality (US Department of Agriculture, 1891). Purity coefficients and sucrose in beets, as measured by US Department of Agriculture (1891) between 1890-1900, were considered crucial for

[7] These counties are Essex County, Massachusetts, Monroe County, Mississippi, and Madison County, Tennessee.

farmers and entrepreneurs looking to start beet sugar factories.[8] These two metrics imply that the lands were considered similar in terms of their potential for the beet sugar industry.

The term "beet belt" refers to counties identified by US Department of Agriculture (1899a) as suitable for growing sugar beets with high sugar content and purity due to their mean summer temperature range of 69°F-71°F (Wiley, 1930, p.177). The USDA collaborated with the Weather Bureau of the Department of Commerce to designate this area. The balance indicates that the USDA believed the treated and control counties were similarly suitable after seeing the experiment results.

Some notable differences remain. For instance, the share of irrigated land is higher in the treated counties. This discrepancy is important as irrigation can significantly impact agricultural productivity and suitability independently from the beet sugar industry. The *Gazette* notes that water availability was a critical factor in the development of sugar beet facilities. Evidence suggests that sugar beet production led to the development of irrigation, as it was more profitable than other crops under irrigation (Palmer, 1908, p. 39). Sugar beets provided sufficient returns to support irrigation, particularly in the West, where crop diversity is limited (Blakey, 1912, p. 414). Thus, it would be crucial to control for the differences in irrigation when estimating the impact of beet sugar plants.

I also examine the differences in suitability for crops such as alfalfa, corn, oat, wheat, and barley, as they were often cultivated alongside sugar beets (Blakey, 1912, p. 147). These differences are examined to isolate the effects of sugar beets from those of other crops. Suitability is the potential yield of each crop, constructed from the Food and Agricultural Organization's Global Agro-Ecological Zones (GAEZ) model, under the assumption that farmlands are irrigated and high inputs are used. The treated counties show a slight advantage in the suitability for growing alfalfa and corn.

I control for initial differences in irrigation, as well as alfalfa and corn suitability, in the regression analysis to ensure that the estimated treatment effects are not confounded by these pre-existing disparities.

[8] Appendix A.4 presents suggestive evidence that the government research shaped the location of beet sugar factories.

3.3 Empirical framework

To investigate the effects of sugar beet plant openings, I estimate the following equation:

$$outcome_{ct} = \sum_{\tau \neq 1900} \gamma_\tau (beet_c \times D_\tau) + \sum_k \sum_{\tau \neq 1900} \theta_{k\tau} (X_{kc} \times D_\tau) + \delta_c + \delta_{st} + \delta_{yt} + \varepsilon_{ct} \quad (1)$$

where c and t denote county and census year, respectively. $outcome_{ct}$ is a range of outcome varibles that could measure the local development effects on the agricultural sector, the manufacturing sector, or general population. I add one to the outcome variables when taking logs on the outcome variables, but I also test for the robustness of my result in alternative transformations following Chen and Roth (2022) in Appendix B.1.

$beet_c$ is an indicator that equals one for counties expected to build sugar beet factories between 1899 and 1912 and that actually constructed at least one sugar beet factory during that period. Conversely, it is zero for counties that were proposed but never built a beet sugar factory. D_τ is a time dummy, and γ_τ captures the differences in the dependent variables over time relative to 1900, after controlling for initial differences in county characteristics (latitude, longitude, irrigation, alfalfa, and corn suitability, denoted by X_{kc}) interacted with time effects, county fixed effects (δ_c), state-by-year fixed effects (δ_{st}), and the first year of being mentioned in the *Gazette* interacted with time fixed effects (δ_{yt}). The first proposed year-by-time fixed effects allow counties that were proposed to have sugar beet factories at different points in time to follow different time trends.[9] Counties that attempted to develop the beet sugar sector earlier might be systematically different from those that did so later in terms of their predisposition for taking risks. Error terms (ε_{ct}) are clustered by county to account for serial corrleation within counties across time. Regressions are weighted by county land area in 1900 to estimate the effect on average land acres rather than the effect on a county (Hornbeck and Keskin, 2015; Kantor and Whalley, 2019).

The identifying assumption of this paper is that, in the absence of the opening

[9] I group every two years into one period (e.g., 1899-1900, 1901-1902, etc.) because some fixed effects were being omitted due to the small number of new counties appearing in the journal in certain years.

of beet sugar factories, the treated and control counties would have followed the same trend in agricultural and manufacturing outcomes. While this assumption is ultimately untestable, the balance table shows that the sample counties are quite balanced in terms of many socioeconomic and soil characteristics. Any remaining differences are controlled for in the regressions. Evaluating pre-existing trends in outcome variables between treated and control counties will provide additional evidence related to the identification assumption.

Another point to note is that these factories were constructed within a short time frame (See Figure 1). Given that the aggregate demand for sugar is bounded, the fact that some counties did not ultimately get a beet sugar factory is unlikely to suggest that these control counties had fundamental disadvantages in industrial growth compared to the treated counties.

3.4 Results

The main results are summarized in Table 2, where the treatment indicator is interacted with a time dummy that equals one after the year 1900. Overall, the beet sugar factory led to a significant increase in agricultural and manufacturing activities. Farm values increased by approximately 40 percent (0.34 log points), manufacturing employment grew by about 350 percent (1.5 log points), and the population increased by around 86 percent (0.62 log points).

To account for treatment effect heterogeneity, I split the sample counties into Western and Eastern states. The effect was more pronounced in Western states,[10] where the territory was relatively unsettled and the population was sparser. All effects are more pronounced in Western states. This aligns with evidence that USDA officials emphasized the local development benefits of the sugar beet industry in less populated areas of the Western states, which garnered significant attention from government officials (Palmer, 1908; Blakey, 1912). In Appendix A.1, I also directly test for the hetereogenous effects by initial manufacturing employment density and find similar patterns. In Appendix B, I also test the robustness of the main results by accounting for spatial spillovers, excluding counties that still had beet sugar factories by 2000, and addressing policy distortions due to the New Deal

[10] Western states are Kansas, Nebraska, North Dakota, South Dakota, Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming, California, Oregon, and Washington. Eastern states are New York, Pennsylvania, Illinois, Indiana, Michigan, Ohio, Wisconsin, Iowa, Minnesota, Virginia, Texas, and Kentucky.

Sugar Cartel (Bridgman et al., 2015).

3.4.1 Impact on the agricultural sector

Next, I examine the impact on the agricultural sector with flexible estimates over time. Figure 3 presents the effects on the agricultural sector where the treatment indicator is interacted with year effects. Figure 3a regresses the log number of farms on time fixed effects separately for treated and control counties where the reference year is 1900 (SD stands for single-difference.). While there is no clear preexisting pretrend between the treated and the control counties, following 1900, the treated counties experieced 47 percent increase (0.39 log points) in the number of farms in 1910 relative to the control counties and the effect remains stable over time.

Figure 3c shows the beet sugar plant openings led to a 50 percent increase in crop revenue per farm acre, and Figure 3d reports the effects on the value of farmlands and buildings per farm acre. The effects on farm value are quite substantial. Relative to the control counties, the treated counties experienced a 28 percent increase in farm value, which rose to over 40 percent by 1930. This coefficient size aligns with anecdotal evidence. Child (1840, p.132) claimed that beet sugar farming increased the value of real estate in French cities by at least 50 percent. He argued that beet sugar is "what the canal would be if every farmer could bring it by his own door," drawing a parallel to the Erie Canal in New York, which was believed to have elevated real estate values by 50 to 100 percent.

The estimated coefficients on the farm value gradually declined after 1960. This could be related to the fact that multiple beet sugar plants were closed down after trade protection against imported sugar was lifted in 1974 (Bridgman et al., 2015).

3.4.2 Impact on the manufacturing sector and population

The effects of beet sugar factories on manufacturing activities are documented in Figure 4. The opening of beet sugar factories had an immediate and lasting impact on manufacturing activities. As of 1997, the treated counties had 8 times the number of manufacturing workers compared to the control counties (2.23 log points). Furthermore, the wage per worker increased by 22 percent in 1997 relative to the control counties.

Figure 5 presents the effects on county population. The graph shows that until 1900, the population trends in treated and control counties were similar. However, divergence occurs in the following years. Figure 5b displays the estimated coefficients from Equation (1) with 95 percent confidence intervals. In 1920, the population in treated counties increased by 60 percent (0.49 log points). By 2000, the population of treated counties became twice as large (0.7 log points) relative to the control counties.

The impact on population and manufacturing employment is larger compared to the effect of the ‘big push’ development project such as Tennessee Valley Authority, which found no effect on population and a 10 percent increase in manufacturing employment after a 30-year period (Kline and Moretti, 2014). While the estimated effects are quite large, they align with historical evidence. As mentioned in the previous section, Sugar City, Colorado, experienced a 40 percent increase in population after the construction of a sugar beet plant, and the railroad company Santa Fe Road’s freight income increased sevenfold due to the sugar beet factory (Palmer, 1908).

This significant impact can be attributed to the necessity of local processing for sugar beets, which attracted large manufacturing facilities to rural farmlands rather than congested urban areas (Austin, 1928, p. 25). In Figure A.1, I also examine the impact on the share of urban population. This also suggests that the impact was concentrated in less populated areas.

This finding also aligns with Eckert et al. (2023), who demonstrated that local transformation within rural counties played a more crucial role in urbanization and industrialization in early twentieth-century United States than migration to large incumbent cities such as New York or Chicago.

4. Evidence for agglomeration spillovers

The preceding section documents the lasting impact of opening beet sugar plants on manufacturing activities. A potential cause for concern regarding the external effects of plant openings on manufacturing activities is that the results could be primarily driven by the beet sugar industry and little else, because it leaves little room for externalities resulting from plant openings. To address this, Figure 6a estimate the impact on manufacturing employment outside the confectionery and related industries by using individual-level census data from 1870 to 1940 (Ruggles et al., 2021). As shown in Figure 6a, beet sugar plants increase manufacturing employment outside the confectionery industry.

Another question that arises is how upstream and downstream industries of beet sugar processing responded to the plant openings. To investigate this, I construct a county-level variable for manufacturing employment weighted by input-output linkages. This is done using an input-output table originally developed by Leontief (1936) and industry data from the individual-level census. I construct county-level manufacturing employment weighted by upstreamness or downstreamness to the confectionary industry. Upstreamness and downstreamness of each manufacturing industry are measured by the coefficients of the Leontief inverse matrix in the input-output table (Leontief, 1986; Lane, 2021).

To calculate the coefficients of the Leontief inverse matrix, I use an input-output table based on the U.S. manufacturing census of 1919, developed by Leontief (1936), and map it to the industries in the individual census data.[11] The procedure is as follows. Suppose the input-output matrix $(a_{mn}) \in \mathbb{R}^{M \times M}$ represents the sales amount from industry m to n, where M is the number of manufacturing industries. From this matrix, I construct the technical coefficient matrix $\mathbf{A} = \left(\frac{a_{mn}}{\sum_{m=1}^{M} a_{mn}}\right) \in \mathbb{R}^{M \times M}$ and compute the Leontief inverse matrix $(\mathbf{I} - \mathbf{A})^{-1} := (l_{mn}) \in \mathbb{R}^{M \times M}$. Each element of the Leontief inverse matrix (l_{mn}) captures the percentage increase in industry n production in response to a one percent rise in industry m output, considering both direct and indirect impacts (Leontief, 1986; Lane, 2021). Conceptually, the Leontief inverse matrix captures the total effect of an initial change in demand by summing the infinite series ($\mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \cdots = (\mathbf{I} - \mathbf{A})^{-1}$). This series accounts for the direct impact ($\mathbf{A}$) and the following ripple effects ($\mathbf{A}^2$, $\mathbf{A}^3$, $\cdots$), illustrating the comprehensive impact of changes in production across all sectors.

Based on these matrices, I calculate the county manufacturing employment weighted by downstreamness: $\sum_{n=1}^{I} s_{nct} l_{Bn}$, where B represents the confectionery industry, s_{nct} denotes the number of jobs in downstream industry n in county c at year t, and l_{Bn} represents the coefficients in the Leontief inverse matrix that captures downstreamness. Similarly, I compute $\sum_{m=1}^{I} s_{mct} l_{mB}$ to measure upstreamness-weighted employment. The confectionary industry are excluded from these measures. The Leontief inverse matrix shows that the confectionery industry has the

[11] Industry crosswalk is presented in Appendix C.

strongest downstream impact on the "not specified food industries" sector and the weakest downstream impact on "miscellaneous nonmetallic mineral and stone products." In terms of upstreamness, the "miscellaneous nonmetallic mineral and stone products" industry is the most affected, while the "motor vehicles and motor vehicle equipment" industry is the least affected. The tables displaying the upstream and downstream weights can be found in Appendix C.

