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Cartels Destroy Productivity: Evidence from the New Deal Sugar Manufacturing Cartel, 1934–74*

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ABSTRACT

The idea that cartels might reduce industry productivity by misallocating production from high to low productivity producers is as old as Adam. However, the study of the economic consequences of cartels has almost exclusively focused on the losses from higher prices (i.e., Harberger triangles). Yet, as the old idea suggests, we show that the rules for quotas and side payments in the New Deal sugar cartel led to significant misallocation of production. The resulting productivity declines essentially destroyed the entire cartel profit. The magnitude of the deadweight losses (relative to value added) was large: we estimate a *lower* bound for the losses equal to 25 percent and 42 percent in the beet and cane industries, respectively.

Keywords: Cartels; Quota; Monopoly
JEL classification: L00, L43, L6

*Note that the issues studied in this paper are distinct from those examined in Bridgman, Qi, and Schmitz (2009). The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

1 Introduction

The idea that cartels might reduce industry productivity by misallocating production from high to low productivity producers is as old as Adam. While the idea has stood the test of time, it has done little else. In particular, it has had very little impact on both the academic literature on cartels and the formulation of economic policy toward cartels.

Regarding the academic literature, the study of the welfare losses from cartels has focused almost exclusively on the losses from higher prices (see, e.g., Levenstein and Suslow's (2006) extensive survey of the cartel literature). Public policy has adopted the same narrow focus: in assessing welfare losses, public policy focuses on cartel price overcharges, not considering the possibility that cartels destroy productivity.

In this paper, we examine the New Deal sugar manufacturing cartel, created during the Great Depression and in operation between 1934 and 1974. As the old idea suggests, we show that cartel rules on *quotas* and *side payments* reduced industry productivity by misallocating production from high productivity to low productivity producers. The rules essentially destroyed the entire cartel profit. We estimate a lower bound for the losses (relative to value added) of 25 percent and 42 percent in the beet and cane industries, respectively.

As part of New Deal economic policy, this industry (and many others) were permitted to form a cartel. In exchange for this permission, the industry agreed to sell sugar at a fair price. In addition, members of the industry, including factory owners and incumbent farmers, agreed to *jointly* draft a plan (subject to government approval) for how the cartel would meet the price targets and share the cartel profits. Of course, disagreements and conflict arose over how to share profits. In addition, this cartel, like others, faced *constraints* on the type of rules it could employ to share profits.[1] Faced with these constraints, the cartel settled for rules that did share profits but also ultimately destroyed productivity (and hence

[1] We will discuss these constraints later, but some constraints arose from legal institutions (such as determining what contracts were legal), others from political considerations, and even some from cultural concerns (such as social norms).

profits) as well.

The U.S. sugar manufacturing industry consists of three subindustries. The *beet sugar* industry is made up of factories that process sugar beets into white sugar, as well as the farms, nearly always located close to the factory, that produce those beets. The *cane sugar* industry (also consisting of factories and surrounding farms) produces and processes sugarcane into *raw* sugar. Finally, the *sugar-refining* industry (whose factories are typically located in major cities, such as Brooklyn, New York) processes imports of raw sugar (and the raw sugar produced by the U.S. cane industry) into white sugar.[2]

During the cartel, foreign sugar producers were given import quotas (for raw sugar). Incumbent U.S. sugar manufacturing firms in the beet and cane industries were given sales quotas. Incumbent sugar crop farmers were also given quotas, specifying the number of acres on which they could grow sugar crops. Incumbent sugar refiners were also (in effect) given quotas, since they processed foreign raw sugar and domestic raw sugar, both of which were subject to quotas.

The size of a farmer's quota in 1934 was tied to the acres of sugar crops grown by the farmer before the cartel. The quotas held by sugar farmers were subject to strict trading rules. Quota rights could not be sold. Quotas could be rented but only locally (i.e., within a farmer's county). Since, before the cartel, the economic profit of the marginal farmer in a region was approximately the same across the country (as we argue later), this initial allotment of quotas achieved cartel profits that were roughly as large as possible.

Over time, however, the economic profit of the marginal farmer began to diverge across regions. First consider the beet industry. In 1934, California and Colorado were the biggest beet sugar producing states. Minnesota and North Dakota were very small producers. After World War II, the opportunity cost of land and (irrigated) water in Colorado and California

[2] Hence, producing beet sugar is a one-step process (in a single factory), whereas producing cane sugar is typically a two-step process: producing *raw* sugar (in one factory) and then *white* sugar (in a different, distant factory). In the early 1930s, beet sugar was produced in many states, from Michigan to Colorado to California. Cane sugar (raw sugar) was produced in Louisiana and Florida (though only a very small amount), as well as in the territories of Hawaii, Puerto Rico, and the Philippines.

grew much faster than in, say, Minnesota and North Dakota. Because cartel rules forbade farmers from renting their quotas beyond the local area, quota rights could not flow from, say, California to North Dakota, from regions where the profit of the marginal farmer was falling to those where it was increasing. In the cane industry, in 1934, Louisiana was a large producer, while Florida had barely started producing sugar (and so received a very small quota). After World War II, the profit of the marginal farmer in Florida began growing much faster than that of his counterpart in Louisiana but, again, quota rights could not move to Florida.

The quotas led to one type of welfare loss: the opportunity cost of inputs used to produce a given quantity of sugar in California was *greater* than the opportunity cost of inputs needed to produce that sugar in North Dakota. The cartel rules for side payments led to a second type of loss. Cartel rules granted side payments to farmers that were *proportional* to a farmer's annual production of sugar crops.[3] This meant that in some regions (including California, Colorado, Puerto Rico, and Louisiana), some farmers produced crops even though they were earning *negative* economic profits. They produced since their payoff, profits plus the side payment, was positive. In the second type of welfare loss, then, the inputs used to produce sugar in California had a greater value in *other uses* in California. The inputs were used to produce sugar because the side payment was tied to production.

In this paper, we focus on this second source of deadweight loss, that inputs used to produce sugar in some states had a greater value in other uses in that state. The cartel could have eliminated this loss if, for example, it had employed lump-sum side payments (by tying payments to acre quotas, for example). We estimate the welfare losses by comparing the cartel profits with proportional side payments (i.e., the actual cartel profit, say, Π^{prop}) with the profit if lump-sum payments had been made (say, Π^{lump}). The welfare loss is then $[\Pi^{lump} - \Pi^{prop}]$. When we make this welfare calculation, we keep the price of sugar fixed. Hence, purchasers of sugar are just as well off.

[3] To pay for these side payments, the cartel imposed taxes on other cartel members. We discuss this scheme in detail later.

That the deadweight losses from the second source might be large follows from the significant size of the side payments. Farmers received a payment from factories for their crop. On top of this, they received a side payment that was roughly 20 percent as large as the factory payment.

In estimating the welfare loss, $[\Pi^{lump} - \Pi^{prop}]$, the New Deal cartel profits (i.e., Π^{prop}) are available from government studies that calculated the *economic* costs and profits of producing sugar. As for the profits Π^{lump}, we develop a simple model to calculate a lower bound for Π^{lump}, call it Π^{qlum} (*qlum* for quasi-lump sum). These profits can also be calculated from available sources. Since $\Pi^{lump} > \Pi^{qlum}$, we have a lower bound for the profit loss, namely $[\Pi^{qlum} - \Pi^{prop}]$.

In the middle 1960s, for the beet industry, for the farming sector alone, the cartel profit was essentially zero, that is, $\Pi^{prop} \approx 0$. The *entire* cartel profit was destroyed. As for the size of the profit loss, we have a lower bound, again $[\Pi^{qlum} - \Pi^{prop}] \approx \Pi^{qlum}$. These (lower bound) profit losses were *economically* significant. That is, they are large when normalized by measures of industry size. For example, the (lower bound) profit loss was roughly 18 percent of industry revenue and 25 percent of industry value added. For the same period for the cane industry, for the farming and factory sector *combined*, the profit loss was 42 percent of industry value added.

While the cartel's economic profit was essentially zero, the cartel had strong support. In some regions of the country, cartel profits were large, and these regions strongly supported the cartel. In other regions, economic profits were negative. Farmers continued to produce (at least with part of their quotas), since profits plus side payments were positive.

In the beet industry, economic profits in midwestern states, such as Minnesota, were large. Profits of western states, such as those in California, were negative (and large in absolute value). In the cane industry, economic profits in Florida were large. The profit losses in other areas, such as Louisiana and Puerto Rico, were so large that *total* cane industry profit was negative.

That some regions significantly benefited from the cartel helps to explain why the cartel persisted. But two questions arise. Why adopt these rules initially? We address this question later. And why not change the rules in, say, the 1950s or 1960s? This cartel had vocal critics. Any attempt to convince Congress in the 1950s or 1960s that other cartel rules could significantly increase cartel profits yet keep sugar purchasers just as well off would have invited the critics' wrath. It was not even clear that the cartel was legal in a strict sense. While the sugar cartel was formed with government approval in 1934, two years later the U.S. Supreme Court ruled the New Deal cartels unconstitutional. Yet the sugar cartel, and a few others, slipped through the cracks and continued to operate for decades. The critics did succeed in closing the cartel in 1974 when world sugar prices soared.

This research contributes to the literature on the *cost of monopoly.* The modern literature begins with Harberger (1954), who estimated the costs to be very small. This view (that costs are small) became widely accepted. Only 20 years after Harberger, Bergson (1973) lamented that the issue had been settled: the costs of monopoly were inconsequential.

This view still reigns. Tullock (1997) admitted that, regarding the costs of monopoly he had proposed in Tullock (1967), no measurable costs had been found (despite extensive research into the issue). For costs of monopoly more generally, Olson (1996) echoes Tullock in saying that "research finds the losses from monopoly in U.S. industry are slight." And McCloskey (2010) reminds those still naive enough to argue that the costs of monopoly are large that they have "an appointment with Harberger," an appointment she assumes will not end well.[4]

Recent studies of monopolies (or near monopolies), however, have shown that the costs can be large. Most of these studies have looked at the costs of monopoly in the context of unions (see, e.g., Schmitz (2005) and Dunne, Klimek, and Schmitz (2015)). They show that workers face conflicts over how to share profits from union monopolies, as well as *constraints* on the types of sharing rules they can employ. The union contracts used to share profits

[4] One voice arguing that monopoly has large costs is Parente and Prescott (2000); see also Bridgman (2015).

decreased productivity.

These conflicts within unions arise in other (near) monopoly settings (see Schmitz (2012)). This paper extends the recent literature on unions and productivity to the economic costs of (traditional) cartels. In next section, we review the (small) literature on the productivity losses and welfare losses from cartels. In the conclusion, we return to a general discussion of the cost of monopoly.

This research also contributes to the recent literature that studies the costs of misallocation (see Hseih and Klenow (2009), Midrigan and Xu (2014), and Restuccia and Rogerson (2013)). This literature, using economic theory, infers misallocation (and its costs) from features of the firm productivity distribution. Similarly, our model shows how cartel rules influenced the evolution of the regional productivity distribution and also allows us to calculate deadweight losses.

2 Literature on the Economic Costs of Cartels

The study of the welfare losses from cartels has almost exclusively focused on the losses from higher prices.[5] One small literature discusses cartels and productivity. Some studies find losses from productivity declines to be small. Rucker, Thurman, and Sumner (1995) study the impact of cartel quotas on misallocation of production in North Carolina tobacco production. Farmer quotas could be transferred within counties but not across counties. They estimate that the productivity losses of misallocation were small. Asker (2010) studies a bidding cartel of stamp dealers. He concludes that the cartel led to small efficiency losses, though he discusses caveats for why losses may have been larger.

By contrast, some studies have found large productivity losses from cartels. Singer (2014) studies another New Deal cartel that slipped through the cracks, operating from 1933 to 1972: the petroleum drilling cartel (for a description of this cartel, see Libecap (1989)). Singer

[5] Levenstein and Suslow (2006) provide an extensive survey of the cartel literature. The vast majority of the survey, and the cartel literature, is *not* about the economic costs of cartels. Rather, it deals with questions such as, What determines cartel success (measured in duration)?

estimates that misallocation of drilling rights during the cartel led to significant deadweight losses, amounting to roughly 10 percent of industry revenue each year.

Cole and Ohanian (2004) (hereafter, CO) study the aggregate economic impact of New Deal cartels during the Great Depression. If these cartels had comprised only factory owners, their impact may have been small. But just as the sugar cartel had many members, so did the hundreds of other New Deal cartels. One member was the U.S. government, since it allowed the cartels to form. Other members were employees of the incumbent firms. In exchange for receiving the government's permission to cartelize, factory owners agreed to grant more power to labor. In a model in which these different groups bargain over profit-sharing rules, CO show that the cartels had a significant negative impact on aggregate economic activity.[6]

Monke, Pearson, and Silva-Carvalho (1987) studied a flour-milling cartel in Portugal, showing that it led to large productivity losses that destroyed 23 percent of cartel profits. One source of loss was misallocation of production resulting from quota assignments. But another source of loss was size restrictions imposed by the cartel on mill size, limiting scale economies.[7] A cartel in the Norwegian cement industry was studied by Röller and Steen (2006) (hereafter, RS). They show that this cartel destroyed productivity. Each year the cartel established a total domestic *sales* quota. A firm's share of the sales quota was equal to its share of previous *production*. Given this rule, each firm found it profitable to expand production beyond their domestic sales quota, exporting the excess production to Europe (at a price below the marginal cost of production). In this sense, the sharing rule destroyed productivity.[8]

Interestingly, the members of the Norwegian cartel merged to a *monopoly* in 1968. RS also study the economic impact of this merger, using the standard theory of monopoly.[9]

[6] See also Symeonidis (2008) for a cross-industry study of cartels in the United Kingdom.

[7] In fact, size restrictions are common in cartels. Taylor (2007) shows that many cartels formed during the New Deal restricted how long machines (or entire plants) could operate or did not permit capacity expansion (or both). In the New Deal sugar cartel, the Puerto Rican administrators imposed size restrictions on farms (see, e.g., Bridgman et al. (2012)).

[8] Here we take an expanded view of productivity as the economic profit produced by the industry.

[9] By the standard theory of monopoly, we mean a firm with a single shareholder that is able to dictate production and pricing decisions.

This theory predicts that the monopoly would increase productivity (by ceasing to export cement). But the theory badly predicts what happened. Exports doubled in the first few years of the monopoly (see RS, Figure 2), did not fall back to their pre-monopoly level until nearly a decade later, and did not cease until 1986.[10] Hence, in this sense, the monopoly led to greater destruction of productivity than the cartel, at least for its first decade.

We mention the cement monopoly since it illustrates an important point. The cartel was unable to reach profit-sharing agreements that did not reduce productivity. Why, then, should the monopoly have been able to reach them? The monopoly consisted of the *same* groups as those in the cartel, including the shareholders of each firm, the managers and employees of each firm, the national government (since it permitted the merger), and others. The conflict among these groups did not disappear with the merger. Cartels reduce productivity, but so do monopolies.[11]

In summary, while only a handful of papers have looked at the productivity impact of cartels, some have found large productivity losses. We are confident that a study of cartels operating today will also find large economic losses. Moreover, many more cartels exist today than is recognized. Consider the dental profession. While many thousands of dentists are practicing, they use state dental associations to limit competition. State dental associations

[10] For example, exports to the United States in 1967 equaled 190,143 tons of cement. In 1973 they were 668,000 tons, amounting to 25 percent of Norway's cement production that year. Exports to Spain in 1969 were 119,106 tons (U.S. Geological Survey, various years).

[11] As for the profit-sharing rules that led to increased exports and further reductions in productivity, there are interesting leads. First, Lorange (1973) suggests that such sharing rules were important. He studied the negotiations among the shareholders of the merging cement firms on how to distribute shares in the new firm (the monopoly). In the conclusion, in a bit of exasperation, Lorange admitted that there were likely negotiations and side payments he was not privy to: "Our analysis ... gives a complete picture of the financial strategic culture only. There may be other important payoff elements. ... Often such factors might even override the financial ones. These might include top managements' personal interest in the new organization, concerns for the future of certain plants, loyalty to employees, customers." Second, Sorgard (1992) provides evidence for one profit-sharing, productivity-reducing rule, though for a later period. The Norwegian government had a strong interest in keeping plants open, particularly the plant in Kjøpsvik. According to Sorgard, in exchange for maintaining production levels, the government provided other monopoly members (employees, shareholders) with protection from foreign competition. Sorgard (1992, p. 111) reports: "In 1984 Norcem [the monopoly] threatened to close down Kjøpsvik if the government did not impose an anti dumping duty on imports from East Germany. An anti dumping duty was put into effect." Lastly, exports to Ghana greatly increased as the cartel was being formed. Norcem reached an agreement with the Ghanaian government to be the sole supplier to the country. What role the Norwegian government had in these negotiations, if any, and the potential impact on productivity, might be explored.

require that hygienists must work under the supervision of a dentist. In some states, a dentist can employ at most one hygienist. Restricting the number of hygienists per dentist limits the scale of the most skilled dentists, those who would have employed two or more hygienists. Hence, these restrictions act just like quotas: they reallocate production from high to low productivity producers. Dunne, Herkenhoff, and Schmitz (2014) use a version of the Lucas (1978) span of control model to estimate the deadweight loss from this reduction in industry productivity.

Briefly, the paper proceeds as follows. An overview of the cartel is presented next. We first study the U.S. beet industry, turning later to U.S. cane. A brief history of the U.S. sugar beet industry is provided. It discusses the forces that led to the divergence in productivity between regional beet industries. We next present a model that enables us to calculate the lower bound for deadweight losses arising from this divergence in productivity. In the model, we take the cartel rules as given (including the determination of total quotas and hence the price of sugar). We calculate the *competitive equilibrium* for farmers facing these cartel rules. We then present detailed data on cartel profits and productivity, which allows us to calculate deadweight losses. We follow the same presentation for the cane industry.

3 New Deal Sugar Manufacturing Cartel

Before the Great Depression, U.S. sugar manufacturing was protected by a tariff on foreign sugar. Domestically, the industry was competitive, with free entry into manufacturing sugar. During the Depression, U.S. industries were permitted, indeed encouraged, to form cartels. The sugar industry formed a cartel in 1934. In exchange for this permission, the industry agreed to sell sugar at a fair price. In addition, members of the industry, including factory owners and incumbent farmers, agreed to *jointly* draft a plan (subject to government approval) for how the cartel would meet price targets and share cartel profits.

A "fair" sugar price was taken to mean that sugar prices would increase at roughly the rate of inflation. The U.S. Department of Agriculture (USDA) estimated the yearly quota that would yield this fair price. Cartel rules then set how this quota was divided between imports of foreign sugar and quotas on the sales of domestic sugar producers.[12]

We now turn to providing more detail on the rules to share profits. We present some arguments as to why these rules (which ultimately destroyed productivity) were chosen.

3.1 Cartel Quotas

Here we describe some of the rules regarding domestic quotas. Once the total domestic *sales* quota was established, cartel rules specified how this quota was divided among beet sugar producers and cane sugar producers. Rules further specified how the beet (cane) quota was divided among beet (cane) producing states. Within each beet (cane) producing state, the sales quota was divided among factories.

Local officials then set acre quotas for incumbent (cartel) farmers. Again, farmer quotas could not be sold. They could be rented but only locally.

Why were farmers given quotas? They seem redundant. Quotas on the sales of factories would determine the price of sugar. So, the acre quotas were not a mechanism to control sugar prices but rather a mechanism to ensure that incumbent farmers received a share of the monopoly profits. Without the acre quotas, for example, nothing stopped firms from moving the locations of their factories.

But why not let farmers trade quotas nationally (whether by sale or rental)? First, some cartel members had an incentive to block national quota markets, in particular, the local and state authorities that administered the cartel locally. By limiting rentals to local areas, states protected their sugar industries from other states that may have attempted to steal the industry.[13] In addition, it is hard to imagine that other cartel members could have envisioned the changes that would occur in California and Colorado after World War II—changes that

[12] Quotas given to foreign producers were larger than those given to domestic producers.

[13] Competition between U.S. states for manufacturing industries is not new. Powell (1913) discusses how states competed for manufacturing in the early 1900s. Cherington (1912) discusses the particular case of states competing for sugar beet factories.

would increase the cost of farming much faster in the West than in the Midwest. For other cartel members, then, restricting rentals to local areas may not have seemed too onerous.

3.2 Side Payments and Taxes

Farmers in the beet sugar industry and the cane sugar industry received side payments. The scheme worked as follows. Sugar factories producing white sugar (that is, the sugar refining factories and beet sugar factories) paid a tax based on their (physical) output, which they sent to the U.S. Treasury. These taxes were then distributed to beet and cane farmers, based on their *production* of crops. We describe the scheme in more detail later on.

Why the side payments to farmers? Actually, an initial cartel plan drafted by the industry did *not* have side payments to farmers. The government rejected the plan, in part, for providing too little of the cartel profits to farmers. This gave farmers more clout in the following negotiations, those resulting in the cartel plan with side payments.[14]

But why were the side payments made in this inefficient way? The payments could have been tied to the original acre quotas. A payment per acre, regardless of the amount of production (if any), would be a lump-sum payment. But such payments would likely face obstacles. In this case, a farmer would receive cash for no effort. Governments are often reluctant to do this because it does not seem fair.[15] Also, from the receiver's point of view, a stigma is sometimes associated with receiving cash without effort.[16] Again, it may have been difficult for cartel members to envision the dramatic changes that would occur in California and Colorado after World War II—changes that would lead to beets earning negative profits.

[14] See Dalton (1937) and Ellison and Mullin (1995), who discuss the significant influence of sugar farmers in policy debates in the period.

[15] Coate and Morris (1995) provide a different theory as to why governments often choose not to use cash when making side payments.

[16] Auerbach (2010) discusses some of the social norms that have arisen against giving cash without effort.

3.3 Local Rules

Cartel rules were also set at the local level. We have already mentioned how farmer quotas were set locally. But local administrators intervened in other ways to affect the distribution of cartel profits. In Puerto Rico, local cartel administrators introduced a bevy of regulations on large farms so as to transfer more cartel profits to small farms.

As mentioned, in 1974, with a surge in world sugar prices, the cartel collapsed. Sales quotas on domestic firms were eliminated, as were side payments. The domestic industry was again competitive. Quotas on foreign sugar continued, however, and became much more restrictive over time (see the later discussion).

4 History of Beet Sugar Manufacturing Industry

This brief history of the U.S. beet sugar industry (1) describes the reasons for diverging regional total factor productivities and (2) shows how regional production levels changed when cartel rules were abandoned. The data in this section (and the paper) are discussed in detail in Bridgman, Qi, and Schmitz (2015).

4.1 Misallocation Arises over Time

Figure 1 presents the harvested sugar beet acres by state in 1950. Colorado and California were the biggest producers. Note that production is spread throughout the country. The wide geographical dispersion of the industry was due in part to the labor constraints faced by the industry (discussed shortly) as it expanded in a region. Forces in play after World War II led to divergence of regional productivity in sugar manufacturing. Here we discuss some of the historical reasons for why productivity, for both the farm and factory sectors, increased faster in the Midwest than in the West.

Farm-Level Productivity

At the farm level (or regional level), we measure productivity as the *ratio* of revenues (price of beets multiplied by quantity of beets) to the economic costs of inputs (cost per unit multiplied by quantity of beets). We will call this measure *total factor productivity* (TFP). The *difference* in revenues and costs we call *economic profits*, and the *difference* in price and costs (both per unit) we call the *markup*.

We use these statistics as follows. Our model below illustrates how, given the cartel rules, divergence in regional input prices and other factors lead to divergence in regional TFPs (as measured earlier). We can then check to see if there was such divergence in the TFP statistics and then use the measures to calculate deadweight losses.

In this section, we briefly present the *historical* reasons for the divergence between regional TFPs. Later we present the statistics. The key factor behind the divergence in farming TFP across regions was that the costs of inputs grew more rapidly in California and Colorado than in the other beet-growing areas. Consider the land input. The opportunity cost of land in California and Colorado grew much faster than in, say, Minnesota and North Dakota. One reason was the growth of urban areas in the former locations.[17] Also, opportunities emerged in the West for crops that were more profitable than beets, such as cotton in California.[18]

Consider another input: water. Irrigated water is used to grow beets in California and Colorado but not the Midwest. In California and Colorado, the costs of irrigated water (per acre foot) increased faster than land costs after World War II.[19]

Factory-Level Productivity

We define factory productivity as the (inverse of) the cost of processing a given tonnage

[17] In California, large amounts of beets were produced in coastal counties, near Los Angeles and other coastal areas with tremendous population growth. Much of the beet industry in Colorado was located on the so-called front range between Denver and Fort Collins, which also experienced tremendous population growth after World War II.

[18] In the 1920s, the opportunity cost of land for beet production in California was roughly twice that in the Midwest (U.S. Tariff Commission, 1928). By the mid-1960s, it was roughly four times as great. The opportunity cost of land for beet production in California was \$59 per acre, while in North Dakota it was \$12 per acre (see Bridgman, Qi, and Schmitz (2015)).