Figure 6b and Figure 6c show that the treated counties had 166 percent more (0.98 log points) jobs in downstream manufacturing industries than control counties by 1940. The effect on upstream industries is noisier, although the direction of the coefficients suggests an increase in employment. More evidence on the spillovers through industry linkage in the long run will be presented in the following section.

5. Mechanisms in the long run

This section further investigates the mechanisms behind the main findings. Previous research suggests that local economic development can result from public goods provision (Ehrlich and Seidel, 2018), improvements in amenities (Diamond, 2016), or localized agglomeration spillovers (Greenstone et al., 2010; Kline and Moretti, 2014). To explore these different channels, I examine several outcome variables from the year 2000 and run cross-county regressions.

The cross-county specification is analogous to Equation (1). It regresses outcome variables on the treatment variable, corn and alfalfa suitability, the share of irrigated lands, first-proposed year fixed effects and state fixed effects. Regressions are weighted by county land area. Unlike previous empirical specifications, I could not control for county fixed effects. However, since many baseline covariates in the balance table are well-balanced once the state fixed effects are controlled for, it is unlikely that the results are driven by pre-existing differences.

To examine the agglomeration channel, I investigate the existence of upstream and downstream industries in the treated counties in 2000 and in 1880. Using County Business Patterns data from 2000, I identify upstream and downstream industries using NAICS codes at the three- or six-digit level. Industry data for 1880 is taken from Hornbeck and Rotemberg (2019).

Historical accounts highlight several byproducts of the beet sugar industry. The sugar beet factory uses limestone to extract juice from sugar beets. Byproducts such as beet tops and pulp were used for producing animal feed (Townsend, 1921, p.49). The lime sludge leftover from the extraction process was used for producing fertilizer, and the beet sugar factory often required rubber belting (Harris, 1919, p. 183).

Figure 7 presents the effects on long-term agglomeration. Panel (a) displays the effects on related industries, showing significant positive impacts in various industries by 2000 but not in 1880. Specifically, the probability of having establishments in the Food (NAICS 311), Other Animal Food (NAICS 311119), Lime Cement (NAICS 327), Nonmetallic Mineral (NAICS 327), Cut Stone Stone Product (NAICS 327991), Rubber Elastic Goods (NAICS 326), Plastics Rubber (NAICS 326), Other Plastics Product (NAICS 326199), and Chemical Manufacturing (NAICS 325) industries increased significantly. Additionally, fertilizer-related industries (NAICS 325314) also showed notable positive impacts. These results contrast with the 1880 data, where no significant differences were observed.

When examining local amenities or public goods provision, I also rely on the County Business Patterns to identify local amenities such as merchandise stores, hospitals, residential care facilities, museums, and drinking places. Data on Social Security recipients, crime rates, and the share of college graduates in 2000 are sourced from Haines (2005).

Panel (b) examines the effects on local amenities, such as merchandise stores, hospitals, residential care facilities, museums, drinking places, Social Security recipients, crime rates, and the share of college graduates, revealing no significant differences. These results suggest that the observed economic development is likely driven by spillovers from the sugar beet factories rather than improvements in amenities or local public goods provision.

6. Conclusion

This paper investigates the long-term effects of sugar beet plant openings on local economies in the United States during the early twentieth century, contributing to the literature on whether agricultural productivity growth can lead to local industrial growth. Previous research has often found that agricultural productivity growth does not necessarily translate into industrial expansion at the local level. However, this study suggests that certain crops may have a high propensity to attract immediate downstream industries near farmland through the establishment of an agricultural processing industry.

Using a unique dataset on suitable plant locations, the study compares counties that successfully established sugar beet factories with those that were proposed but did not ultimately build factories. The findings reveal that the openings of sugar beet plants had substantial and enduring impacts on both agricultural and manufacturing activities. The presence of sugar beet factories increased the value of farmland, crop revenue, population, and manufacturing employment, particularly in downstream industries. These results indicate that the economic benefits were primarily due to local spillovers through input-output linkages rather than improvements in public goods or amenities.

This study suggests that the agricultural processing industry can foster local industrial growth by attracting manufacturing facilities close to farmlands. Future research could systematically examine which types of crop processing industries are more likely to attract additional manufacturing sectors. Or it could explore the long-term impacts of other agricultural processing industries, such as dairy or meatpacking, on local economies.

Contemporary observers have noted that the beet sugar industry is particularly effective at encouraging local industrialization (Grant, 1867; Blakey, 1912). This suggests that the type of agricultural processing would have a differential impact on local industrial development. For example, cotton can be processed into textiles far from the farmlands. Similarly, coffee and cocoa can also be processed far from their growing regions once they undergo initial processing, such as drying. This finding implies that structural change is influenced not just by agricultural productivity growth, but also by the types of crops being processed. While many papers have investigated whether agricultural productivity growth leads to industrialization, my research suggests that the type of crops can have a significant impact, and agricultural producers may not account for positive externalities they would have on local industries.

The historical success of the sugar beet industry highlights the importance of strategic investments in agricultural processing industries as a means of fostering local economic development. Contemporary policymakers can draw lessons from this history to design policies that support the establishment and growth of similar industries, which can help bridge the gap between agriculture and manufacturing and promote regional development.

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Table 1: Balance test

Variables	(1) Mean	(2) (log) difference (unconditional)	(3) (log) difference (within-state)	(4) $N_{control}$	(5) $N_{treated}$
(log) total population, 1900	25835.96	0.00(0.22)	-0.10(0.22)	56	263
(log) farms, 1900	1404.36	0.30(0.21)	0.19(0.18)	56	263
(log) farmland acres, 1900	402.39	0.03(0.22)	0.14(0.22)	56	263
(log) crop revenue per farm acre ($)	1.74	0.32(0.14)**	0.06(0.12)	56	263
(log) farm value per farm acre ($)	18.23	0.53(0.16) ***	0.12(0.15)	56	263
(log) farm equipment per farm acre ($)	0.86	0.41(0.16)***	0.10(0.13)	56	263
irrigated farmlands per county acre, 1900	1.09	1.67(0.47)***	1.25(0.42)***	56	263
(log) manufacturing workers, 1900	1782.60	-0.03(0.34)	0.01(0.31)	56	263
(log) manufacturing establishments, 1900	190.47	0.24(0.26)	0.19(0.24)	56	263
(log) total manufacturing wages ($000), 1900	876.45	0.03(0.40)	-0.02(0.38)	56	263
(log) manufacturing value added ($000), 1900	2264.82	0.06(0.39)	-0.11(0.37)	56	263
share literate farmers, 1900	0.91	0.02(0.03)	0.00(0.02)	56	263
distance to agricultural experiment stations (km)	1638.39	-142.67(48.39)***	-54.05(34.22)	56	263
beet sugar purity (percent)	76.76	-1.45(2.62)	1.04(0.89)	47	193
sugar in beet (percent)	12.99	-0.33(0.80)	0.33(0.42)	47	196
average beet weight (grams)	718.65	166.56(95.59)*	78.68(67.95)	47	196
USDA experiment (0/1)	0.63	0.19(0.10)*	0.17(0.11)	56	263
beet belt (0/1)	0.45	0.00(0.11)	-0.05(0.08)	56	263
alfalfa suitability (ton/ha)	1.51	0.28(0.15) *	0.17(0.10) *	56	263
corn suitability (ton/ha)	7.65	1.98(1.00)**	1.31(0.71)*	56	263
sugarbeet suitability (ton/ha)	8.60	0.08(0.52)	0.13(0.45)	56	263
oat suitbility (ton/ha)	4.24	0.20(0.17)	0.15(0.17)	56	263
wheat suitability (ton/ha)	8.13	0.60(0.43)	0.43(0.42)	56	263
barley suitability (ton/ha)	7.72	0.62(0.46)	0.40(0.42)	56	263

Notes: Column (1) reports the mean of county characteristics. Columns (2) and (3) document the unconditional (log) differences and the within-state (log) differences. Columns (4) and (5) document the number of the treated and the control counties in the sample. All reported mean values are in their raw form. All differences represent the raw differences in means unless otherwise specified as logged variables. Regressions are weighted by county land area. The sources of each variable are explained in Section 3.1 and Section 3.2. *** p<0.01, ** p<0.05, * p<0.1

Table 2: Main results

Dep var: (log)	(1) farms	(2) crop revenue per farm acre	(3) farm value per farm acre	(4) mfg. workers	(5) mfg. value added	(6) mfg. wage per worker	(7) population
Panel A: All states							
beet × after 1900	0.49***	0.47***	0.34***	1.50***	2.78***	0.13***	0.62***
	(0.17)	(0.11)	(0.11)	(0.31)	(0.53)	(0.03)	(0.20)
Counties	319	319	319	319	319	319	319
Observations	4,466	4,466	4,466	4,147	4,147	4,147	4,466
R-squared	0.89	0.88	0.93	0.82	0.71	0.72	0.92
Panel B: Western states							
beet × after 1900	0.69***	0.61***	0.44***	1.90***	3.65***	0.16***	0.79***
	(0.18)	(0.15)	(0.15)	(0.44)	(0.73)	(0.05)	(0.24)
Counties	127	127	127	127	127	127	127
Observations	1,778	1,778	1,778	1,651	1,651	1,651	1,778
R-squared	0.91	0.89	0.92	0.81	0.71	0.70	0.93
Panel C: Eastern states							
beet × after 1900	0.23**	0.14*	0.09*	0.52***	0.84**	0.05**	0.21
	(0.10)	(0.08)	(0.05)	(0.18)	(0.33)	(0.02)	(0.14)
Counties	192	192	192	192	192	192	192
Observations	2,688	2,688	2,688	2,496	2,496	2,496	2,688
R-squared	0.93	0.89	0.96	0.79	0.64	0.84	0.92
County controls	✓	✓	✓	✓	✓	✓	✓
State-year FE	✓	✓	✓	✓	✓	✓	✓
First-proposed year FE	✓	✓	✓	✓	✓	✓	✓

Notes: Regression results from Equation (1). Panel A runs the regression on the entire sample and Panel B and Panel C splits the sample states into Western and Eastern states. The variable beet × after 1900 is an indicator equal to one for treated counties after the year 1900. All regressions control for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. Error terms are clustered by county, and regressions are weighted by county land area. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

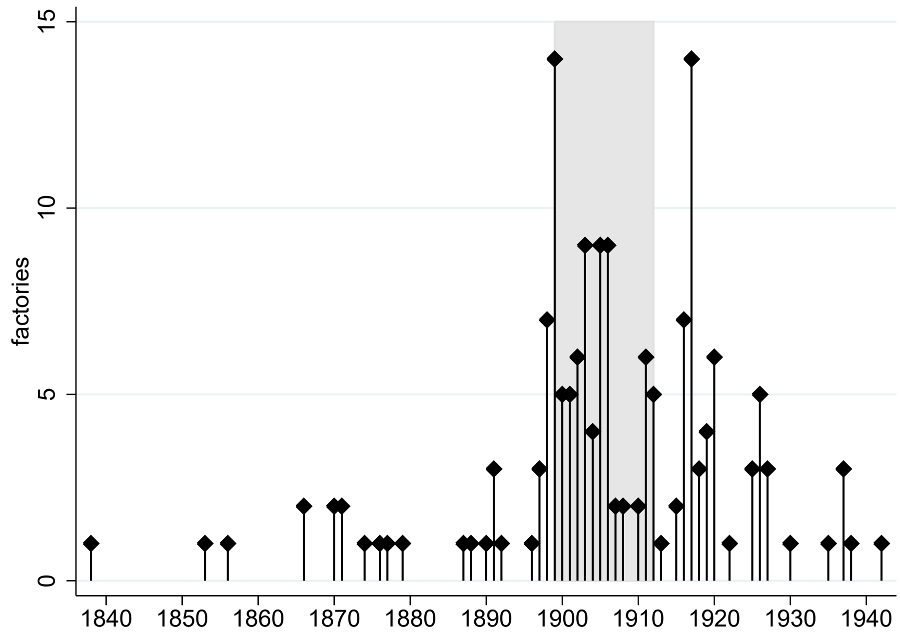


Figure 1: Number of newly established sugar beet factories

Source: The figure illustrates the number of newly established beet sugar factories by year. Data is taken from War Food Administration (1946). The period between 1899 and 1912 is marked in gray.