[19] In the mid-1960s, the cost of irrigated water used in beet farming in California was \$31 per acre (see Bridgman, Qi, and Schmitz (2015)). This charge was 2.5 times the land cost in Minnesota and North Dakota (\$12 per acre).

of beets into white sugar (we will also call this TFP). Again, with this measure we can compare factory productivity across regions at a point in time and how the difference in productivity in two regions changes over time. In the post–World War II period, TFP in Midwest factories grew faster than in California and Colorado factories. The major reason was that the technology for storing beets improved faster in the Midwest than in the West, meaning that capital costs (per unit of sugar) fell much quicker.

To understand this, first note that once beets are harvested, they start to lose their sugar content. They need to be quickly processed into sugar (called "slicing the beets") or stored. The storing of beets is economical only in cold climates, where they can be stored outside in beet piles. This process leads to lower capital costs, as we explain.

The number of days over which a factory can (economically) slice beets is referred to as (the length of) its *sugar campaign*. Factories in cold climates have always had longer sugar campaigns than those in warmer climates (because of the possibility of economical storage). Given that factories in the Midwest have longer campaigns, they have lower capital costs (and hence higher TFP). For example, suppose Y tons of beets are to be processed in a season and that the factory campaign is s days. Then the daily capacity required to slice beets is $k = Y/s$.[20] The bigger is s, the smaller is k.

After World War II, the length of sugar campaigns increased faster in the Midwest than in the West. This was because of advances in storage technology after World War II, which benefited Midwest factories but not those in the West. New methods (e.g., types of sprays) for treating beets *before* they were stacked in piles outdoors reduced quality losses. New methods for detecting *hot spots* in beet piles, so the spots could be removed without spreading, were also developed. This meant that TFP, while higher in the Midwest, also grew faster.[21]

[20] If there are Y tons to be sliced, then if they are sliced over 200 days in one state, instead of 100 days in some other state, the factory in the first state can be much smaller than the factory in the second state. In this sense, capital costs are smaller.

[21] Today, factory slicing days exhibit very large variation. In North Dakota and Minnesota, factories typically slice for 250 days (some as many as 275 days) ("Moorhead Factory Specs," American Crystal Sugar Company, http://www.crystalsugar.com/coopprofile/moorhead.aspx). Next would be Idaho at 180 days, followed by Michigan at roughly 165 days. In eastern Montana (Sidney), factories slice for about 135 days ("Facility Information," Sidney Sugars, http://www.sidneysugars.com/profile/facility.asp). In California,

4.2 Production History

Initial cartel rules called for state production levels to roughly increase at the same rate over time. With both farm and factory TFP growing faster in the Midwest than the West, this created pressure to move quotas to the Midwest. It also meant that once the cartel ended, the share of the industry in the Midwest would significantly increase (to the extent that the Midwest was not successful in moving quotas). We discuss both issues here.

Figure 2 presents the *share* of U.S. harvested beet acres by group of states over time. The first vertical line is the year the cartel started; the second is the year it ended. One group of states — Minnesota, North Dakota, Michigan, and Idaho — are the states where beets can be stored economically for long periods after harvesting and whose factories have the greatest number of slicing days (we will often refer to this group as the Midwest, though it includes Idaho). Another group — California and Colorado — are the states where the opportunity cost of land and water grew the fastest (we will often refer to this group as the West). We combine all other beet-producing states in the last group.

During the cartel period, the number of acre quotas increased as the U.S. population grew. One imagines that the demand for quota was larger in the Midwest than in the West. While Colorado and other western state farmers would not always use their allotment, the demand for allotment by midwestern farmers was great. Consider this example. When new quota was given to an area, the vast majority was distributed to incumbent farmers.[22] While new farmers could apply for an allotment, new farmers (in aggregate) received very small amounts. Still, in some areas, they applied. In 1958, for example, 465 farmers had an allotment in the Red River Valley (in Minnesota and North Dakota). In that year, local administrators strongly discouraged new farmers from applying to receive part of the new quota to be distributed in 1959. Still, 294 new farmers applied, while only 5 were given an allotment (see, e.g., Loftsgard and Miller (1961), p. 11).

factories slice for about 110 days.

[22] This was true in all regions except Puerto Rico.

Though the demand for allotments was great in the Midwest, its share of acres increased only modestly. Its share of acres was 28.8 percent and 28.5 percent in the period 1932-33, respectively. For the period 1972-73, the share was 33.5 percent and 36.3 percent. The average share in the two years prior to the cartel's founding, then, was 28.6 percent, and the share in the two years prior to the cartel's demise was 34.9 percent — an increase of 6.3 percentage points. This was a modest increase in share, at least compared with the increase over the next 40 years.

Why didn't the Midwest share of acres increase more? Economic profit was often not a significant factor in the allocation of allotments. Consider the early 1960s, when the cartel expanded capacity. The cartel permitted new factories to be opened in Maine and New York.[23] It is hard to imagine that these locations were among the most profitable areas in which to expand. And, yes, the two factories closed quickly. The Midwest was allowed, in 1972, to open two factories. These factories had large capacities and account for the increased share of harvested acres in the Midwest seen in the early 1970s in (see Figure 2).

When the cartel ended in 1974 and domestic quotas were eliminated, the share of acres by states began to change more rapidly. The share of acres accounted for by the Midwest grew significantly. California and Colorado's share began a significant decline.

We next turn to the *levels* of production by state. In Figures 3A, 3B, and 3C, we present time series for beet production for individual states. We present both the state's acreage allotment and harvested acres. We mention three important facts about farmer allotments. First, in some years the cartel allowed farmers without allotments to grow sugar crops. If the cartel forecast that more sugar was needed to keep the sugar price from rising too fast, as when the Cuba quota was initially eliminated, farmers were not restricted in planting. Regional production was still limited by factory capacity in the region. While farmers (who were not cartel members) were permitted to produce during these periods, this did not

[23] Herder (1964) discusses the negotiations among cartel members regarding where to open factories. The *Federal Register* (27 FR 10745, November 3, 1962) reports that the USDA heard proposals for 13 new beet factories and 7 expansions of existing plants during the period.

entitle them to allotments later. Second, in some states, some farmers stopped using their allotments, since profits plus side payments were negative. Third, in a year with allotments, a state's initial allotment could later be increased if other areas could not fill their allotment because of bad weather or because an area was in decline (see, e.g., Puerto Rico).

In Figure 3A, we present the allotments and acres harvested for Utah (top panel). The acres harvested for Utah (solid line), though volatile, show no trend in the period 1950-74 (though perhaps a collapse was under way before 1974). Note that there were no farmer allotments in the years after the Cuban revolution (which ended in 1959). In years with allotments, Utah was not using all of them. So, for some farmers, the profit plus the side payments were less than zero. After 1974, the industry in Utah closed quickly.

In the bottom panel, we present the allotments and harvested acres for Colorado. Note the upward trend in harvested acres from 1950 to the middle 1960s. The allotment in 1970 was actually (a bit) smaller than that in the middle 1960s. Farmers were not using their allotments, so the cartel reduced state allotments. The industry shrinks quickly after 1974, though a small industry remains (in contrast to Utah).

In Figure 3B, we present the allotments and acres harvested for California (top panel). Harvested acres increase significantly from the 1950s to the middle 1960s. In California, many crops competed with sugar beets, so changes in crop prices could lead to big swings in planted sugar beet acres.[24] Farmers were not using allotments in the middle 1960s. California's allotment in 1970 was smaller than in the middle 1960s. We also see that a state's production could exceed its initial allotment (as in 1970). After 1974, the industry starts to shrink, but at a slower rate than in Utah and Colorado. The rate of decline was not uniform throughout California. The bottom panel presents production for two regions, California coastal counties, where it shrank quickly, and the San Joaquin Valley, where the decline began a decade later.

[24] For example, in the Imperial Valley (a major producing area during the cartel and the only area still producing today), Dean, Johnson, and Carter (1963, p. 7) report that it was only at "extremely low cotton prices, [that] the maximum sugar beet acreage allotment is planted." See also Phelps (1951).

In Figure 3C, we present the allotments and acres harvested for Minnesota (top panel). During the cartel, the economic profit per acre for beets was typically three times greater than for wheat, the closest competitor (see Loftsgard and Miller (1961), pp. 12-13). As a result, profit for harvested beet acres in Minnesota is less volatile than in, say, California.[25] Minnesota's increase in allotments in the 1950s was modest (but not because of lack of demand). Production and allotments significantly increased in the 1960s. In the 30 years after the cartel collapsed, harvested acres grew significantly in Minnesota. Allotments and harvested acres for North Dakota are in the bottom panel. They follow a pattern very similar to that for Minnesota.

When the cartel ended, total U.S. sugar production increased. The major reason for the increase was that quotas on foreign sugar became much more stringent over time.[26] So, even though U.S. sugar production increased, it fell dramatically in the West.

4.3 Digression: Increasing Regional Costs

In Figure 4, we show the acres harvested to beets in 2010. A comparison with Figure 1 illustrates the dramatic geographic shift in the industry. In 1950, the combined harvested acres in California and Colorado were roughly 4 times greater than the combined total in Minnesota and North Dakota. In 2010, the harvested acres in the latter states were roughly 12 times larger than the former. This comparison leads to the question: Why isn't all beet sugar production in North Dakota and Minnesota? Stated differently: What (per unit) input prices are increasing in Minnesota and North Dakota so that they do not produce all U.S. beet sugar? While the answer to this question is not important for the deadweight loss calculations that follow, for completeness we briefly discuss the issue.

[25] Interestingly, though, the drop in acres in Minnesota and North Dakota in the early 1970s was due to large increases in wheat prices (stemming from the wheat crisis in the Soviet Union and developing countries; see Runge and Halbach (1990)).

[26] In 1974, the receipt of sugar from foreign sources totaled 5.9 million tons (raw value) (see U.S. Department of Agriculture, 1991, p. 210). In 1976, foreign receipts fell to 3.1 million tons. In the period 1987-89, they were 1.6, 1.4, and 1.9 million tons, respectively. Soon thereafter, foreign receipts hit 1.25 million tons, the minimum required under world trade rules. (The quotas were binding in all years.)

Land prices are an obvious candidate. But in this industry, farm labor wages is another input price that increases with scale. Historically, the cost of farm labor was a very large share of total costs in sugar beet and cane farming (in the 1930s, it was 50 percent and more of total costs). A big part of the labor cost was incurred in harvesting, including cutting the beets, loading them onto trucks, and transporting them to factories or storage facilities.[27] Hence, the sugar beet industry in a region faced an increasing per unit farm labor wage if production grew too large.

After World War II, major advances in mechanized harvesting greatly reduced labor used in cutting beets. But large amounts of labor are still needed to transport beets to storage facilities. Harvesting costs are still significant. Today, in Minnesota and North Dakota, the harvest period is very short, ideally completed in 10 to 20 days. The large number of acres harvested in Minnesota and North Dakota puts significant upward pressure on the hourly labor rate for truckers (and their equipment) during harvesting (see, e.g., Lee (2013)).

We now turn to quantifying the deadweight losses (DWLs) from cartel rules. Again, we study the DWL from the second type of loss: that inputs used to produce sugar in some states had a greater value in other uses in that state. By looking at the second loss alone, we understate DWLs. But the main goal of the paper is to show that deadweight losses can be large, since the *consensus* is that they are small. The losses we calculate are large.

By looking at the second loss, we keep the analysis simple. In calculating our lower bound DWL, we can use a very stark model. For example, our lower bound does not depend on the distribution of farmer skills in a region (or the distribution of land quality). So, we will assume that farmers have identical skills (and that land is of the same quality). These assumptions, and others that follow, do not affect our lower bound calculation.

[27] Transportation was a very large cost, since beets and cane are roughly 15 percent sugar, so much waste is transported.

5 Economic Environment

Consider a country, say, the United States, composed of sugar-producing regions and non-sugar-producing regions. A sugar-producing region is one that has endowments of land, weather, and other factors (discussed later) that make it possible to produce sugar. Endowments, of course, are limited, so production may occur in more than one region. Imagine also that a region outside the country produces large amounts of sugar, such as the Caribbean in the U.S. case.

Let r denote the sugar-producing regions, $r \in \{1, 2, ..., R\}$. In each region, the sugar-producing industry (if it operates) consists of two sectors. One sector, farming, produces intermediate goods, the sugar beets or sugarcane. Factories, the second sector, process the intermediates into final goods, either white sugar or raw sugar. The intermediates are processed in the *same* region as where they are produced because of the prohibitively high transportation costs on intermediates.

In the farm sector, *individual* farm size is limited by decreasing returns to scale (due to farmers' limited span of control). *Total* farm production in a region is limited by the region's endowments. Farmland is one such endowment. But another is the availability of a large supply of labor for short periods, such as harvesting. In any case, our assumption is that some inputs, local inputs, have increasing unit prices.

Factories in the region (typically only a few) face fixed costs. Otherwise, they produce under constant returns to scale. While factories have an incentive to expand, increasing farm costs limit the industry's size in the region.

The demand for sugar comes from sugar-producing and non-sugar-producing regions. We assume that the costs of transporting the final good are zero (in the country and around the world). We discuss this assumption later. Since there are no internal tariffs, there is a national market for sugar, with the price denoted by p_x. Let $p_{x,W}$ denote the world price of white sugar. We assume that in autarky, $p_x > p_{x,W}$. We also assume that if the United States went from autarky to free trade, it would have a small impact on $p_{x,W}$.

5.1 Definitions

We call the model industry the beet industry, though we use it to study both the cane and beet industries. Initially, we assume a single time period.

Let y denote tons of sugar beets. Of course, sugar is contained in the beets. Let $\widetilde{x}$ denote tons of this "sugar in the beets." This potential white sugar must be extracted from the beets in a factory. Let x denote (tons) of extracted white sugar. The ratio $\widetilde{x}/y$ is the percentage of the beet that consists of sugar. This is one measure of beet quality, often called *sugar content*. We label this ratio as $\gamma_{qual} = \widetilde{x}/y$. The ratio $x/\widetilde{x}$ is the percentage of the sugar in the beet that is extracted as white sugar. This is often called the *extraction rate*. We label this ratio as $\gamma_{extr} = x/\widetilde{x}$.

We assume beet quality can differ across regions but is fixed over time in a region. We make assumptions about the factory technology so that, while the extraction rate can vary by region, it also is fixed over time in a region.[28]

5.2 Number of Farmers

Each region has a large number of potential entrants to sugar beet farming. The potential entrants are identical: they have the same skill in farming and the same outside opportunity, z_r. Let B_r be the number of individuals that decide to farm.

5.3 Farm Technology

For simplicity, we use two inputs, land and farm labor, in the farming technology. If a person enters farming, the farmer produces according to

$$y_r = \theta_r \cdot f_r(l, n),$$

[28] We have examined the ratios γ_{qual} and γ_{extr} in Bridgman, Qi, and Schmitz (2009).

where y is tons of sugar beets, l is land input and n is farm labor (i.e., hired farmworkers).[29] Inputs are chosen at the beginning of the season. Production also depends on a technology shock θ, capturing the randomness in weather (sun, rain, and so on) that may influence output. The function $f_r(\cdot)$ is subject to decreasing returns in the spirit of the Lucas (1978) span of control model. The production of sugar in the beets is $\widetilde{x} = \gamma_{qual} \cdot y$.[30]

5.4 Factory Technology

Denote the factory production function by $x = F(\widetilde{x}, e, k, ...)$. White sugar produced depends on capital, k, and two materials: sugar in the crop $\widetilde{x}$ and energy e. The amount of white sugar extracted cannot be larger than the sugar in the beets, that is, $x = F(\widetilde{x}, e, k, ...) < \widetilde{x}$. For simplicity, we use

$$x = \gamma_{extr} \cdot \min(\widetilde{x}, A_e \cdot e, A_k \cdot k). \tag{1}$$

If $A_e \cdot e \geq \widetilde{x}$ and $A_k \cdot k \geq \widetilde{x}$, then $x = \gamma_{extr} \cdot \widetilde{x}$. We will denote fixed costs by Λ.[31]

5.5 Prices

Let p_x denote the price of white sugar (in dollars per ton) at the factory door. During the tariff period, the price p_x is determined by the world price of sugar (typically the price of white sugar at Caribbean ports), $p_{x,W}$, and the tariff on foreign sugar. During the cartel, the price p_x is determined by quotas.

Let p_{yr} denote the price of sugar beets (in dollars per ton), the payment farmers receive from the factories. The payment was set according to contracts negotiated between farmers and factories (before the growing season began). Since farmers typically sold beets to only one factory, potentially giving factory owners significant bargaining power, farmers formed associations that bargained for the group of farmers. Typically the contracts specified that

[29] Later, when we examine the data, we will introduce the entire range of inputs used to produce sugar.

[30] Notice that the land input does not vary in quality.

[31] In our model, we assume that beets are produced and processed in the same period of time. For simplicity, we do not consider that in some regions, beets can be stored and processed over time.

the price p_{yr} was a function of the season's sugar price (p_x) and the percentage of sugar in the farmer's beets (γ_{qual}), say, $p_{yr} = \widetilde{p}_{yr}(p_x, \gamma_{qual})$.

Let p_{lr} and p_{nr} denote the rental rate for land and the wage rate for farm labor. As we mentioned, we assume that the price of land is fixed. However, we assume that the wage increases as total farm labor employment increases. Letting N denote farm employment, we assume that the industry wage (the labor supply curve) is increasing in N, that is,

$$p_{nr} = g_r(N),$$

where $g_r(\cdot)$ is increasing in N.[32]

6 Before the Cartel: Tariff Case

We first consider the industry before the cartel. The domestic industry was competitive, with free entry into sugar manufacturing. We will define and calculate an equilibrium in this tariff case. But roughly, the price p_x is given by the world price and tariff. The price of a ton of beets is then $p_{yr} = \widetilde{p}_{yr}(p_x, \gamma_{qual})$. This determines individual farmer scale, y_r, for a given p_{nr}. As farmers enter, this drives up the farm labor wage, a process that continues until the marginal farmer is indifferent between farming and the outside option. This determines the farmers that enter a region, B_r, along with regional production, Y_r, $Y_r = B_r \cdot y_r$. We then ask whether the factory earns enough to cover fixed costs at this scale, Y_r.

[32] An alternative way to introduce increasing costs would assume that potential farmers have different outside opportunities. In particular, we would have $z_{r,i}$ be the outside opportunity of potential entrant i and have a distribution over $z_{r,i}$.

6.1 Farmer Problem

Economic costs are factor payments plus the opportunity cost of farmer time. If we let c_r denote the economic costs per ton of sugar beets, we have that total economic costs are

$$c_r \cdot y = [p_{lr} \cdot l + p_{nr} \cdot n] + z_r.$$

Farmer profit, π_r, is revenues less economic costs,

$$\pi_r = p_{yr} \cdot y - c_r \cdot y. \tag{2}$$

Profits are a random variable since, among other things, production depends on the technology shock θ. For simplicity, though, we will proceed as if there is no uncertainty.

We have the first order condition for n,

$$p_{yr} \cdot \frac{\partial y_r(\cdot)}{\partial n_r} = p_{nr}, \tag{3}$$

and the first order condition for l,

$$p_{yr} \cdot \frac{\partial y_r(\cdot)}{\partial l_r} = p_{lr}. \tag{4}$$

6.2 Definition of (Farmer) Equilibrium

The price p_x is given. A farmer equilibrium is a list of four numbers, $(l_r^{tar}, n_r^{tar}, B_r^{tar}, p_{nr}^{tar})$, where "$tar$" refers to the tariff case, such that:

1. Conditional on entering, farmers maximize profits π_r. That is, given p_{nr}^{tar}, the choices l_r^{tar} and n_r^{tar} solve the system of two equations (3) and (4) in two unknowns l_r and n_r.

2. The marginal (last) entrant to farming is indifferent between farming and the outside option,

$$\pi_r^{tar} = 0, \tag{5}$$

where π_r^{tar} is equation (2) evaluated at p_{nr}^{tar}, l_r^{tar}, and n_r^{tar}.

3. The price of farm labor satisfies

$$p_{nr}^{tar} = g_r((N^d)^{tar}), \tag{6}$$

where $(N^d)^{tar} = n_r^{tar} \cdot B_r^{tar}$ is the demand for labor.

6.3 Discussion

We make a few remarks.

1. We have four equations in four unknowns. Under certain assumptions, the equilibrium will entail entry, that is, $B_r^{tar} > 0$. Also, there is a limit to entry because the price of farm labor increases with regional employment.

2. From equation (5), the economic profit of the marginal farmer in a region is zero. Average farmer profit is also zero, since we assume that farmers are identical. Regional TFPs are the same and equal one. Regional TFPs would differ if, for example, there was a distribution over farmers' outside opportunities and these differed across regions. Let the opportunity cost of farmer i in region r be z_{ir}. Entry still occurs until the last farmer is indifferent between farming and the outside option. The last farmer has the highest z_{ir} and the smallest TFP (of one). Farmers with a smaller z_{ir} than the last farmer have TFPs exceeding one.[33]

Now suppose that California has lots of farmers with very low opportunity costs relative to that of the marginal farmer. Then average profits would be greater than zero, with TFP exceeding one. Suppose in Minnesota all the farmers had the same opportunity costs of time. Then TFP would equal one.

3. We now add *time* in the simplest way. We assume a dynamic model that is a sequence of one-period models, the only changes over time being in the exogenous prices (such as

[33] To see this, note that all farmers choose the same inputs. Hence, all farmers have the same revenues. They have the same costs (not including the opportunity cost of time). Farmers with lower time costs thus have lower total costs and hence higher TFPs.

p_x and p_{lr}). We can use the previous equilibrium to generate time series on the model's endogenous variables, such as the number of farmers in a region at time t, $B_{r,t}^{tar}$.

6.4 Factory Problem

We assume there is one factory in the area. The factory purchases two materials: sugar in the crop and energy.[34] Profits, denoted Ψ_r, are $\Psi_r = p_x \cdot X_r - p_e \cdot E_r - p_{yr} \cdot Y_r - \Lambda_r$, where $p_{yr} \cdot Y_r$ and $p_e \cdot E_r$ are payments for beets and energy. Recall the production function is $x = \gamma_{extr} \cdot \min(\widetilde{x}, A_e \cdot e)$. We can write profit as a function of Y_r. Assuming $A_e \cdot E = \widetilde{X}$, and using $\widetilde{X} = \gamma_{qual} \cdot Y$, we have $X = \gamma_{extr} \cdot \gamma_{qual} \cdot Y$, and

$$\Psi_r = \mu \cdot Y_r - \Lambda_r, \tag{7}$$

where $\mu = p_x \cdot \gamma_{white} - \widetilde{p}_{yr}(p_x, \gamma_{qual}) - p_e \cdot (\gamma_{qual}/A_e)$ where $\gamma_{white} = \gamma_{extr} \cdot \gamma_{qual}$. Assume $\mu > 0$. Then if regional production, Y_r^{tar}, is big enough so that $\Psi_r^{tar} \geq 0$, we have an *equilibrium with production.*

7 New Deal Cartel

We model the cartel's formation as follows. While the industry was operating under a tariff, the government unexpectedly permitted the industry to form a cartel (at, say, $\widetilde{t}$). Factories were given sales quotas, and farmers (who had grown sugar crops before the cartel) were given acre quotas. In terms of notation, the farmers given cartel membership were the $B_{r,1933}^{tar}$ farmers in 1933. A farmer's quota, $\widehat{l}_{r,1934}$, depended on his previous harvested acres $l_{r,1933}^{tar}$. In terms of skill at farming, recall that all potential farmers have the same skill. Hence, as time marches on from $\widetilde{t}$, both cartel members and nonmembers may farm. In the next subsection, we provide more details on some of the cartel's rules.

[34] For simplicity, we drop capital.

7.1 Cartel Rules on Price, Quota Rental, and Side Payments

As for sugar prices, the cartel agreed that consumers should receive a fair sugar price, which was taken to mean that the sugar price should increase at roughly the rate of inflation. It imposed quotas on imports of foreign sugar and quotas on domestic firms' sales to deliver this price. Next we give details on other important rules governing cartel operations.

Rule 1 (quota rental). A member's acre quota was typically tied to the individual, not a piece of land.[35] The acre quota could be rented but not sold.[36] Rentals were to be within the county, though over time some quota drifted over county lines.

Rule 2 (side payment). Quota owners received a side payment roughly proportional to yearly production. Given production of y tons of beets, the side payment was roughly

$$s = \widehat{\sigma} \cdot \gamma_{white,t} \cdot y,$$

where s denotes side payment and $\gamma_{white,t} = \gamma_{extr,t} \cdot \gamma_{qual,t}$, where $\gamma_{extr,t}$ is the average factory extraction rate in the region (the average over the last few years) and $\gamma_{qual,t}$ is the percentage of sugar in the farmer's beets.[37] The parameter $\widehat{\sigma}$ is the side payment rate, the payment per ton of white sugar produced by the farmer.[38]

The rate $\widehat{\sigma}$ was typically fixed for a number of years. In the 1960s, it equaled \$16 per ton of white sugar. As an example, if $\gamma_{qual} = 0.15$ and $\gamma_{extr} = 0.95$, a ton of sugar beets yields 0.1425 tons of white sugar, giving a side payment of \$2.28 per ton. The *actual* average side payment in, say, 1960, was \$2.32 (U.S. Department of Agriculture, 1975a, p. 16). The U.S. average price paid by factories for a ton of sugar beets (p_{yr}) in 1960 was \$11.60 (U.S. Department of Agriculture, 1975a, p. 16). So, on average, farmers received $2.32 + 11.60 = 13.92$ for their beets. The side payment was 20 percent of the factory payment (2.32/11.60).