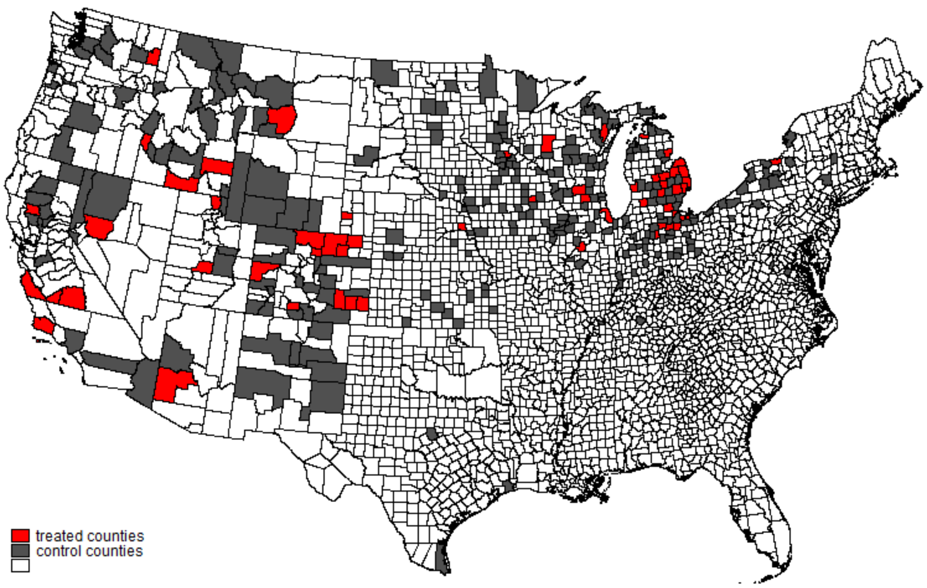
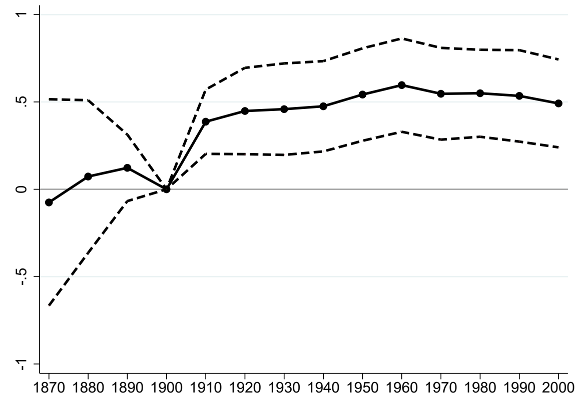


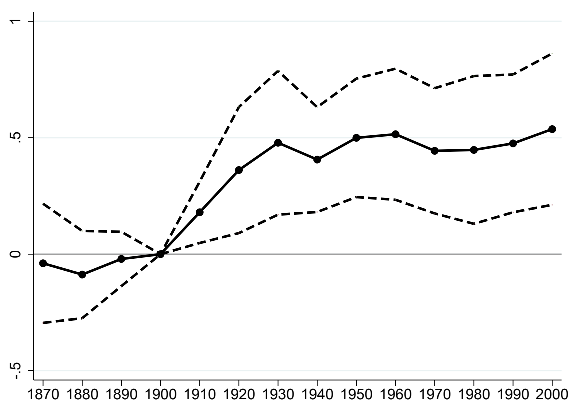
Figure 2: Treated and control counties for sugar beet plant openings

Source: Red counties indicate where sugar beet factories were opened between 1899 and 1912, while grey counties are where sugar beet factories were proposed to be constructed between 1899 and 1912 but ended up with no sugar beet factories until 2000. The data was constructed by consulting War Food Administration (1946) and the *Sugar Beet Gazette*.

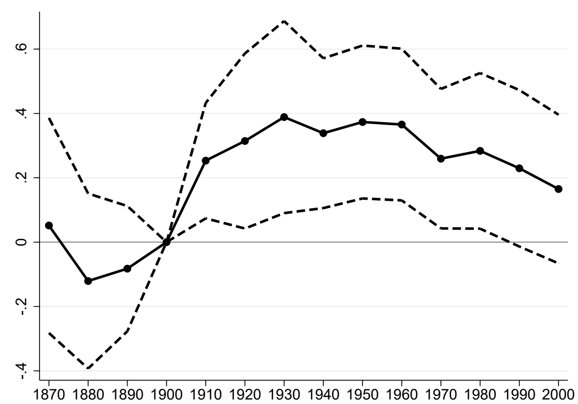
(a) SD, log farms



(b) DID, log farms



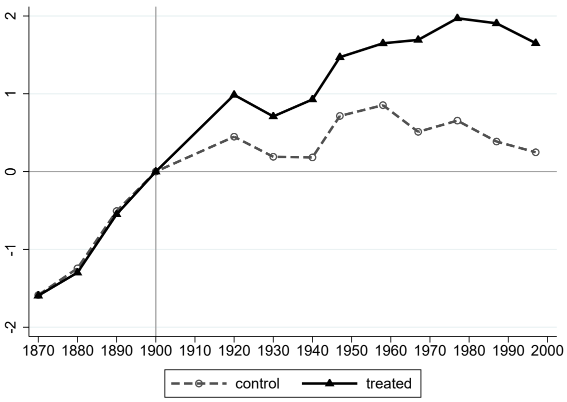
(c) DID, log crop revenue per farm acre



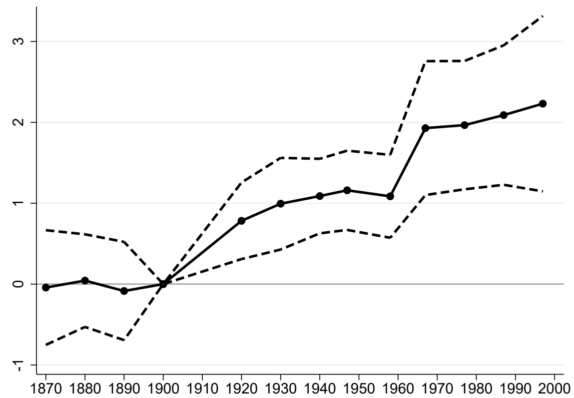
(d) DID, log farm value per farm acre

Figure 3: Effects on the agricultural sector

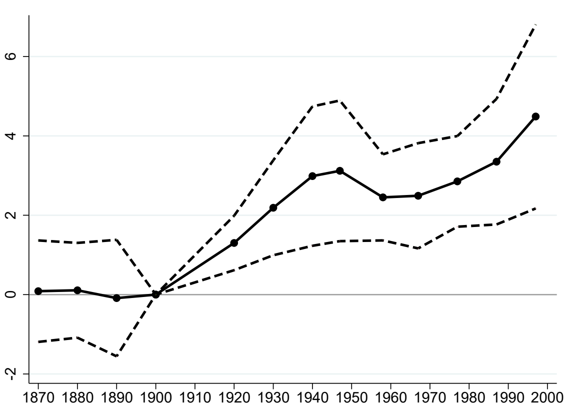
Note: Figure (a) displays the time-fixed effects estimated separately for the treated and control counties when regressing outcome variables solely on the time-fixed effects. Figures (b)-(d) report differences-in-difference estimates from Equation (1). All regressions from (b) to (d) control for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. All results are based on a balanced panel of 319 treated and control counties. The dashed lines in Figures (b)-(d) indicate 95 percent confidence intervals, based on robust standard errors clustered by county. Regressions are weighted by county land area.



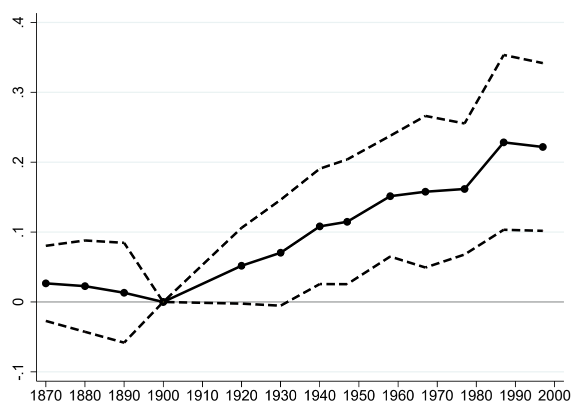
(a) SD, log manufacturing workers



(b) DID, log manufacturing workers



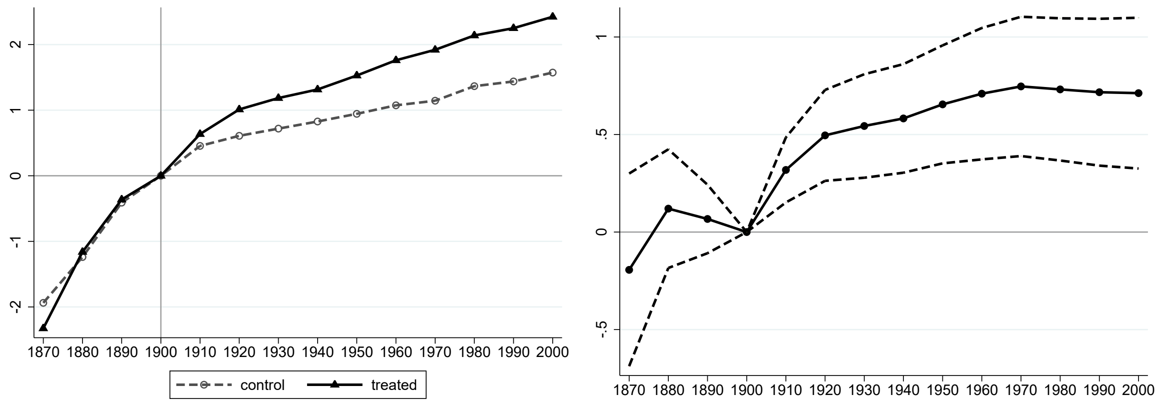
(c) DID, log manufacturing value-added



(d) DID, manufacturing wage per worker (relative to 1900)

Figure 4: Effects on the manufacturing sector

Note: Figure (a) displays the time-fixed effects estimated separately for the treated and control counties when regressing outcome variables solely on the time-fixed effects. Figures (b)-(d) report differences-in-difference estimates from Equation (1). All regressions from (b) to (d) control for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. All results are based on a balanced panel of 319 treated and control counties. The dashed lines in Figures (b)-(d) indicate 95 percent confidence intervals, based on robust standard errors clustered by county. Regressions are weighted by county land area.



(a) SD, log total population

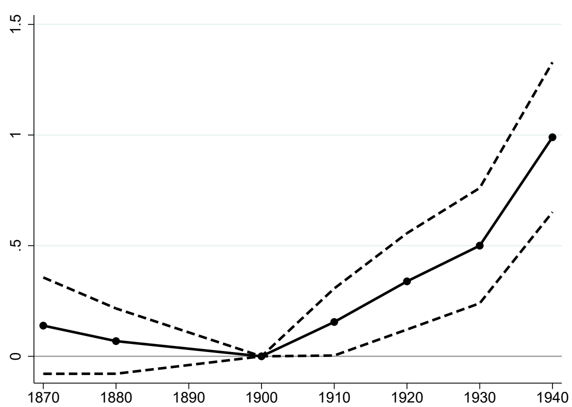
(b) DID, log total population

Figure 5: Effects on population

Note: Figure (a) displays the time-fixed effects estimated separately for the treated and control counties when regressing outcome variables solely on the time-fixed effects. Figures (b) reports differences-in-difference estimates from Equation (1). Panel (b) controls for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. All results are based on a balanced panel of 319 treated and control counties. The dashed lines in Figures (b) indicate 95 percent confidence intervals, based on robust standard errors clustered by county. Regressions are weighted by county land area.