Rule 3 (taxes). Factories that produce white sugar, that is, the beet and sugar refining

[35] Hence, quotas were not capitalized into land values.
[36] The quota could be transferred within a family.
[37] We say "roughly," since the side payment rate would decrease if farm production became very large.
[38] The cartel used this language — white sugar "produced" by the farmer — and aimed to estimate it.

factories, paid a tax τ on each ton of white sugar produced. In the 1960s, the tax equaled \$10 a ton.

Consider the magnitudes of taxes and side payments (in, say, 1959). Taxes were levied on white sugar produced by the beet industry (say, X_{beets}) and the sugar refiners (say, X_{ref}), where $X_{beets} = 2.095$ million tons and $X_{ref} = 6.544$ million tons (U.S. Department of Agriculture, 1975b, Table 3, p. 7).[39] Taxes were levied, then, on a base of $X_{beets} + X_{ref} = 8.639$ million tons. Taxes collected in 1959 were \$86.378 million (U.S. Department of Agriculture, 1975b, Table 69, p. 116).

Side payments were paid to farmers in the beet industry and to farmers in *some* of the industries that supplied raw sugar to the refiners. Let X_E denote sugar eligible for side payments and X_M the sugar not eligible (roughly foreign country imports), so $X_{ref} = X_E + X_M$. The quantity X_E consisted of the production of mainland cane (Louisiana plus Florida) (0.540 million tons), Hawaii (0.913), and Puerto Rico (0.896), so $X_E = 2.349$. The quantity X_M consisted of the production of Cuba (3.006), Philippines (0.916), and other nations (0.261), so $X_M = 4.183$. Hence, side payments were paid on the base of $X_{beets} + X_E = 4.444$ million tons. Side payments in 1959 were \$70.464 million (U.S. Department of Agriculture, 1975b, Table 68, p. 115).

Taxes collected, then, exceeded side payments, roughly \$86 million compared with \$70 million. The U.S. Treasury collected the taxes, paid the side payments, and kept the balance. Since the USDA and other government agencies incurred considerable expenses running day-to-day cartel operations, cartel members agreed that taxes would exceed side payments, in part, to fund these costs of the USDA.

Rule 4 (government monitoring of factory farmer contracts). As we mentioned, farmers were paid by factories on the basis of contracts negotiated before the season, which we denoted $p_{yr} = \widetilde{p}_{yr}(p_x, \gamma_{qual})$. Factories had an incentive to alter contract terms when farmers began receiving side payments. To avoid this, the cartel agreement contained provisions for

[39] Production in this table is in raw value. We multiply by 0.935 to convert to white sugar.

government monitoring of contract negotiations and for it to set "fair and reasonable" prices for beets and cane.[40]

We now move to describe maximization problems of the cartel members and nonmembers.

7.2 Cartel Member Problem

We break the decision problem of a cartel member into two steps. First, he rents his acre quotas (in a competitive market) at rate q_r per acre. Then he decides to farm or not.

7.3 Market for Acre Quotas

In the model, we assume there is a competitive rental market in acre quotas. If a person rents a quota, that person has the right to grow an acre of sugar crops. As a convention, we assume the renter receives the side payment. The side payment will be reflected in the equilibrium quota rental rate.

7.4 Farmer Problem

Consider the problem of an entrant to farming during the cartel (again, this could be a cartel member or nonmember). To farm an acre, the person must rent an acre of land, at price p_{lr}, and also rent quota for an acre, at price q_r. The person renting the quota receives the side payment, which equals $\sigma \cdot y$, where $\sigma = \widehat{\sigma} \cdot \gamma_{white,t}$. The farmer maximizes *payoff*, v_r, which is *profit*, π_r, plus the side payment less quota rental,

$$v_r = p_{yr} \cdot y - [p_{lr} \cdot l + p_{nr} \cdot n] - z_r + [\sigma \cdot y - q_r \cdot l]. \tag{8}$$

Note that the quota rental rate is indexed by region, since quota cannot be rented outside the region. Profits are a random variable since, among other things, production depends

[40] See, for example, U.S. Department of Agriculture (1965, p. 10), which announces the fair and reasonable prices for the year.

on the technology shock θ. As in the tariff case, though, we will proceed as if there is no uncertainty.

The farmer takes p_x as given, and hence $p_{yr} = \widetilde{p}_{yr}(p_x, \gamma_{qual})$ as well. We have the first order condition for n,

$$(p_{yr} + \sigma) \cdot \frac{\partial y_r(\cdot)}{\partial n_r} = p_{nr}. \tag{9}$$

We have the first order condition for l,

$$(p_{yr} + \sigma) \cdot \frac{\partial y_r(\cdot)}{\partial l_r} = p_{lr} + q_r. \tag{10}$$

7.5 Definition of Farmer (and Quota) Equilibrium

A farmer equilibrium is a list of five numbers, $(l_r^{prop}, n_r^{prop}, B_r^{prop}, p_{nr}^{prop}, q_r^{prop})$, where "$prop$" refers to proportional side payments (i.e., the New Deal cartel), such that:

1. Conditional on entering, farmers maximize payoffs v_r. That is, given p_{nr}^{prop} and q_r^{prop}, the choices l_r^{prop} and n_r^{prop} solve the two equations (9) and (10) in unknowns l_r and n_r.

2. The marginal (last) entrant to farming is indifferent because farming and the outside option,

$$v_r^{prop} = 0, \tag{11}$$

where v_r^{prop} is equation (8) evaluated at l_r^{prop}, n_r^{prop}, p_{nr}^{prop}, and q_r^{prop}.

3. The price of farm labor satisfies

$$p_{nr}^{prop} = g_r((N^d)^{prop}), \tag{12}$$

where $(N^d)^{prop} = n_r^{prop} \cdot B_r^{prop}$ is the demand for labor.

4. Demand for quota is less than or equal to supply,

$$l_r^{prop} \cdot B_r^{prop} \leq \widehat{L}_r, \tag{13}$$

where $\widehat{L}_r$ is the regional quota set by the cartel.

7.6 Factory Problem

The expression for factory *profit* is in (7). Factory *payoff* is profit less taxes (to fund side payments), where taxes are $T_r = \tau \cdot X = \tau \cdot \gamma_{white} \cdot Y$. Factory *payoff* is then

$$\Psi_r - T_r = (\mu - \tau \cdot \ \gamma_{white}) \cdot Y_r - \Lambda_r.$$

Assume $(\mu - \tau \cdot \gamma_{white}) > 0$. Then if regional production, Y_r^{prop}, is big enough so that $\Psi_r^{prop} - T_r^{prop} \geq 0$, we have an equilibrium-with-production.

7.7 Discussion

Again, we have a few remarks.

1. We have five equations in five unknowns. Let us look at the case in which the quota has value, that is, $q_r^{prop} > 0$. This means equation (13) holds with equality.

2. Using equation (11), we can solve for the quota price as

$$q_r^{prop} = \frac{\pi_r^{prop} + \sigma \cdot y_r^{prop}}{l_r^{prop}}. \tag{14}$$

From this equation, we see that the quota may have value ($q_r^{prop} > 0$) even if economic profits are negative ($\pi_r^{prop} < 0$). Since the side payment is tied to producing output, farmers may operate even if profits are negative.

3. Again, the price p_x is determined by the cartel. We can roughly describe the process using our notation. The cartel sets a target price and quotas to hit that price. In particular, the cartel announces p_x and $\widehat{\sigma}$. It also announces regional quotas, $\{\widehat{L}_1, \widehat{L}_2, ..., \widehat{L}_R\}$. A farmer equilibrium in each region gives $\widehat{X}_r$, which yields $\widehat{X}_{beets} = \sum \widehat{X}_r$. In a similar way, we arrive at $\widehat{X}_E$. Foreign country imports, $\widehat{X}_M$, are announced. This yields total sugar supply,

$\widehat{X} = \widehat{X}_E + \widehat{X}_M + \widehat{X}_{beets}$. Given the demand curve for sugar, this yields a price, $\widehat{p}_x$. Through experience, the cartel is able to approximate the target price, so that $\widehat{p}_x \approx p_x$.

4. During the tariff period, farmers entered until $\pi_r^{tar} = 0$. In the cartel, farmers enter until $v_r^{prop} = 0$. Using equation (11), we have

$$\pi_r^{prop} = [q_r^{prop} \cdot l_r^{prop} - \sigma \cdot y_r^{prop}],$$

where $y_r^{prop} = f_r(l_r^{prop}, n_r^{prop})$. Hence, the economic profit of the marginal (and average) farmer, π_r^{prop}, is no longer zero and, at the cartel's start, was, with little doubt, positive. So, regional TFPs exceeded one. TFPs were not necessarily the same across regions but were likely not too different at the start of the cartel.

5. We now illustrate how the cartel's rules led to DWLs and divergence in regional TFPs. Again, we take the total quota, $\widehat{X}$, as given. And, again, we are showing how alternative rules can lead to greater cartel profits. We are not finding the rules that maximize profits.

We explore how the equilibrium average profit in a region varies with model parameters. From the solution to the previous (cartel) farmer equilibrium, we write profits as

$$\pi_r^{prop} = \pi_r^{prop}(p_x, p_l, \widehat{L}_r, \widehat{\sigma}). \tag{15}$$

We first ask how $\pi_r^{prop}(p_x, p_l, \widehat{L}_r, \widehat{\sigma})$ depends on $\widehat{L}_r$, plotting the relationship in Diagram 1, top panel. In this panel, we fix p_x, p_l, and $\widehat{\sigma}$. To maintain the assumption that price p_x is fixed as we vary $\widehat{L}_r$ (and hence $\widehat{X}_r$ and $\widehat{X}$), we could assume the region is very small. However, we will keep the price fixed by changing $\widehat{X}_M$ so as to keep $\widehat{X}$ fixed. We use this approach later in calculating lower bound DWLs. Under this interpretation, the quantity $\widehat{X}_M$ differs at each point in Diagram 1.

Imagine we are plotting the relationship for 1934, the first year of the cartel. We make assumptions such that the circled point in Diagram 1 corresponds to profits in the tariff equilibrium of 1933. First, let us choose model parameters in 1934 to equal model parameters in 1933. In particular, let $p_{lr,1934} = p_{lr,1933}$. Let $\widehat{\sigma} = 0$. Let the acre quotas in 1934 (in region r) equal the acres harvested (in region r) in 1933 (e.g., $\widehat{L}_r = L^{tar}_{r,33}$). Assume the demand curve for sugar does not change between 1933 and 1934. Let the cartel announce that price $p_{x,1934}$ is last year's price, $p_{x,1934} = p_{x,1933}$. We have constructed (in 1934) the tariff equilibrium from 1933, so, $\pi^{prop}_r(p_x, p_l, \widehat{L}_r, \widehat{\sigma}) = 0$. Again, this corresponds to the circled point in Diagram 1 (where the average profit curve hits zero at $\widehat{L}_r = L^{tar}_{r,33}$).

Now, we reduce $\widehat{L}_r$. We assume that there is no change in the sugar price $p_{x,1934}$ as we reduce acre quotas (we will think of increasing $\widehat{X}_M$ to keep the price $p_{x,1934}$ unchanged).[41] When reducing $\widehat{L}_r$, regional output (and employment) falls, the wage rate falls, and average economic profit $\pi^{prop}_r(.)$ increases.

Turning to the bottom panel, let us start with the same parameters as in the top panel. We reproduce the profit function from the top panel as the solid curve (where, again, $\widehat{\sigma} = 0$). Now we introduce a side payment, so that $\widehat{\sigma} > 0$. Farmers expand output (and employment) to receive the side payment, increasing wages and reducing profits. The new profit (associated with $\widehat{L}_r = L^{tar}_{r,33}$) is at the circled point in the bottom panel, where $\pi^{prop}_r(\widehat{\sigma} > 0) < 0$. So that this year's price equals last year's price, $p_{x,1934} = p_{x,1933}$, we reduce $\widehat{X}_M$. The new profit curve is the dashed curve.

Suppose the acre quota is set at $\widehat{L}_r = \widetilde{L}_r$. *Regional* profits are negative (since average profits, at the intersection of the vertical line at $\widehat{L}_r = \widetilde{L}_r$ with the dashed profit curve, are negative). Average profits can be increased by using lump-sum side payments (corresponding to the profit curve with $\widehat{\sigma} = 0$). Also, we can increase regional profits by simply closing the region, so that profits are zero. This discussion illustrates how DWLs emerge from using proportional side payments.

In Diagram 2, we present an illustration of events in California (top panel), where land became very expensive, and Minnesota (bottom panel). In the top panel, we reproduce the dashed profit curve from the bottom panel of Diagram 1, letting it be the dashed curve here

[41] We want to keep the price unchanged so that purchasers of sugar are just as well off.

as well. We increase the price of land in California, keeping other prices fixed, from p_l to p_l'.[42] The profit curve shifts down, to the dashed-dotted line. While profit had been positive at the quota $\widehat{L}_r = \widetilde{L}_r$, economic profit becomes negative. In the bottom panel, we decrease the price of land. Economic profit had been positive at the quota $\widehat{L}_r = \widetilde{L}_r$, and now it increases. This illustrates how cartel rules led to diverging TFP between regions. It also illustrates another DWL: the quota cannot move from regions where productivity is falling to regions where it is growing.

6. For members holding acre quotas, the cartel payoff is the rental payments,

$$q_r^{prop} \cdot \widehat{L}_r = \frac{\pi_r^{prop} + \sigma \cdot y_r^{prop}}{l_r^{prop}} \cdot \widehat{L}_r = (\frac{\pi_r^{prop}}{l_r^{prop}}) \cdot \widehat{L}_r + (\frac{\sigma \cdot y_r^{prop}}{l_r^{prop}}) \cdot \widehat{L}_r$$

$$= \Pi_r^{prop} + S_r^{prop},$$

where Π_r^{prop} and S_r^{prop} are total regional economic farm profits and side payments. The cartel payoff to factory owners is, again, $\Psi_r^{prop} - T_r^{prop}$. We denote total beet industry cartel payoff as (where we sum over regions)

$$[\Pi_{beets}^{prop} + \Psi_{beets}^{prop}] + [S_{beets}^{prop} - T_{beets}^{prop}]. \tag{16}$$

The net side payment, $[S_{beets}^{prop} - T_{beets}^{prop}]$, is large. In 1964, for example, it was roughly \$30 million, \$53.9 million in side payments less \$24.8 million in taxes.

8 Economic Costs of Cartel: Beet Industry

We begin by developing a formula for the deadweight loss suffered from using proportional side payments rather than lump-sum payments (Section 8.1). We then introduce the data (Section 8.2) and calculate losses (Section 8.3).

[42] One can think of the experiment as increasing the price of sugar and the price of land, but increasing the land price at a faster rate.

8.1 Profit Losses from Proportional Side Payments

We start with a few assumptions. In our calculations, we keep the sugar price p_x fixed. Hence, purchasers of sugar are just as well off. We also give the beet industry the same net side payment, $(S^{prop}_{beets} - T^{prop}_{beets})$. Hence, we only need to find a production allocation with greater profits than $\Pi^{prop}_{beets} + \Psi^{prop}_{beets}$. We discuss these assumptions later.

One allocation is that associated with using lump-sum side payments. The equilibrium could be found by solving the cartel farmer equilibrium using $\widehat{\sigma} = 0$ in equation (8). Some areas would cut back production, some might even close. Wages would fall in the regions scaling back production. The DWL from using proportional payments and not lump sum, denoted $DWL^{\sim lump}$, is

$$DWL^{\sim lump} = \Pi^{lump}_{beets} - \Pi^{prop}_{beets} = \sum_r [\Pi^{lump}_r - \Pi^{prop}_r], \tag{17}$$

where Π^{lump}_r is regional profit with lump-sum side payments.

We calculate the DWL for another allocation, which we call the quasi-lump-sum allocation. If a region had a negative economic profit during the cartel, that is, $\Pi^{prop}_r < 0$, we close the region (i.e., give it a zero quota, $\widehat{L}^{qlum}_r = 0$). If the region had a positive economic profit, we give that region the same quota (i.e., $\widehat{L}^{qlum}_r = \widehat{L}_r$). Hence, the profit for the latter regions is the same as in the New Deal, with average profit given in (15). We can write quasi-lump-sum profits as

$$\Pi^{qlum}_{beets} = \sum_{\pi^{prop}_r > 0} \Pi^{prop}_r, \tag{18}$$

where the sum is over areas with positive profits.[43]

The DWL from using proportional payments and not the quasi-lump-sum allocation is

$$DWL^{\sim qlum} = \Pi^{qlum}_{beets} - \Pi^{prop}_{beets} = - \sum_{\pi^{prop}_r < 0} \Pi^{prop}_r. \tag{19}$$

[43] In the regions that remain open, side payments are still based on production. We hope our term "quasi-lump-sum profits" does not lead to confusion.

8.2 Costs and Returns Studies

Statistical programs (called costs and returns studies) to measure the costs, revenues, and profits of the sugar beet and sugarcane industry date back to the early 1920s. Both the federal and U.S. state governments have conducted such programs.[44] For purposes of discussing the data, we will add farmers' material costs, $p_{mr} \cdot m$, and capital costs, $p_{kr} \cdot k$, and write farmers' payoffs as

$$v_r = p_{yr} \cdot y - [p_{lr} \cdot l + p_{nr} \cdot n + p_{mr} \cdot m + p_{kr} \cdot k] - z_r + [\sigma \cdot y - q_r \cdot l]. \tag{20}$$

To make our calculations of DWLs, we need the economic profits of farmers, that is,

$$\pi_r = p_{yr} \cdot y - [p_{lr} \cdot l + p_{nr} \cdot n + p_{mr} \cdot m + p_{kr} \cdot k] - z_r. \tag{21}$$

As we said, the programs were designed to calculate the *economic* costs of producing sugar crops. So, we observe average profits, π_r, and all its components (e.g., $p_{nr} \cdot n$) and sub-components (e.g., p_{nr} and n). Regarding the price of land, the studies used the opportunity costs of land, p_{lr}.[45] They also deducted the opportunity cost of farmer time.

One measurement issue with sugar beets is that the crop is rotated with other crops. Sugar beets make up only a small share (at most one-third) of a farm's acres. Some costs could be directly attributed to the beet operation, such as materials (fertilizer, seed, fuel, and so on). But other costs, such as capital costs, had to be apportioned between crops. The programs typically involved detailed calculations of capital use by crop and then apportioned capital costs based on use.

We first present some statistics for the pre-cartel period. In Table 1, columns 1-3, we present data for the 1921-23 period (U.S. Tariff Commission, 1928). In column 1, we present average revenue per acre by state (average price per ton multiplied by average yield per

[44] Again, we discuss these programs in detail in a separate appendix (Bridgman, Qi, and Schmitz (2015)).
[45] So, for example, the cost of renting quotas was typically not included in costs.

acre).[46] Column 2 presents average cost per acre (average cost per ton multiplied by average yield per acre). Column 3 presents TFP, or column 1 divided by column 2. No data are available for Minnesota and North Dakota in 1921-23 (because they were small producers and hence not studied).

In column 3, TFP levels in many states are close to 1. This means that average economic profits were close to zero. Note that TFP in Michigan is less than 1, equaling 0.90. Earlier we emphasized the advantages of producing beet sugar in the Midwest relative to the West. In many areas of California and Colorado where beets were produced, rain is scarce, and farmers primarily used purchased irrigated water, an added cost. But while farmers in the Midwest typically had plentiful rain (and no access to irrigated water), rain is unpredictable. If it rains close to harvest, the beets take up water but do not have time to produce sugar. Hence, the sugar content of the beets decreases, which increases costs at both the farm (harvesting) and factory level. The period 1921–23 was a bad one for Michigan's beet sugar producers, explaining its low TFP.[47]

In Table 1, columns 4-6, we present data from the cartel period. Most studies during the cartel period were U.S. state studies, done only periodically. We focus on the 1964-66 period, since most beet-producing states had a study in this period. Minnesota and North Dakota have the highest TFP, while California and Colorado have the smallest. TFP varies more in 1964-66 than in 1921-23. In 1921-23, five of nine states are in the interval [0.95,1.05]. In 1964-66, one of ten states are in the interval [0.95,1.05].[48]

In Table 2, we give more detailed information on prices, costs, markups, and so on. For each state, we present the 1964-66 (weighted) average for price per ton (p), cost per ton

[46] We present time-series averages of (average) revenue per acre, since farming conditions may vary over time.

[47] For the four-year period 1916–20, the average sugar content of Michigan beets was 15.92 percent. In 1921, the average was 13.28 percent (in 1922 and 1923, the averages were 14.38 and 15.29 percent) (U.S. Bureau of Foreign and Domestic Commerce, 1923). For each state listed in the abstract that was outside the Midwest, the sugar content of beets in 1921 was higher than the 1916–20 average. Michigan's low TFP was the result of poor weather in the Midwest.

[48] Later we discuss what our model predicts about TFP dispersion and other features of the productivity distribution.

(c), markup ($p - c$), TFP (p/c), side payment (s), and payoff ($p + s - c$).[49] The range in prices per ton is roughly 13 percent, from a low of Michigan (11.46) to a high of Idaho and Montana (12.91). The difference in prices is primarily driven by differences in the sugar content of beets across areas. The range in costs per ton is much larger, roughly 63 percent, from Minnesota (8.97) to Colorado (14.60). The difference in costs is driven by a number of factors. We have mentioned differences in the opportunity costs of land and water, but there were also important differences in taxes, wage rates, and other factors. Markups are negative in four of the ten states: Utah, Wyoming, Colorado, and California. The payoff per ton is positive in all states but very small in California.

Table 3 presents U.S. state-level totals for tons produced, revenues, costs, profits, and so on. As we said earlier, some areas, such as Minnesota and North Dakota, have large profits, while others, such as Colorado and California, have large losses. All areas have positive payoffs. The top part of the table (above the dashed lines) are U.S. states where economic profits were positive, $\Pi_r^{prop} > 0$, and would produce in the quasi-lump-sum allocation. The subtotal for these states is given between the dashed lines. Letting R and C denote revenue and costs, we have (in millions of dollars) $R_{beets}^{qlum} = 101.3$, $C_{beets}^{qlum} = 86.2$, and $\Pi_{beets}^{qlum} = 15.1$.

U.S. states that were producing beets in the New Deal cartel include those above and below the dashed lines. Production of beets in California accounts for more than a third of the total ($6,391/18,260 = 0.35$). California and Colorado together account for nearly half ($8,787/18,260 = 0.48$). Total industry profits are negative, nearly a \$3 million loss (-2.9). Cartel profits are completely destroyed: rather than profits of $\Pi_{beets}^{qlum} = 15.1$, profits are $\Pi_{beets}^{prop} = -2.9$.

8.3 Size of Deadweight Losses

The DWL, $DWL^{\sim qlum}$, given in equation (19), is the sum of the profit losses in four states, Wyoming, Utah, Colorado, and California, or \$18 million. While the entire cartel profit is

[49] We examine ten states, those for which we could find a cost and return study. These states account for 88 percent of acres and 85 percent of industry production.

destroyed, compared with the big picture this is a very small amount of money. However, a key issue is the size of the loss *relative to industry size.* To show that the deadweight losses of monopoly in the economy are large, we first need to show they are large in individual industries. Then we need to understand the breadth of monopoly, a point we discuss later.

The loss $DWL^{\sim qlum}$, relative to industry revenue, R^{qlum}, was 17.8 percent. Next, we consider value added, which we denote by V.[50] Value added is revenue less materials costs (which we denote M), or $V = R - M$. Total cost, C, is the sum of materials and factor payments (which we denote F), payments to land, labor, and capital, or $C = F + M$. If the cost of materials is κ percent of total costs, we have

$$\frac{DWL^{\sim qlum}}{V^{qlum}_{beets}} = \frac{-\sum_{\pi_r^{prop}<0} \Pi_r^{prop}}{R^{qlum}_{beets} - \kappa \cdot C^{qlum}_{beets}}. \tag{22}$$

While the cost and returns survey is a unique data source, it is sometimes difficult to separate some costs into materials costs and factor payments.[51] So, we will explore a range of values for κ, a range obtained from examining the studies. For $\kappa = 0.35$, $V^{qlum}_{beets} = 71.1$, and the DWL is 25.3 percent of value added. For $\kappa = 0.45$, $V^{qlum}_{beets} = 62.5$, and the DWL is 28.8 percent of value added. Profit losses (or losses in value added, which is the same thing), then, are roughly between 25 and 29 percent of industry value added.[52] These are large losses. Recall that these are lower bounds.

[50] We hope there will be no confusion between industry value added, V, and farmer payoff, v.

[51] For example, a study might report the cost to contract the transportation of beets to the factory. Combined in the fee are payments to factors, such as the labor of the truck driver, and materials, such as fuel. In such a case, we need to apportion the costs.