(a) DID, log manufacturing labor (excluding confectionery industry)

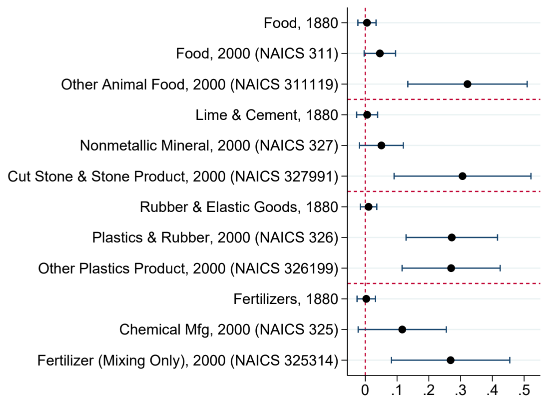
(b) DID, log manufacturing labor (upstream)



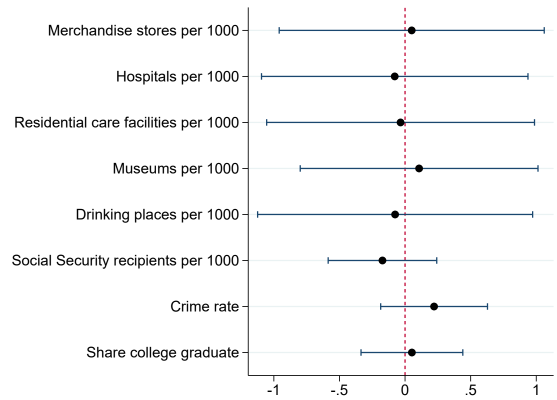
(c) DID, log manufacturing labor (downstream)

Figure 6: Effects on manufacturing employment

Note: Figures (a), (b), and (c) report differences-in-difference estimates from Equation (1). All regressions control for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. All results are based on a balanced panel of 319 treated and control counties. The dashed lines indicate 95 percent confidence intervals, based on robust standard errors clustered by county. Regressions are weighted by county land area.



(a) Effects on related industries



(b) Effects on amenities

Figure 7: Effects on the long-run agglomeration and amenities

Note: Figures (a) and (b) the cross-county regression analogous to Equation (1), where the outcome variables are regressed on the treatment variable, latitude, longitude, share of irrigated lands, corn and alfalfa suitability, state fixed effects, and the first proposed period fixed effects. Regressions are weighted by county land area. The outcome variables in Panel (a) are indicator variables representing the presence of each industry. The outcome variables in Panel (b) are standardized, with a mean of zero and a standard deviation of one. The error bars display the 95% confidence intervals.

A. Additional results

A.1 Non-constant agglomeration elasticity

The results documented in Table 2 do not test for heterogeneity in agglomeration elasticities, which is the elasticity of local productivity with respect to local employment density. However, if the increase in local productivity growth relative to the growth in employment is larger in less populated areas, this provides a strong rationale for place-based policies as it indicates that allocating government resources to underperforming areas could boost aggregate welfare (Kline and Moretti, 2014; Gruber and Johnson, 2019). I test for non-constant agglomeration elasticity as follows. First, I define the county manufacturing value-added using the Cobb-Douglas production function:

$$Y_{ct} = G_{ct} L_{ct}^{\alpha} K_{ct}^{\beta} F_c^{1-\alpha-\beta} \tag{2}$$

where Y_{ct}, L_{ct}, and K_{ct} denote manufacturing value-added, labor, and capital, respectively. F_c represents exogenous county-level fixed factors that allow the labor demand to shift downward. It is also assumed that $\alpha, \beta, (1-\alpha-\beta) \in (0,1)$. I adopt the capital share ($\beta = 0.3$) and long-run labor demand elasticity ($-\frac{1-\beta}{1-\alpha-\beta} = -1.5$, $\alpha \approx 0.47$) from Kline and Moretti (2014).

Under the assumption that capital is perfectly mobile across counties at a price of R_t, local productivity growth can be expressed as follows:

$$\ln\left(\frac{Y_{ct}^{1-\beta}}{L_{ct}^{\alpha}}\right) = \ln\left(G_{ct} F_c^{1-\alpha-\beta}\left(\frac{\beta}{R_t}\right)^{\beta}\right) \tag{3}$$

When the left-hand side of Equation (3) is regressed as an outcome variable in Equation (1), the county fixed effects and time fixed effects in the regression equation absorb the variation in county-fixed factors (F_c) and changes in capital costs over time (R_t). Thus, the estimated effect of plant openings (γ_τ) capture the effects of beet sugar plant openings on county productivity growth.

In the next step, I follow split the treatment indicator based on whether a county has above or below median manufacturing density (number of manufacturing workers per county area in 1900). The results presented in Table A.1 show that the effects on manufacturing outcomes are indeed stronger in less dense counties. The difference in local productivity growth between below median and above median counties is statistically significant, as evidenced by the fact that the p-value of testing the equality of coefficients is 0.01.

The implied agglomeration elasticity in above median density counties and below median density counties are 0.6 (0.58/0.9) and 0.9 (1.53/1.67) respectively. The elasticity is higher in below median density counties. To examine if the difference in agglomeration elasticity $\left(\frac{d\ln(G_{ct})}{d\ln(L_{ct})}\right)$ is statistically significant, I estimate the difference in elasticity using seemingly unrelated regression. The estimated coefficient is 0.31 with a standard error of 0.19 (p-value = 0.10). Hence, the difference is not statistically significant.

Agglomeration elasticity of 0.6 or 0.9 is lower than the elasticities of 1.25 to 3.1 found in Greenstone et al. (2010), but higher than the elasticity of 0.2 reported in Kline and Moretti (2014). Previous studies have reported agglomeration elasticities between 0.02 and 0.1 (Duranton, 2015).

Table A.1: Non-constant agglomeration elasticity

	(1)	(2)	(3)	(4)
Dep var: (log)	productivity	mfg value added	mfg workers	wage per worker
beet × after 1900	0.58**	1.39***	0.90***	0.17***
× above median density	(0.23)	(0.48)	(0.27)	(0.06)
beet × after 1900	1.53***	3.17***	1.67***	0.20***
× below median density	(0.33)	(0.63)	(0.38)	(0.06)
Counties	319	319	319	319
Observations	4,147	4,147	4,147	4,147
R-squared	0.60	0.71	0.82	0.74
Test of coef. equality (above=below)	0.01	0.01	0.07	0.73
County controls	✓	✓	✓	✓
State-year FE	✓	✓	✓	✓
First-proposed year FE	✓	✓	✓	✓

Notes: Replication of Table 2 accounting for non-constant agglomeration elasticity. The variable beet × after 1900 is an indicator equal to one for treated counties after the year 1900. The treatment indicator is split by the initial density of manufacturing workers (number of manufacturing workers per county area in 1900). The test of coefficient equality (above = below) indicates the p-value from testing the equality of coefficients for above and below median density. All regressions control for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. Error terms are clustered by county, and regressions are weighted by county land area. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

A.2 Spatial equilibrium

To better understand the underlying mechanisms behind the differences-in-differences estimator regarding manufacturing employment growth, I present a simple Rosen-Roback spatial equilibrium model (Moretti, 2010).

Production There are two counties $c = a, b$ at time t. County manufacturing value-added is modeled using the Cobb-Douglas production function as in Equation (3).

County-level productivity G_{ct} evolves as follows:

$$\ln(G_{c,t+1}) = \ln(G_{c,t}) + \lambda B_{c,t+1} + \sum_{k=1}^{K} \phi_k X_{kc} + \mu_{c,t+1} \tag{4}$$

where $B_{c,t+1}$ denotes an indicator variable for the presence of a beet sugar factory in a given county c. The beet sugar factories start operations in county b at the start of time $t+1$, and not in county a. λ denotes the effect of a beet sugar plant opening in t. X_{kc} accounts for initial differences in county characteristics.

$\mu_{c,t+1}$ is an unobserved shock. By the identifying assumption in the reduced-form evidence presented in the previous sections, the term $(\mu_{b,t+1} - \mu_{a,t+1})$ is uncorrelated with the beet sugar factory openings. Capital is perfectly mobile, and the capital price, R_t, is equalized across counties. The inverse labor demand in county c is then

$$\ln(w_{ct}) = \frac{1}{1-\beta}\ln(G_{ct}) - \frac{1-\alpha-\beta}{1-\beta}\ln(L_{ct}) + \ln\left(\frac{\alpha}{1-\beta}\left(F_c^{\frac{1-\alpha-\beta}{\beta}}\frac{\beta}{R_t}\right)^{\frac{\beta}{1-\beta}}\right) \tag{5}$$

where w_{ct} indicates local manufacturing wage.

Preferences Labor supply and housing demand are given by individuals i who choose their residential location c to maximize the indirect utility function,

$$V_{ict} = \frac{w_{ct} M_{ct}}{p_{ct}^{\sigma}} u_{ict} \tag{6}$$

where M_{ct} and p_{ct} denote local amenities and housing price. σ indicates the share of land in the household budget. u_{ict} is an idiosyncratic taste by agent i for location c at time t that is drawn independently from a Fréchet distribution $F(u_{1t}, \cdots, u_{Ct}) = \exp(-\sum_{c=1}^{C} u_{ict}^{-\rho})$ where ρ is a parameter that governs the degree of labor mobility.

Housing supply The inverse housing supply is of the form

$$p_{ct} = \xi L_{ct}^{\delta} \tag{7}$$

By the standard property of the extreme value distribution, the difference in inverse labor supply of county a and b is given by

$$\ln(w_{bt}) - \ln(w_{at}) = \left(\frac{1}{\rho} + \sigma\delta\right)(\ln(L_{bt}) - \ln(L_{at})) - (\ln(M_{bt}) - \ln(M_{at})) \tag{8}$$

Equilibrium and comparative statics The sugar beet factory opening in county b at the beginning of time $t = 2$ will increase the county-level productivity by λ relative to time $t = 1$. I also allow beet sugar factories to increase the local amenities by $m(= \ln(M_{b2}) - \ln(M_{b1}))$ based on suggestive evidence that the opening of beet sugar factories may have contributed to the improvement of local amenities, including the potential for better schools and post office (Beet Sugar Gazette Company, 1908a, p. 5). Under the assumption that county a is similar to county b in period $t = 1$, the differences in the growth of equilibrium employment between the two counties from $t = 1$ to $t = 2$ can be expressed as

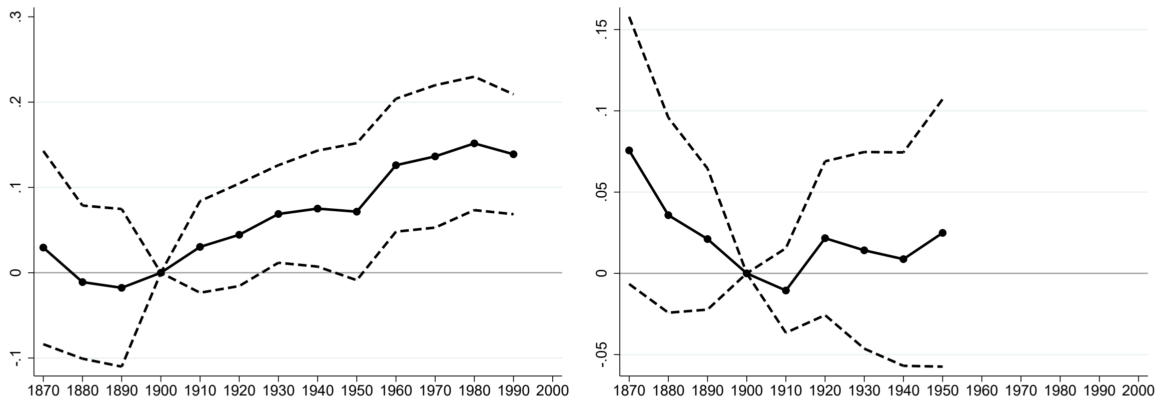
$$\mathbb{E}[\{\ln(L_{b2}) - \ln(L_{b1})\} - \{\ln(L_{a2}) - \ln(L_{a1})\}|B_{c2}, \{X_{kc}\}_{k=1}^{K}] = \frac{\lambda + (1-\beta)m}{(1-\beta)(\frac{1}{\rho} + \sigma\delta) + (1-\alpha-\beta)} \tag{9}$$

The above equation demonstrates that the differences-in-difference estimator of opening beet sugar plants on manufacturing employment can be broken down into labor mobility (ρ), housing supply elasticity ($\frac{1}{\delta}$), capital share (β), long-run labor demand elasticity ($-\frac{1-\beta}{1-\alpha-\beta}$), share of land in the household budget (σ), and localized productivity gains (λ) and improvement in amenities (m) resulting from the opening of beet sugar factories. In Section 5, I present suggestive evidence that local productivity spillover (λ) was more important than local amenities improvement (m).

A.3 Impact on urban population

Table 2 documents that the opening of beet sugar plants led to significant population increases. I further divide county population into the number of people living in cities or towns with populations greater than 2,500 or 25,000 using Haines (2005). I then construct the share of the population in cities greater than 2,500 or 25,000 for each county.