[52] The profit loss is, of course, also equal to the loss in value added. To see this, note that value added also equals factor payments plus economic profits, $V = \Pi + F$. Cartel value added is

$$V^{prop} = \sum_{\pi_r^{prop}>0} (F_r + \Pi_r) + \sum_{\pi_r^{prop}<0} (F_r + \Pi_r).$$

In the quasi-lump-sum case, we close regions where profits are negative. Factors in those regions are then free to work elsewhere, where we assume they earn the same payments. So, value added in the quasi-lump-sum case (where we include payments to moving factors) is

$$V^{qlum} = \sum_{\pi_r^{prop}>0} (F_r + \Pi_r) + \sum_{\pi_r^{prop}<0} F_r.$$

So, the difference in value added equals the difference in profits.

We have not mentioned consumption DWLs. Since U.S. sugar prices were roughly twice the world price, there was a DWL from too little consumption. These consumption DWLs have been calculated at the wholesale (or retail) sales level. We have not explored the size of these consumption DWLs (so as to compare them with the previous DWLs in beet farming), since the value of U.S. sugar sales (say, at the wholesale level) was an order of magnitude greater than the value of beets produced by farmers. To see this, first note that the value added in beet farming is only a share of the value added in the beet industry (which includes farms and factories). Second, and importantly, the value of manufactured *beet* sugar was only a small share of *total* U.S. manufactured sugar, accounting for 20 to 25 percent of the total (see U.S. Department of Agriculture, 1975b, p. 7).[53] And third, the value of total manufactured sugar was only a share of the (wholesale) value of U.S. sugar sales.

Thus far we have only discussed the loss in farmer profit. The change in factory profit is

$$\Psi^{qlum}_{beets} - \Psi^{prop}_{beets} = - \sum_{\pi^{prop}_r < 0} \Psi^{prop}_r . \tag{23}$$

Obviously, the change in profits might be negative. The cost and return studies in beets do not estimate the economic profits of factories (though they do in cane; see later discussion). To estimate economic profits, one option is to use (published) Census of Manufacturers data. But one issue (among others) is that factory profits varied a lot by state, and geographic statistics are limited in the published data. While we are not able to derive regional profit estimates, we present evidence (1) that factory profits were smallest in the West, in particular, California and Colorado, the areas closed in the quasi-lump-sum allocation, and (2) that it is not unreasonable to conclude that factory profits in the West were very small, if not zero, that is, $\sum_{\pi^{prop}_r < 0} \Psi^{prop}_{Ind} \approx 0$.

Cartel rules led to a significant decline in beet quality in the West. Farmers in irrigated areas (such as the West, but not the Midwest) can control the quality of beets. By irrigating

[53] Sugar manufactured by sugar refiners made up the remaining 75–80 percent, with the majority of this produced from imported raw sugar.

close to harvest, farmers raise beet tonnage but decrease beet quality (see Bridgman, Qi, and Schmitz (2009)). Contracts attempted to penalize late season irrigation by tying beet prices to the sugar content of the beets. However, the cartel side payment created added incentives for farmers to irrigate late in the season.[54] Hence, during the cartel, the quality of beets significantly declined in areas with irrigated farming, such as the West.

In the late 1920s, the average sugar content of California beets was above 18 percent. The average for the country was roughly 16 percent. By the early 1960s, the ranking had reversed: the national average was 15 percent, and the average in California was 14.5 percent (see Bridgman, Qi, and Schmitz (2009), Figure 6). The decrease in the national average was driven to no small degree by California, since it accounted for about a third of beet tonnage.

This drop in beet quality in the West led to significant increases in factory costs (and reductions in factory profits). First, factories shared the costs of transporting beets to the factory. Since beets now contained more waste, transport costs per unit of finished sugar increased. Second, processing beets of lower quality leads to higher energy costs per unit of finished sugar. These cost increases were so significant that firms began to close factories in the West. In Colorado, National Sugar, a small beet sugar manufacturer, closed its only factory in 1967. Great Western, a large manufacturer, closed its Fort Collins plant in 1960, its Windsor plant in 1967. In California, American Crystal (AC), another large manufacturer, closed its Oxnard, California, factory in 1959. Oxnard is 47 miles from Santa Monica. Recall that when a company closed a factory, it was not permitted to increase production in another area. Farmers in, say, Oxnard could not rent quota to farmers in North Dakota (where AC had other factories).

The decision to close a factory and lose its sales suggests that the factory's economic losses may not have been small. Likely a not-insignificant option value was associated with remaining in the cartel. In closing a factory, the firm drops out of the cartel (at least for this factory), losing this value. So, we take these factory closings as some evidence that aggregate

[54] While the factories would have liked to renegotiate the structure of contracts given this side payment, recall that the USDA monitored contracts, and firms had little leeway in changing contracts.

factory economic profits were very small, if not roughly zero, in the West.

8.4 Return to Assumptions

We return to discuss some of the assumptions used in calculating DWLs.

First, we assumed that the price of sugar p_x was fixed. In the quasi-lump-sum allocation, total beet production, X_{beets}, was reduced. To satisfy our assumption of a fixed price, we increase imports X_M. Is it feasible to increase imports without changing the price p_x? First, the increased imports would likely not have much impact on the world price, $p_{x,W}$. In any case, the U.S. price was typically twice the world price. So, there is little doubt that imports can be increased at the price p_x *without* pushing the world price $p_{x,W}$ above p_x.

Second, we assumed the beet industry received the same net side payment, $(S_{beets}^{prop} - T_{beets}^{prop})$. Total taxes fall as we decrease X_{beets}. But as sugar refiners process the increased imports, they pay a tax. These taxes will cover the lost beet factory taxes.

Third, we assumed that the transport cost of finished sugar is zero. It is not. One concern is that the transportation costs of white sugar in the quasi-lump-sum case is greater than in the New Deal cartel. There is no a priori reason to think so. For example, just the opposite was true in the Portuguese flour-milling cartel mentioned earlier. Monke, Pearson, and Silva-Carvalho (1987) argued that transport costs in the cartel case were much larger than the costs when the cartel was disbanded. In fact, the extra transportation costs stemming from the cartel was the biggest source of cartel DWL.

Let us briefly look at this issue in the beet industry. In the quasi-lump-sum allocation, we stopped production in California and Colorado. We ask: Where was this production *consumed*? And can we transport sugar to these *consumption-locations* for lower cost? We begin with an overview of the types of sugar consumed in U.S. regions, that is, beet sugar versus cane sugar (see U.S. Department of Agriculture (1965), p. 23).[55] For U.S. states along the East Coast, from New England to Florida, nearly all sugar consumed was from cane. The

[55] The statistics are sugar deliveries by primary dealers received in each state. The period covered is January to September 1965.

same is true for states bordering the Gulf of Mexico. For the 12 states in the U.S. *Midwest Census Division*, comprising the two *Census Regions*, East North Central and West North Central, consumption of beet sugar was a bit larger than cane sugar. In terms of millions of hundredweights, beet sugar was 25.4 and cane sugar 20.1.[56] States where beet sugar consumption exceeded cane included Illinois (beets, 10.1, cane 5.8) and Michigan (beets, 3.0, cane 2.2). Note that while Michigan was a significant beet producer, cane consumption was still over 40 percent of its consumption. In some states, cane consumption was larger, including Indiana (cane, 3.0, beets 1.3), Ohio (cane, 4.9, beets 1.8), and Missouri (cane, 2.0, beets 1.7).

The cane sugar consumed in the Midwest was from Louisiana and Caribbean imports, with the vast majority being imports, since Louisiana was a small producer. The beet sugar consumed in the Midwest was from Midwest beet producers in Minnesota, North Dakota, and Michigan but also from beet producers in Colorado and Idaho.[57]

Return to our original questions and consider Colorado's production. Roughly, Colorado production was consumed in Colorado and points east in the Midwest. Hence, we must deliver sugar to these locations. The large Midwest population centers would be the big recipients. We will lump these centers together, calling them "Chicago," since Chicago was the biggest. How can we supply sugar to Colorado and Chicago (which had previously been produced in Colorado)? One method is to ship Caribbean sugar up the Mississippi River. The shipments to Chicago would be by water; those to Colorado would need to travel over land as well. A cheaper way is to bring Idaho into the mix, as we now describe.

Let X_{CO}^{prop} and X_{ID}^{prop} denote production in Colorado and Idaho during the cartel. Let $x_{i,j}$ denote shipments from i to j during the cartel.[58] So, $X_{CO}^{prop} = x_{CO,CO} + x_{CO,CHIC}$, that is, Colorado production is shipped to Colorado and Chicago. The quantity $x_{CO,CHIC}$ is an

[56] Statistics were often reported in units of 100 pound bags, that is, hundredweights.

[57] See Ballinger (1971) and Idaho State Historical Society (1974) for a discussion of Colorado and Idaho shipments to Chicago.

[58] We do not put superscripts on shipments during the cartel (we will for the proposed quasi-lump-sum shipments described later).

order of magnitude larger than $x_{CO,CO}$. Similarly, $X_{ID}^{prop} = x_{ID,ID} + x_{ID,CHIC}$. Consider the transportation costs for Colorado and Idaho beet sugar in the New Deal cartel. We will assume the shipments $x_{CO,CO}$ and $x_{ID,ID}$ were at no cost. Then the costs are

$$\tau_{L,land} \cdot (x_{ID,CHIC} + x_{CO,CHIC}),$$

where $\tau_{L,land}$ is the transportation cost for *long* distance over *land*.

The transportation costs in our proposed quasi-lump-sum shipments are

$$\tau_{S,land} \cdot (x_{ID,CO}^{qlum}) + \tau_{L,land} \cdot (x_{ID,CHIC}^{qlum}) + \tau_{CAR,water} \cdot (x_{CAR,CHIC}^{qlum}),$$

where $\tau_{S,land}$ is the charge for *short* distance over land and $\tau_{CAR,water}$ is the transport charge from the Caribbean (over *water*). Sugar is shipped from Idaho to Colorado, $x_{ID,CO}^{qlum} = x_{CO,CO}$, from Idaho to Chicago, $x_{ID,CHIC}^{qlum} = x_{ID,CHIC} - x_{ID,CO}^{qlum}$, and from the Caribbean to Chicago, $x_{CAR,CHIC}^{qlum} = x_{CO,CHIC} + x_{ID,CO}^{qlum}$. Transportation costs in the cartel, less those in the proposed quasi-lump-sum shipments, is

$$(\tau_{L,land} - \tau_{CAR,water}) \cdot x_{CO,CHIC} + (\tau_{L,land} - \tau_{CAR,water} - \tau_{S,land}) \cdot x_{CO,CO}.$$

We surmise that the quantity, $(\tau_{L,land} - \tau_{CAR,water})$, is positive. Shipments over water are typically much cheaper than over land. Since the shipments to Chicago are an order of magnitude greater than those within Colorado, we are confident that the quasi-lump-sum transportation costs are smaller.

Now consider California. Consumption of cane sugar in California was roughly one-third of total consumption (5.2 million hundredweights of cane, 10.0 of beets). We know less about California beet shipments than Midwest beet shipments, but presumably most of California production was consumed in the state. Some of the sugar may have traveled long distances by land across the state, though production of beets was spread throughout the state. We can replace these beet shipments with shipments of cane over water, since the large population centers in California were on the coast. The cane would obviously come from long distances, though, again, water transportation is very cheap compared with that over land.

In summary, we are confident that we can reduce transportation costs in the Midwest under the quasi-lump-sum allocation. We are unsure about transportation costs in California.

8.5 Digression: Calculating Deadweight Losses in Competitive Industry

Many studies of the welfare impact of quotas and tariffs using competitive models have done. Contrasting this methodology with our approach is worthwhile.

Graphically, the competitive model has an upward-sloping industry supply curve and a downward-sloping demand curve. Let the world price be *below* the price that would prevail if the domestic industry was in autarky. Next, a tariff is added to the world price. This leads to two DWLs—two "triangles": a consumption triangle and a production triangle. Tullock (1967) produces this classic diagram in his Figure 2. Of course, we can achieve the same increase in the domestic price with a quota. In these studies, if domestic output is reduced and replaced by foreign quotas (imports) so as to keep the domestic price constant, domestic profits *fall*. But there is welfare gain because foreigners (who sell in the United States at the quota price) can more than cover that profit loss.[59]

But the U.S. sugar industry was a cartel in this period, with no traditional supply curve. Our analysis takes the supply of sugar as fixed, determined by the cartel. When we move from proportional side payments to the quasi-lump-sum case, we reduce domestic production and increase imports. But domestic industry profits *increase*. This, of course, is the *opposite* of the competitive model.