Figure A.1 document the regression results from estimating Equation (1) using the share of urban population as outcome variables. The effects of plant openings on the share of the population in cities greater than 2,500 showed an increase of approximately 15 percentage points by 1990. Although the effects on cities with populations greater than 25,000 are only available until 1950, the coefficient size is much smaller compared to the effects on cities with populations greater than 2,500. This result is consistent with historical evidence indicating that sugar beet plants primarily led to population increases in less populated areas rather than in already densely populated urban cities (Austin, 1928).



(a) Share of urban population (pop>2,500) (b) Share of urban population (pop>25,000)

Figure A.1: Effects on urban population

Note: Figures (a) and (b) present the regression results from Equation (1), with the outcome variables being the share of the urban population. Panel (a) focuses on the share of the population in cities with more than 2,500 residents, while Panel (b) examines the share of the population in cities with more than 25,000 residents. All regressions control for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. All results are based on a balanced panel of 319 treated and control counties. The dashed lines in Figures (b) indicate 95 percent confidence intervals, based on robust standard errors clustered by county. Regressions are weighted by county land area.

A.4 US Department of Agriculture experiments

Section 2 and Section 3.2 introduced the US Department of Agriculture's nation-wide experiments aimed at assessing the suitability of sugar beets across the country (US Department of Agriculture, 1891). This subsection explores whether the provision of such information influenced the emergence of a new industry.

To identify general trends, I regress an indicator variable (multiplied by 100) for the establishment of beet sugar factories between 1890 and 1942 against several independent variables, controlling for latitude-longitude and state fixed effects. Columns (1) and (2) examine the outcome variable using an indicator variable that equals one hundred for counties where the USDA measured sugar quality. The results suggest that USDA experiments are associated with a higher probability of beet sugar plant openings, even after controlling for sugar beet suitability under high input and irrigation conditions as provided by the Global Agro-ecological Zones model. This correlation could imply that information provision mattered for the sugar beet industry, or it might simply reflect the fact that experiments were conducted in areas where the sugar beet industry was likely to thrive.

Columns (3) to (5) instead control for the actual outcome of the experiments, specifically the quality of sugar. This quality was assessed using two measures: sugar content in beets and the purity coefficient. Thus, the sample in these columns is restricted to counties where USDA experiments were conducted. Conditional on the presence of USDA experiments, higher sugar quality was associated with a greater likelihood of plant openings. Further investigation into this government research is left for future research.

Table A.2: USDA experiments

	(1)	(2)	(3)	(4)	(5)
Dep var:	Beet sugar plants opening 1890-1942				
USDA experiment	4.91***	4.56***			
	(1.66)	(1.53)			
FAO beet suitability		1.55**			1.54*
		(0.59)			(0.85)
Sugar in beet			1.13***		1.18**
			(0.41)		(0.47)
Purity coefficient				0.36**	0.05
				(0.15)	(0.11)
lat-lon	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
Observations	2,807	2,807	1,207	1,138	1,138
R-squared	0.14	0.15	0.21	0.22	0.22

Notes: The unit of observation is the county. The dependent variable is an indicator (multiplied by 100) for the opening of beet sugar factories between 1890 and 1942. The USDA experiment indicator represents the presence of USDA experiments testing beet sugar quality in a county. FAO beet suitability refers to the potential yield of sugar beets under high input and irrigation conditions. Sugar in beets and purity coefficient denote the quality of sugar from beets as described in (US Department of Agriculture, 1891). *** $p<0.01$, ** $p<0.05$, * $p<0.1$

B. Robustness checks

B.1 Log transformation

When examining agricultural or manufacturing outcomes, I add one to the outcome variables before taking their logarithms. This transformation, or the inverse hyperbolic sine transformation, has known issues, as the log of one-plus transformation places arbitrary weights on the intensive and extensive margins depending on how outcome variables are scaled.

Following Chen and Roth (2022), I test the robustness of the manufacturing employment results by explicitly assigning a value of 29.5 to observations with zero manufacturing employment. This value is calibrated by comparing county-level census data with individual-level census data. In the sample counties of this study in 1900, there are three counties with zero manufacturing employment. According to the individual-level census, these three counties have 0, 4, and 55 manufacturing workers, respectively. Thus, I assign a mean value of 29.5 manufacturing workers to counties that have zero manufacturing employment according to the county-level census. Figure B.1 documents the regression results from the same regression as in Figure 4b, but with the adjusted outcome variables.

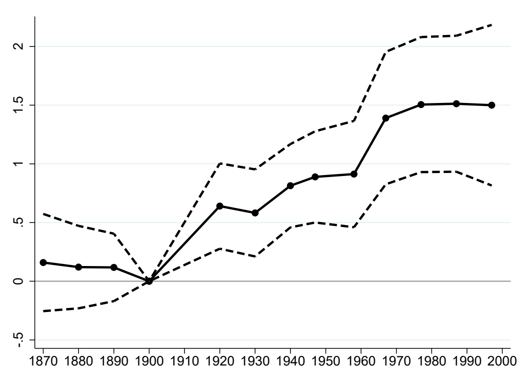


Figure B.1: Effects on log manufacturing employment

B.2 Spatial spillover

Equation (1) abstracts away from spatial spillovers between counties. Since the treated and control counties are often proximate to each other, spatial spillovers could bias the main results. Positive spillovers from the treated counties would underestimate the true effects, while negative spillovers would overestimate them. Negative spillovers could occur if the treated counties pull resources away from the control counties. To account for spatial spillover, I rerun the main results in Table 2 after excluding control counties that are within 100km of the treated counties. Table B.1 shows that the results are quantitatively similar.

Table B.1: Spatial spillover

Dep var: (log)	(1) farms	(2) crop revenue per farm acre	(3) farm value per farm acre	(4) manufacturing workers	(5) mfg. value added	(6) mfg. wage per worker	(7) population
beet × after 1900	0.41**	0.51***	0.33**	1.17***	2.40***	0.12***	0.48*
	(0.20)	(0.15)	(0.15)	(0.42)	(0.67)	(0.04)	(0.28)
Counties	212	212	212	212	212	212	212
Observations	2,968	2,968	2,968	2,756	2,756	2,756	2,968
R-squared	0.91	0.89	0.94	0.84	0.73	0.75	0.93
County controls	✓	✓	✓	✓	✓	✓	✓
State-year FE	✓	✓	✓	✓	✓	✓	✓
First-proposed year FE	✓	✓	✓	✓	✓	✓	✓

Notes: Replication of Table 2 after excluding control counties within 100 km of the treated counties. The variable beet × after 1900 is an indicator equal to one for treated counties after the year 1900. All regressions control for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. Error terms are clustered by county, and regressions are weighted by county land area. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

B.3 Self-sustaining agglomeration

A true test of agglomeration spillovers is to examine whether a temporary shock leads to a permanent effect, yet several counties in the baseline samples still had beet sugar factories by 2000. To conduct a clearer test of self-sustaining agglomeration forces, I also run the regression after excluding eleven treated counties that still had beet sugar factories by 2000, as identified in Risch et al. (2014). The results, presented in Table B.2, are quantitatively similar to those in Table 2.

Table B.2: Self-sustaining agglomeration

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	farms	crop revenue	farm value	manufacturing	mfg. value added	mfg. wage	population
Dep var: (log)		per farm acre	per farm acre	workers		per worker	
beet × after 1900	0.41**	0.43***	0.29**	1.19***	2.28***	0.10***	0.51***
	(0.18)	(0.12)	(0.13)	(0.28)	(0.51)	(0.03)	(0.20)
Counties	308	308	308	308	308	308	308
Observations	4,312	4,312	4,312	4,004	4,004	4,004	4,312
R-squared	0.89	0.89	0.93	0.83	0.71	0.72	0.92
County controls	✓	✓	✓	✓	✓	✓	✓
State-year FE	✓	✓	✓	✓	✓	✓	✓
First-proposed year FE	✓	✓	✓	✓	✓	✓	✓

Notes: Replication of Table 2 after excluding treated counties with beet sugar factories by 2000. The variable beet × after 1900 is an indicator equal to one for treated counties after the year 1900. All regressions control for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. Error terms are clustered by county, and regressions are weighted by county land area. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

B.4 New Deal Sugar Cartel

The effects of opening beet sugar plants on local economies could be primarily due to protection from international trade provided by the New Deal Sugar Cartel (Krueger, 1988). This cartel, established in 1934, tied sugar beet quotas for farmers to the acres of sugar beets cultivated prior to the Great Depression. Bridgman et al. (2015) document that California, Colorado, and Utah were given disproportionately large beet sugar production quotas compared to states like Minnesota or North Dakota. This was because innovations in crop storage technology and the rise of alternative profitable crops raised the opportunity cost of producing sugar beets in the West.

To address this channel, I drop counties in California, Colorado, and Utah from the analysis and re-estimated the effect on manufacturing employment. The results are presented in Table B.3.

Table B.3: New Deal Sugar Cartel

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	farms	crop revenue	farm value	manufacturing	mfg. value added	mfg. wage	population
Dep var: (log)		per farm acre	per farm acre	workers		per worker	
beet × after 1900	0.67***	0.52***	0.44***	1.77***	3.44***	0.16***	0.87***
	(0.19)	(0.15)	(0.15)	(0.42)	(0.72)	(0.04)	(0.23)
Counties	272	272	272	272	272	272	272
Observations	3,808	3,808	3,808	3,536	3,536	3,536	3,808
R-squared	0.91	0.89	0.94	0.83	0.71	0.74	0.93
County controls	✓	✓	✓	✓	✓	✓	✓
State-year FE	✓	✓	✓	✓	✓	✓	✓
First-proposed year FE	✓	✓	✓	✓	✓	✓	✓

Notes: Replication of Table 2 after excluding control counties within 100 km of the treated counties. The variable beet × after 1900 is an indicator equal to one for treated counties after the year 1900. All regressions control for latitude, longitude, alfalfa suitability, corn suitability, and irrigated farmlands as a share of county area, interacted with time effects, as well as state-year fixed effects and first-proposed period group-by-year fixed effects. Error terms are clustered by county, and regressions are weighted by county land area. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

C. Coefficients of the Leontief inverse matrix

Table C.1: Manufacturing industry crosswalk

Industry name	Ind1950 code	Ind1950 industry name
flour and grist mill products	409	Grain-mill products
canning and preserving	408	Canning and preserving fruits, vegetables, and seafoods
bread and bakery products	416	Bakery products
sugar, glucose, and starch	417	Confectionery and related products
liquors and beverage	418	Beverage industries
tobacco manufactures	429	Tobacco manufactures
slaughtering and meatpacking	406	Meat products
butter, cheese, etc	407	Dairy products
other food industries	426	Not specified food industries
blast furnaces	336	Blast furnaces, steel works, and rolling mills
steel works and rolling mills	336	Blast furnaces, steel works, and rolling mills
other iron and steel and electric manufactures	337	Other primary iron and steel industries
automobiles	376	Motor vehicles and motor vehicle equipment
brass, bronze, copper, etc	338	Primary nonferrous industries
non-metal minerals	326	Miscellaneous nonmetallic mineral and stone products
refined petroleum	476	Petroleum refining
coal	477	Miscellaneous petroleum and coal products
coke	477	Miscellaneous petroleum and coal products
chemicals	466	Synthetic fibers
chemicals	467	Drugs and medicines
chemicals	468	Paints, varnishes, and related products
chemicals	469	Miscellaneous chemicals and allied products
lumber and timber products	307	Sawmills, planing mills, and mill work
other wood products	308	Miscellaneous wood products
paepr and wood pulp	456	Pulp, paper, and paperboard mills
other paper products	458	Miscellaneous paper and pulp products
printing and publishing	459	Printing, publishing, and allied industries
yarn and cloth	439	Yarn, thread, and fabric mills
clothing	448	Apparel and accessories
other textile products	446	Miscellaneous textile mill products
leather tanning	487	Leather: tanned, curried, and finished
leather shoes	488	Footwear, except rubber
other leather products	489	Leather products, except footwear
rubber manufactures	478	Rubber products

Notes: The first column lists the manufacturing industry names from Leontief (1936), while the second and third columns correspond to the manufacturing industries in the individual-level census data (Ruggles et al., 2021).

Table C.2: Upstreamness coefficients

ind1950 Code	Upstream Weight	Industry Name
417	1.01	Confectionery and related products
326	0.102	Miscellaneous nonmetallic mineral and stone products
337	0.023	Other primary iron and steel industries
477	0.0127	Postal Service
476	0.00816	Petroleum refining
409	0.00757	Grain-mill products
307	0.00622	Sawmills, planing mills, and mill work
466	0.004841	Synthetic fibers
469	0.004841	Miscellaneous chemicals and allied products
468	0.004841	Paints, varnishes, and related products
467	0.00484	Drugs and medicines
336	0.004555	Blast furnaces, steel works, and rolling mills
406	0.001262	Meat products
489	0.000828	Leather products, except footwear
439	0.000609	Yarn, thread, and fabric mills
338	0.000498	Primary nonferrous industries
487	0.000359	Leather: tanned, curried, and finished
459	0.000307	Printing, publishing, and allied industries
308	0.000123	Miscellaneous wood products
446	7.51e-05	Miscellaneous textile mill products
478	6.28e-05	Rubber products
456	9.96e-06	Pulp, paper, and paperboard mills
408	0	Canning and preserving fruits, vegetables, and seafoods
429	0	Tobacco manufactures
407	0	Dairy products
426	0	Not specified food industries
376	0	Motor vehicles and motor vehicle equipment
418	0	Beverage industries
488	0	Footwear, except rubber
448	0	Apparel and accessories
416	0	Bakery products
458	0	Miscellaneous paper and pulp products

Notes: Upstreamness coefficients are calculated from Leontief inverse matrix (Leontief, 1986) based on Leontief (1936).

Table C.3: Downstreamness coefficients

ind1950 Code	Downstream Weight	Industry Name
417	1.009545	Confectionery and related products
426	0.088695	Not specified food industries
416	0.040011	Bakery products
408	0.03931	Canning and preserving fruits, vegetables, and seafoods
407	0.027933	Dairy products
418	0.010702	Beverage industries
487	0.005128	Leather: tanned, curried, and finished
488	0.002168	Footwear, except rubber
439	0.001842	Yarn, thread, and fabric mills
489	0.0018	Leather products, except footwear
406	0.00159	Meat products
409	0.001582	Grain-mill products
446	0.000993	Miscellaneous textile mill products
448	0.000697	Apparel and accessories
429	0.000441	Tobacco manufactures
478	0.000312	Rubber products
466	0.000275	Synthetic fibers
467	0.000275	Drugs and medicines
469	0.000275	Miscellaneous chemicals and allied products
468	0.000275	Paints, varnishes, and related products
308	0.000137	Miscellaneous wood products
338	5.5e-05	Primary nonferrous industries
456	1.8e-05	Pulp, paper, and paperboard mills
459	1.3e-05	Printing, publishing, and allied industries
458	9e-06	Miscellaneous paper and pulp products
336	3e-06	Blast furnaces, steel works, and rolling mills
307	3e-06	Sawmills, planing mills, and mill work
476	3e-06	Petroleum refining
337	3e-06	Other primary iron and steel industries
477	3e-06	Miscellaneous petroleum and coal products
376	2e-06	Motor vehicles and motor vehicle equipment
326	1e-06	Miscellaneous nonmetallic mineral and stone products

Notes: Downstreamness coefficients are calculated from Leontief inverse matrix (Leontief, 1986) based on Leontief (1936).

D. Factory location

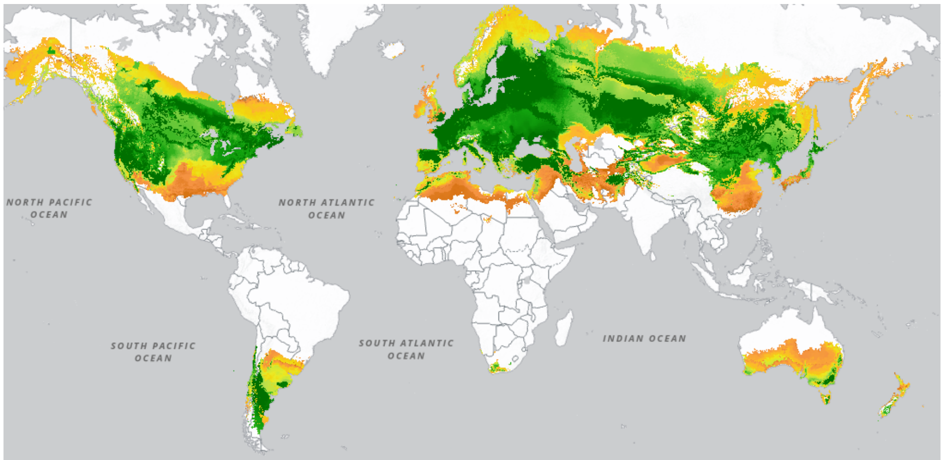
This study uses the data from War Food Administration (1946) to identify the location of beet sugar plants (see Figure F.6). To assess the reliability of this data, I cross-referenced it with other sources (Beet Sugar Gazette Company, 1908b; Federal Trade Commission, 1917; Townsend, 1921; American Sugar Refining Company, 1930). Samples of data are displayed in Figure F.7 and Figure F.8. Although the time coverage of these other data sources is shorter than that of War Food Administration (1946), they are consistent with each other during the periods of overlap.

E. Brief history about the invention of beet sugar

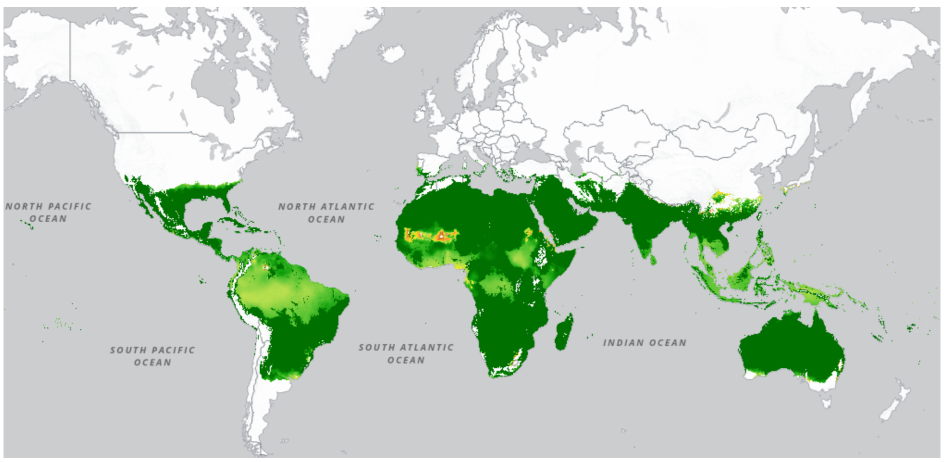
Andreas Margraff, a Prussian chemistry professor, first discovered that sugar could be produced from beets in 1747. However, mass production of this new technology was not possible at the time, and it remained an academic concept. It was not until the late 18th century, during the Haitian revolution, which disrupted cane sugar production, that interest in beet sugar production resurfaced. In 1797, Franz Achard, a Huguenot refugee from France who had been a student of Magraff, published his discoveries on an improved process of beet sugar production. He produced his first sample in 1799 (Child, 1840). The British government, concerned about the profits from the sugar business in its colonial possessions, attempted to bribe Achard to prevent him from sharing his knowledge, but he refused and continued his work (US Beet Sugar Association, 1936).

Napoleon's continental blockade in 1812 significantly reduced the shipment of cane sugar from tropical colonies. In response, Napoleon encouraged the production of sugar from beets by subsidizing the sugar beet industry and establishing chemical schools. Despite some obstacles after the trade barrier was lifted in 1815, the sugar beet industry expanded across several European countries, including the Netherlands, Austria, Germany, Russia, Belgium, Poland, Italy, and Sweden. By 1867, about 27.87 percent in the world sugar market were produced from beets (Goessmann, 1870, p. 44).

F. Appendix figures



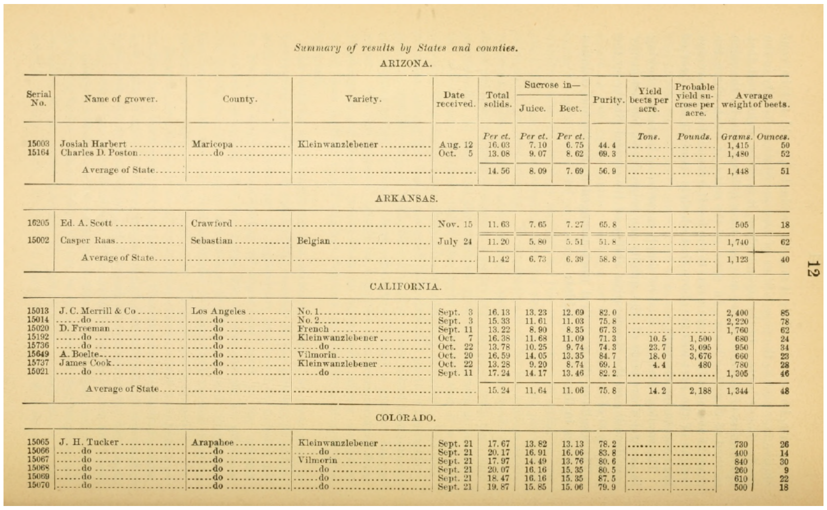
(a) Sugar beet suitability



(b) Sugar cane suitability

Figure F.1: Sugar beet and sugar cane suitability

Source: Panels (a) and (b) are taken from the Global Agro-Ecological Zones (v4) by the Food and Agricultural Organization. Greener areas indicate higher suitability, orange areas indicate lower suitability, and white areas are unsuitable.

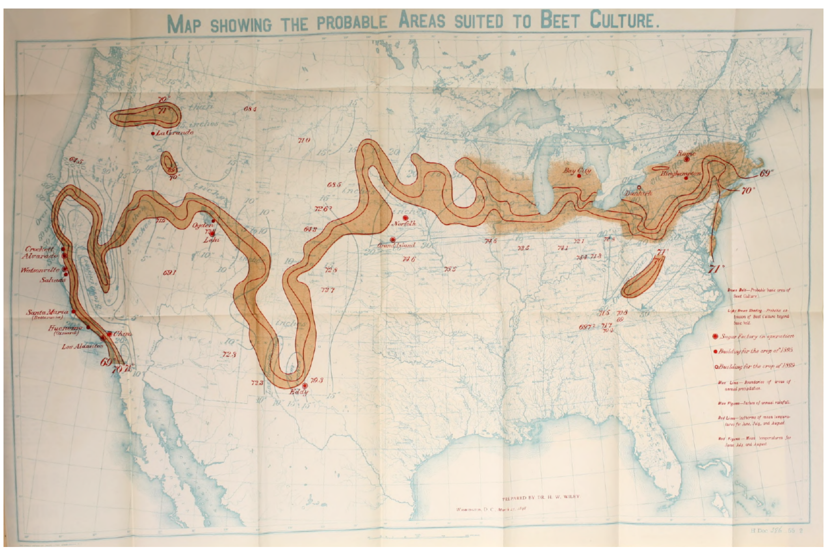


Summary of results by States and counties.

Serial No.	Name of grower.	County.	Variety.	Date received.	Total solids.	Sucrose in— Juice.	Sucrose in— Beet.	Purity.	Yield beets per acre.	Probable yield sucrose per acre.	Average weight of beets.	
					Per ct.	Per ct.	Per ct.		Tons.	Pounds.	Grams.	Ounces.
			ARIZONA.									
15003	Josiah Harbert	Maricopa	Kleinwanzlebener	Aug. 12	16.03	7.10	6.75	44.4			1,415	50
15164	Charles D. Poston	do		Oct. 5	13.08	9.07	8.62	69.3			1,480	52
	Average of State				14.56	8.09	7.69	56.9			1,448	51
			ARKANSAS.									
16205	Ed. A. Scott	Crawford		Nov. 15	11.63	7.65	7.27	65.8			505	18
15002	Casper Raas	Sebastian	Belgian	July 24	11.20	5.80	5.51	51.8			1,740	62
	Average of State				11.42	6.73	6.39	58.8			1,123	40
			CALIFORNIA.									
15013	J. C. Merrill & Co	Los Angeles	No. 1	Sept. 3	16.13	13.23	12.69	82.0			2,400	85
15014	do	do	No. 2	Sept. 3	15.33	11.61	11.03	75.8			2,220	78
15020	D. Freeman	do	French	Sept. 11	13.22	8.90	8.35	67.3			1,760	62
15192	do	do	Kleinwanzlebener	Oct. 7	16.38	11.68	11.09	71.3	10.5	1,500	680	24
15736	do	do	do	Oct. 22	13.78	10.25	9.74	74.3	23.7	3,095	950	34
15649	A. Boelte	do	Vilmorin	Oct. 20	16.59	14.05	13.35	84.7	18.0	3,676	660	23
15737	James Cook	do	Kleinwanzlebener	Oct. 22	13.28	9.20	8.74	69.1	4.4	480	780	28
15021	do	do	do	Sept. 11	17.24	14.17	13.46	82.2			1,305	46
	Average of State				15.24	11.64	11.06	75.8	14.2	2,188	1,344	48
			COLORADO.									
15065	J. H. Tucker	Arapahoe	Kleinwanzlebener	Sept. 21	17.67	13.82	13.13	78.2			730	26
15066	do	do	do	Sept. 21	20.17	16.91	16.06	83.8			400	14
15067	do	do	Vilmorin	Sept. 21	17.97	14.49	13.76	80.6			840	30
15068	do	do	do	Sept. 21	20.07	16.16	15.35	80.5			260	9
15069	do	do	do	Sept. 21	18.47	16.16	15.35	87.5			610	22
15070	do	do	do	Sept. 21	19.87	15.85	15.06	79.9			500	18

12

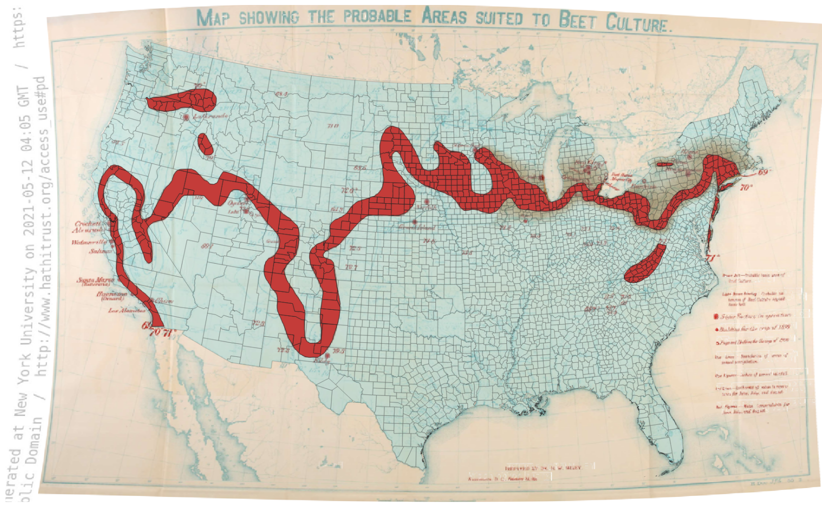
(a) Measurement of sugar quality



(b) Beet belt

Figure F.2: Study of beet sugar industry by USDA

Source: Panel (a) is taken from US Department of Agriculture (1891), and (b) from US Department of Agriculture (1899a).



(a) Beet belt (intersected on 1900 county polygon)

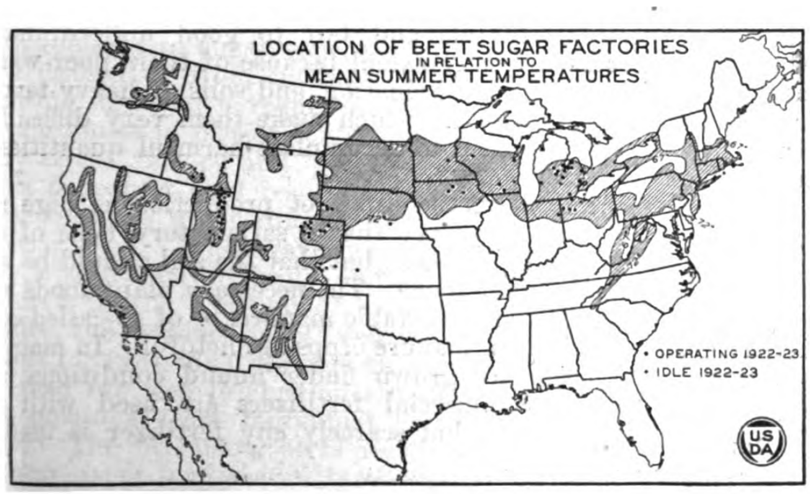


Fig. 18.—Sugar beets thrive best in localities where the temperature during the summer (average of June, July, and August) does not vary greatly from 70° F. Nearly all of the beet-sugar factories in the United States are located between the isotherms of 67 and 72° F. summer temperature. Owing to great variations in altitude in the Western States, the shaded area includes a wide range of climatic conditions in these States.

(b) Beet belt as of 1923

Figure F.3: Beet belt

Source: Panel (a) is the beet belt ((US Department of Agriculture, 1899a)) intersected with the 1900 county shape file. Panel (b) is the updated beet belt US Department of Agriculture (1923). Red line that highlights the temperature is done by author. The red line that highlights the temperature is added by the author.

SPRINGFIELD, O.

A company was recently organized at Dayton, O., for the purpose of starting a beet sugar factory at some convenient place in that state. The prime mover in the project is Mr. R. R. Dickey, Jr., vice-president of the Globe Iron Works of Dayton, and he is ably assisted by Mr. John S. Harshman, president of the Ohio Beet Sugar Association.

There is no reason why the great state of Ohio should not have a beet sugar factory. In fact, there is every reason why it should not only come into line, but soon occupy a place in the front rank of beet sugar producing states. The soil is eminently suited to the growing of this crop, the farmers are wide-awake, and the capitalists enterprising and resourceful.

A friendly rivalry has started between several cities as to which one should be selected for a site for the new factory. The city of Springfield is at present making a great effort to secure it. A meeting of business men was held recently in the Board of Trade rooms of that city and a committee appointed to look into the matter and make a report on it. Mr. Dickey and others having declared their readiness to subscribe stock, the question seems to turn, as usual, on the prospects of securing the necessary contracts for acreage to be planted to beets. It is stated that about 3,000 acres are in sight and there are strong hopes of securing the requisite 5,000 in a short time. The plans contemplate a factory of 500 tons capacity.

Figure F.4: American Sugar Industry and Beet Sugar Gazette, September 1899

NEW FACTORIES FOR 1900.

OSBORN, O.

Mr. R. R. Dickey, Jr., president of the Dayton Beet Sugar Company, writes that they are making strenuous efforts to secure sufficient acreage in the neighborhood of Dayton to justify them in erecting a 500-ton factory at Osborn, a small town 10 miles northeast of Dayton. A picnic was held at Osborn on September 16th, under the auspices of the Osborn Sugar Beet Growers' Association, for the purpose of interesting farmers in sugar beet culture and with a view of securing contracts for next year. This picnic was attended by fully 3,000 farmers, and was a great success.

Samples of beets grown near Osborn were exhibited at the picnic and a large number of tests were made right on the ground. They showed remarkably high sugar contents; the highest was 16.32 and the average well above 14, with a purity of 80 or higher. Addresses were delivered by Messrs. R. R. Dickey, E. M. Thacker, Dr. T. V. Crabell, Hon. R. L. Holman, Hon. L. B. Gunckel, Dr. K. G. Korn, W. C. Kennedy and others. The speakers assured those present that the Dayton Beet Sugar Company would build a 500-ton factory at Osborn if the farmers will guarantee a sufficient acreage of beets to furnish the factory with the raw material. To judge from the interest shown by the farmers who attended the picnic, and counting on the efforts of the promoters who are pushing the matter, the acreage should be easily secured and a factory be ready at Osborn for the campaign of 1900. It all depends on the farmers, and if they are at all alive to their own interest, they will quickly sign contracts for the acreage required. The Dayton Beet Sugar Company is capitalized at $500,000, and is backed by the most substantial business men of that city.

* * *

NORTH JUDSON, IND.

Walkerton, Ind., Sept. 30, 1899.

Editor Beet Sugar Gazette:—

Replying to yours of the 26th inst., will say that we now have contracted five thousand (5,000) acres, and that before another month we expect to have increased that number to about six thousand (6,000) acres. All our contracts are for three years, and the farmers will be paid four dollars per ton for all beets containing not less than twelve per cent sugar to the

PUEBLO, COLO.

Mr. Henry T. Oxnard, accompanied by Morris Weinreich, the expert for the American Beet Sugar Company visited Pueblo, Colo., the latter part of September with a view of examining the adaptability of the Arkansas Valley to the cultivation of sugar beets. They were taken over the ground by Mr. C. B. Schmidt, land agent for the Suburban Land and Improvement Company, and Mr. Jas. A. Davis, the industrial commissioner for the Atchison, Topeka & Santa Fe Railroad. After a thorough examination, Mr. Oxnard pronounced the Arkansas Valley "an ideal spot for raising sugar beets," and held out hopes that the American Beet Sugar Company would decide to locate a factory a few miles west of Rocky Ford, to be in readiness for the campaign of 1900. The Suburban Land & Improvement Company will put 1,500 acres into beets next spring. It is said Mr. Oxnard took an option on 5,000 acres of land belonging to the company. Whether or not a factory will be located at Pueblo will be decided at a meeting of the directors of the American Beet Sugar Company in New York some time this month.

* * *

LAWRENCE, KAN.

Robert Hoodless, a promoter, working in conjunction with the construction firm of Hoff Bros. of Chicago, has been in Lawrence, Kan., for the past three weeks, working up an interest in the beet sugar industry. He has met with a good deal of encouragement from the local business men, and several agitation meetings have been held at which Mr. Hoodless pointed out the benefit of this industry to a farming community, and showed that the land in the great Kaw Valley was the equal of any beet sugar land in the country. On September 25, at a largely attended meeting of the Commercial Club, held at the court house, Mr. A. F. Postel, an agricultural expert, also connected with the firm of Hoff Bros., made a concise explanation of the plans and conditions for a factory. At his suggestion a committee was appointed to investigate the matter and to conduct preliminary experiments along the line he suggested. This committee consists of W. F. Barteldes, A. Henley, R. W. Sparr, J. N. Roberts and A. L. Selig. It is proposed to experiment for a year, and if everything is satisfactory the plans for the factory are to be taken up in earnest next fall.

* * *

FT. DODGE, IOWA.

Figure F.5: American Sugar Industry and Beet Sugar Gazette, 1900

1906

VISALIA, CALIF. Erected by Pacific Sugar Corp. Machinery moved from Rome, New York, and St. Louis Park, Minn. Capacity, 350 tons. Machinery moved to Hooper, Utah in 1919.

BRUSH, COLO. Erected by Morgan County Construction Co. Original capacity, 600 tons. Present capacity, 1,600 tons. Present owner, Great Western Sugar Co.

FT. MORGAN, COLO. Erected by Morgan County Construction Co. Original capacity, 600 tons. Equipped with Steffens process. Present capacity, 1,600 tons. Present owner, Great Western Sugar Co.

SWINK, COLO. Erected by Holly Sugar Co. Original capacity, 1,200 tons. Equipped with Steffens process. Present capacity, 2,200 tons. Present owner, Holly Sugar Corp.

NAMPA, IDAHO. Erected by Western Idaho Sugar Co. Capacity, 750 tons. Machinery moved to Spanish Fork, Utah in 1916.

GARDEN CITY, KANS. Erected by U. S. Sugar and Land Co. Original capacity, 1,000 tons. Equipped with Steffens process and steam pulp dryer. Present capacity, 1,200 tons. Present owner, Garden City Co.

CHARLEVOIX, MICH. Erected by West Michigan Sugar Co. Capacity, 600 tons. Machinery moved to Ottawa, Ohio in 1912.

CHASKA, MINN. Erected by Carver County Sugar Co. Machinery moved from East Tawas, Mich. Original capacity, 600 tons. Equipped with fire pulp dryer. Present capacity, 1,700 tons. Present owner, American Crystal Sugar Co.

BILLINGS, MONT. Erected by Billings Sugar Co. Original capacity, 1,200 tons. Equipped with Steffens process and pulp dryer. Present capacity, 3,500 tons. Present owner, Great Western Sugar Co.

REMOVED: Rome, N. Y.; St. Louis Park, Minn.; East Tawas, Mich.
TOTAL: 92-26-66

1907

LAS ANIMAS, COLO. Erected by American Beet Sugar Co. Capacity, 700 tons. Dismantled in 1942.

WAVERLY, IOWA. Erected by Iowa Sugar Co. Machinery originally erected at Bay City, Mich. in 1898. Original capacity, 400 tons. Equipped with fire pulp dryer. Present capacity, 700 tons. Present owner, Waverly Sugar Co.

REMOVED: Bay City, Mich.
TOTAL: 94-27-67

1908

CORCORAN, CALIF. Erected by Pacific Sugar Corp. Machinery originally erected at Crockett, Calif. Capacity, 600 tons. Machinery moved to Preston, Idaho in 1922.

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Figure F.6: Beet sugar plant opening records

Source: Beet sugar opening records from War Food Administration (1946).

38 THE AMERICAN SUGAR INDUSTRY AND BEET SUGAR GAZETTE.

BEET SUGAR FACTORIES

OF THE

UNITED STATES AND CANADA

It is the aim of the publishers to keep this list up to date and reliable. Factory managers will therefore, confer a favor by promptly notifying us of any change in name or capacity.

NAME OF COMPANY AND FACTORIES	LOCATION OF FACTORIES	DAILY SLICING CAPACITY TONS BEETS
CALIFORNIA		
Alameda Sugar Co.	Alvarado......Cal.	800
Los Alamitos Sugar Co.	Los Alamitos... "	700
Spreckles Sugar Co.	Spreckles...... "	3,000
Union Sugar Co.	Betteravia..... "	600
American Beet Sugar Co., main office, 32 Nassau St., New York. Pacific Coast, office, 604 Mission St., San Francisco	Chino......... "	900
	Oxnard........ "	2,000
Pacific Sugar Corporation, main office, Los Angeles, Cal.	Visalia......... "	400
Alta, Cal., Beet Sugar Co.	Hamilton City.. "	700
	Total..........8	9,100
COLORADO		
American Beet Sugar Co., western office, 1530 Sixteenth St., Denver, Colo.	Rocky Ford....Colo	1,100
	Lamar......... "	600
	Las Animas....Colo	700

NAME OF COMPANY AND FACTORIES	LOCATION OF FACTORIES	DAILY SLICING CAPACITY TONS BEETS
MICHIGAN—Cont.		
German-American Sugar Co.	Bay City, Sta. A. "	650
Mt. Clemens Sugar Company	Mt. Clemens.... "	600
Menominee River Sugar Co.	Menominee.... "	1,200
St. Louis Sugar Co.	St. Louis.....Mich.	600
The Continental Sugar Co., main office, Cleveland, Ohio: Blissfield Works	Blissfield....... "	600
West Michigan Sugar Co.	Charlevoix...... "	600
	Total........16	11,550
MINNESOTA		
Carver County Sugar Co.	Chaska......Minn.	600
MONTANA		
The Great Western Sugar Co.	Billings......Mont.	1,200
NEBRASKA		
American Beet Sugar Co.	Grand Island..Neb.	350

(a) Beet sugar plant locations, 1920

8 THE BEET SUGAR INDUSTRY IN THE UNITED STATES.

1897.

Los Alamitos Sugar Co., Los Alamitos, Cal.
Pecos Valley Beet Sugar Co., Carlsbad, N. Mex. (Operated unsuccessfully for two years. It was closed and later destroyed by fire.)
First Beet Sugar Co., Rome, N. Y. (On account of bad management and lack of beets died after two years.)

1898.

California Beet Sugar & Refining Co., Crockett, Cal. (Removed to Corcoran, Cal., in 1909.)
Oregon Sugar Co., La Grande, Oreg. (Removed to Burley, Idaho, in 1911.)
Ogden Sugar Co., Ogden, Utah.
Michigan Sugar Co. (old), Bay City, Mich. (Removed to Waverly, Iowa, in 1907.)
Minnesota Sugar Co., St. Louis Park, Minn. (Burned in 1905.)
Binghamton Sugar Co., Binghamton, N. Y. (Removed to Blackfoot, Idaho, in 1904.)
American Beet Sugar Co., Oxnard, Cal.

(b) Beet sugar plant locations, 1930

Figure F.7: Factory locations in 1920 and 1930

Source: Panel (a) is from Beet Sugar Gazette Company (1908b). Panel (b) is from Federal Trade Commission (1917).

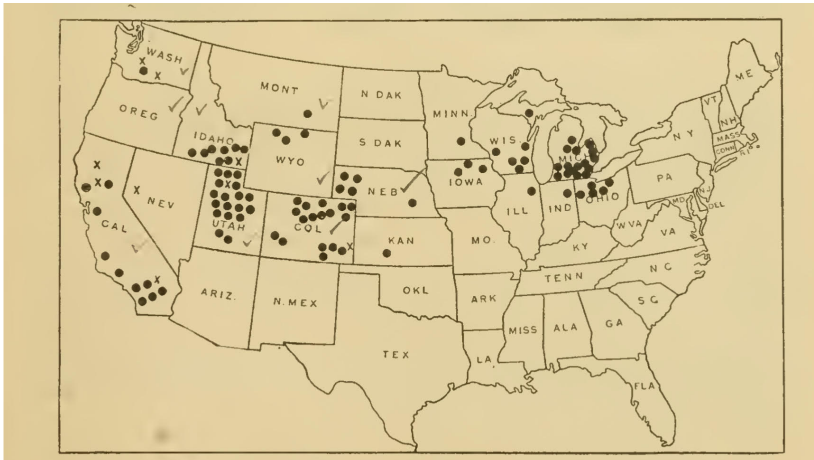
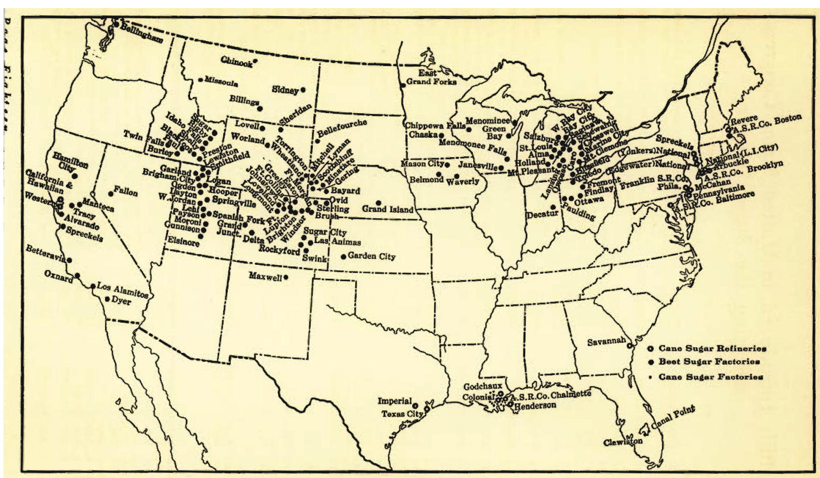


FIG. 1.—Outline map showing by black dots the locations of beet-sugar mills that were in operation during the 1920–21 campaign. Mills that were standing idle during the 1920–21 campaign are indicated by an × mark.

(a) Beet sugar plant locations, 1920

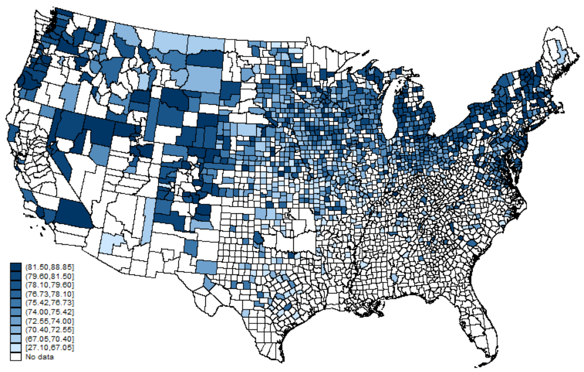


Map Showing Beet and Cane Sugar Factories and Cane Sugar Refineries in the United States
December 31, 1930

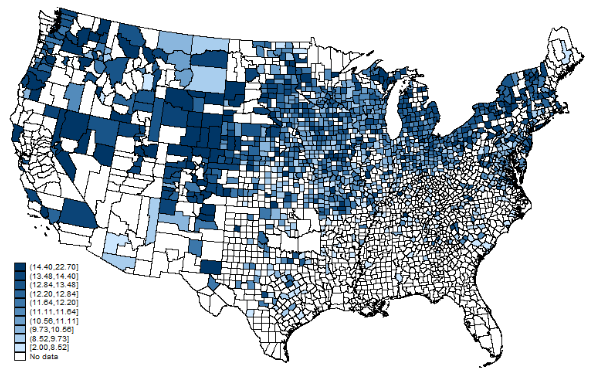
(b) Beet sugar plant locations, 1930

Figure F.8: Factory locations in 1920 and 1930

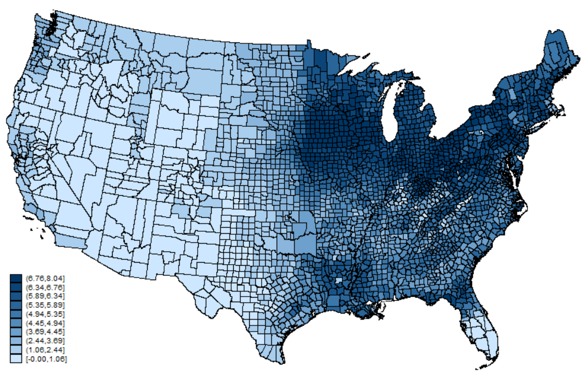
Source: Panel (a) is from Townsend (1921). Panel (b) is from American Sugar Refining Company (1930). Hollow circles in Panel (b) indicate sugar cane plants.



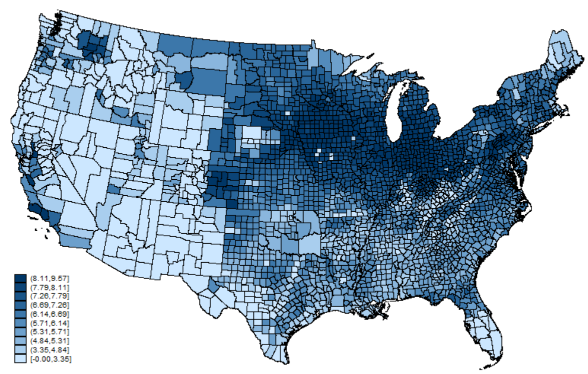
(a) Purity coefficients (percent)



(b) Sugar in beets (percent)



(c) potential yield (ton/ha), rain-fed with high input



(d) potential yield (ton/ha), irrigation with high input

Figure F.9: Sugar beet suitability

Notes: Purity coefficients and sucrose in beets are county-level mean of USDA experiment results between 1890-1900 (US Department of Agriculture, 1891). Potential yield (ton/ha) data are taken from Global Agro-ecological Zones at Food and Agriculture Organization (2012).

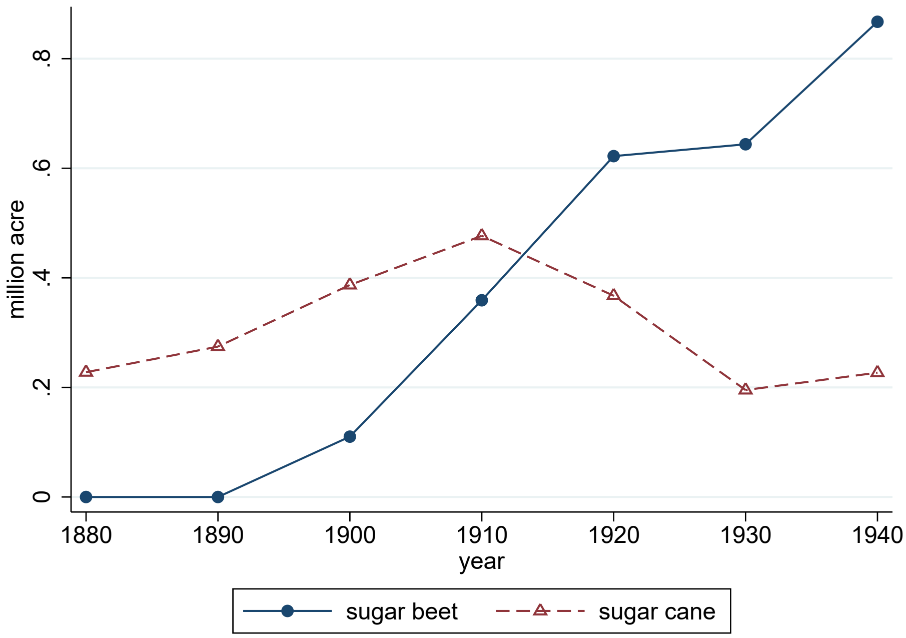


Figure F.10: Farmland acres cultivated for sugar beet and sugarcane

Source: Data is taken from Haines et al. (2019).