[59]This competitive model was used to study the U.S. sugar industry (when it was a cartel) by, among others, Johnson (1966), Bates (1968), Mintz (1973), and Gemmill (1977). Johnson (1974) is a very extensive study of the cartel, which he refers to as an evil system. He, too, uses the competitive model.

8.6 Moving Acres

Profit gains may be earned by moving some acre quotas from Colorado and California to the Midwest. We briefly assess upper bounds for these gains.

Recall the average profit earned in the cartel, given in equation (15). Write this as $\pi_r^{prop} = \pi_r^{prop}(p_x, p_l, \widehat{L}_r, \widehat{\sigma}) = \pi_r^{prop}(\widehat{L}_r)$. Think of moving L_r^{move} acres from the West to region r, say, Minnesota. We can solve for the new equilibrium in region r, using the new quota $\widehat{L}_r + L_r^{move}$. Average profit is now $\pi_r^{prop}(\widehat{L}_r + L_r^{move})$. Acres per farmer is $l_r^{prop}(\widehat{L}_r + L_r^{move})$. So, we have the new profit

$$\Pi_{beets}^{move} = \sum_{\pi_r^{prop}>0} (\widehat{L}_r + L_r^{move}) \cdot \frac{\pi_r^{prop}(\widehat{L}_r + L_r^{move})}{l_r^{prop}(\widehat{L}_r + L_r^{move})}.$$

Of course, if $L_r^{move} = 0$, this is the quasi-lump-sum profit.

The upper bound is achieved when we assume average profit per acre does not fall as we increase a region's acre quotas. We calculate an upper bound to moving 50,000 (50K) acres each to Minnesota and North Dakota. In Table 3, the last two columns give acres harvested and average profit per acre, by state. If we use average profit per acre of \$33 for the 100K acres we move (50K to both Minnesota and North Dakota), the gain is \$3.3 million. This is a 20 percent increase in the quasi-lump-sum profit, of 15.1.

It is not unreasonable to conclude that profit per acre would not fall much in Minnesota and North Dakota if we moved 50K acres to each state. First, in 1965, Minnesota had some beet-producing regions that were *untapped* and highly productive. Recall that in the early 1970s, the cartel permitted a new factory to be opened in Minnesota. The factory was in south central Minnesota (in Renville), not in the Red River Valley (as were all the other Minnesota factories). The factory was large, processing roughly 50,000 acres when it opened. Measures of farmer TFP by location in Minnesota and North Dakota (for the 1970s) show that farmers supplying this factory had the highest TFP (see Bridgman, Qi, and Schmitz (2015)). So, opening this factory would have increased state TFP in the 1960s.

Second, evidence suggests that modest expansion of beet production in *existing* areas in Minnesota and North Dakota would not have led to increases in land cost per acre. As we mentioned, the economic profit per acre in beet farming typically greatly exceeded that of alternative crops, such as wheat. Yet the opportunity cost of farmland used in beets was *essentially the same* as that used in producing wheat (see, e.g., Loftsgard and Miller (1961)), some evidence that a modest expansion in beet acres would not increase land costs. Wage rates may have increased, though we do not have estimates of how much.[60]

8.7 Predictions

We mentioned earlier (in discussing Table 1) that the dispersion in state TFPs increased during the cartel period. Theory (in general) does not imply that the cartel rules (that led to misallocation) would lead to a wider range of TFPs.

At the cartel's outset, for example, TFP in California could have been higher than in Minnesota.[61] Then, during the cartel, when input prices grow faster in California than Minnesota, TFP dispersion would begin to fall. At some point, the TFPs would be equal, and then dispersion would again start to increase.

Rather than focus on dispersion of regional TFPs, we examine the difference between TFPs in West regions and Midwest regions, and explore how they vary over time. Does the difference between Minnesota TFP and California TFP increase over time? While unfortunately we do not have TFP for Minnesota and North Dakota in 1921-23, we do for Michigan and Idaho. So, for example, let us examine the quantity

$$TFP_{ID} - TFP_{CA}$$

[60] This evidence does not mean there were no differences in land quality. For example, suppose an area has good and fair land. Suppose wheat is grown on good land. Then if the amount of beet acres is very small relative to the good land total, expansion of beets may not influence the land price.

[61] Again, we argued earlier that this arises if we introduced differences in the opportunity cost of farmers' time, denoting the costs by z_{ir}. We imagined a situation with lots of farmers in California with very low opportunity costs, much smaller than that of the marginal farmer, so that regional TFP exceeded one. If in Minnesota all farmers had the same opportunity costs of time, regional TFP would equal one.

over time. From Table 1, in the period 1921-23, $TFP_{ID} - TFP_{CA} = 0.06$. For the period 1962-65, $TFP_{ID} - TFP_{CA} = 0.29$. So, the difference in TFPs between Idaho and California increased over the period. Similar results hold if we compare Idaho with Colorado.[62]

9 History of Cane Sugar Manufacturing Industry

The experience of the cane sugar industry is similar to that of the beet sugar industry. In particular, cartel profit-sharing rules destroyed productivity by precluding cane sugar production from moving from low to high productivity areas. The rules also meant that the industry continued to produce in regions where economic profits were negative. In the beet industry, Minnesota and North Dakota emerged as the most profitable producers, while in cane it was Florida that played this role.

In this section, we will closely follow the earlier discussion of the beet industry. We describe forces leading to TFP divergence and then present the history of production.

9.1 Misallocation Arises over Time

In this paper, we study cane producers in Florida, Louisiana, and Puerto Rico.[63] In 1900, Louisiana was a significant producer of sugar, while Puerto Rico and Florida produced very little. In roughly 1900, Puerto Rico was allowed to export (tariff free) to the United States. Within the decade, its production exceeded Louisiana's; by 1930, it was four times larger. Florida was a tiny producer in 1900 and remained so in 1930. So, in 1934, Florida was given a small quota and was earmarked to receive a small quota in the future.

Why was Florida such a small producer before 1930? Florida has many endowments that make it a productive area in which to produce sugar (see later discussion). But it had

[62] We can make comparisons between Michigan and California and Colorado, but, as we said, Michigan's TFP was low in the 1921-23 period. That said, using Michigan, we have, in the period 1921-23, $TFP_{MI} - TFP_{CA} = -0.12$. For 1962-65, we have $TFP_{MI} - TFP_{CA} = 0.37$.

[63] We actually started the project focusing on beets. As we collected better data on cane, we added the previous three regions. Data on Hawaii have been harder to obtain.

drawbacks (at least initially). Given its high humidity, south Florida was an inhospitable place to live. For this and other historical and geographic reasons, south Florida had a very small population before 1930. In 1900, the population of Miami was only 1,681. The tiny population provided little infrastructure to support a large industry. From the standpoint of an individual industry, lack of infrastructure is a small regional endowment.

Figure 5 shows sugar production by region in 1950. Puerto Rico's and Louisiana's production are roughly 12 times and 4 times greater than Florida's, respectively.

After World War II, with its population and infrastructure growing, Florida was soon becoming a much more productive sugar manufacturing location than Louisiana. As for farming, for example, freezing conditions were less likely in Florida. Also, given its geography, it is also possible to have larger farms. Larger cane farms were more productive than smaller ones.[64] In addition, when farms are larger, factories can be larger, since, among other factors, coordinating harvesting schedules is less problematic.

After World War II, Puerto Rico was likely a more productive area (in terms of weather and land endowments) to manufacture sugar than Florida (and likely still is). But Florida had significant policy advantages. We will present two. First, in 1948, Florida sugar growers made agreements with the U.S. government to permit migrant cane cutters from the Caribbean to work in Florida (see, e.g., McCoy and Wood (1982)). They worked on a piece-rate basis. In contrast, Puerto Rico had policies that promoted the development of unions in cane cutting. The unions did not permit piece-rate payments. As a consequence, in the early 1950s, labor productivity (tons of cane produced per man-hour) in Florida was roughly four times greater than in Puerto Rico (U.S. Department of Agriculture (1975a), p. 7).[65] Second, Puerto Rico had policies that favored small farms and penalized farms for growing. This was

[64] Good evidence for this concerns the cartel side payment scheme. As we mentioned, if farm production became very large, the rate of side payment per unit of sugar crop production began to decline. By breaking up, a large farm could have noticably increased its side payments.

[65] The differences in labor productivity were not due to mechanization. Puerto Rico failed to mechanize at any point. Florida did not mechanize until late, compared with, say, Louisiana. The highly productive cane cutters from the Caribbean delayed mechanization until the 1960s and 1970s. It was during this time that U.S. unions forbid the paying of piece rates in Florida sugar. Mechanization quickly followed.

a problem for two reasons: (1) as we said, large farms have higher productivity than small ones, and (2) large farms have the greatest incentive to mechanize, so this discouraged the development of machines.

9.2 Production History

Initial cartel rules called for regional production levels to increase roughly at the same rate over time. With both farm and factory TFP growing faster in Florida than in Louisiana and Puerto Rico, pressure grew to move quotas across regions. The experience of the cane industry is similar to beets in the sense that Florida was initially unable to increase its quota. It is also similar in that when Florida was permitted to expand, it grew significantly. One difference is that Florida was given permission to expand in the 1960s with the fall of Cuba. It was permitted to expand further with the end of the cartel.

Turning to the post-World War II period, we see in Figures 6A–6C a display of sugar production and allotments by area over time. Note that Puerto Rican allotments were in terms of sugar production, while in the other two areas it was in acres. So, the units in Figure 6A differ from those in 6B and 6C. As seen in Figure 6A, Puerto Rico's production exceeded its quota in the early 1950s (by nearly a third, 1200 vs. 900).[66] Its quota was raised and its production scaled back, so that they were equal for a few years in the middle 1950s. But Puerto Rico's production then declined by 25 percent between 1955 and 1958, the start of a secular decline in production.

Turning to Figure 6B, we see that Louisiana's production was falling through the 1950s. Its quota was scaled back, but it still did not fill that lower quota. Production picked up in the 1960s. By the early 1970s, Louisiana was not using nearly 25 percent of its allotment ([400-300]/400). After the cartel, production started falling, but not to the extent that it was falling in Colorado and Utah, for example.[67]

Production in Florida is shown in Figure 6C. Between 1950 and 1960, Florida did not

[66] Puerto Rico had argued that it was shortchanged during the quota assignments in 1934.

[67] The surge in the 1990s was most likely related to the sharp reduction in Hawaiian production.

receive additional quota. In 1959, its acre quotas were still very small relative to Louisiana's. With the fall of Cuba, Florida began a significant expansion. The cartel permitted the Florida industry to open new factories, the number increasing from 3 to 11 between 1960 and 1964 (U.S. Department of Agriculture (1975a), p. 3). In the middle 1960s, allotments again limited Florida's expansion. When the cartel ended, Florida was again able to expand.

Figure 7 plots the share of cane sugar production by region over time. The figure looks similar to Figure 2, where the Midwest gained significant share after the cartel. In Figure 7, it is Florida that gains significant share, though it first gains share after the fall of Cuba.

10 Economic Costs of Cartel: Cane Industry

This section closely follows the analysis of the beet industry. One difference is that the cane cost and return studies estimate the economic profits of both the farm and factory.

10.1 Profit Losses from Proportional Side Payments

We calculate the DWL from using proportional payments and not the quasi-lump-sum allocation. Again, if a region had a negative economic profit (farm plus factory) during the cartel, that is, $\Pi^{prop}_{r,cane} + \Psi^{prop}_{r,cane} < 0$, we close the region (i.e., give it a zero quota). If the region had a positive economic profit, we give that region the same quota. Hence, the profit for the latter regions is the same as it was during the New Deal, with average profit given in (15).[68] Quasi-lump-sum profits are

$$\sum_{\Pi^{prop}_{r,cane}+\Psi^{prop}_{r,cane}>0} \Pi^{prop}_{r,cane} + \Psi^{prop}_{r,cane}, \tag{24}$$

[68] Of course, equation (15) gives farm profit. Factory profit is easy to calculate.

where the sum is over areas with positive profits. The DWL, $DWL^{\sim qlum}$, is then the (negative of) the sum of New Deal profits in areas with negative profits,

$$DWL^{\sim qlum}_{cane} = -\{ \sum_{\Pi^{prop}_{r,cane}+\Psi^{prop}_{r,cane}<0} \Pi^{prop}_{r,cane} + \Psi^{prop}_{r,cane} \}. \tag{25}$$

10.2 Cost and Return Studies

As with beets, both federal and U.S. state studies of costs and returns in cane sugar producing have been conducted. One helpful feature of the cane studies is that the economic profits of both farm and factory are typically calculated.

The federal government conducted studies before the cartel for both Puerto Rico and Louisiana (but not Florida). For the years 1929-32, a federal study (U.S. Tariff Commission, 1934, p. 131) calculated that the average farm cost of producing sugarcane (in cents, per pound of raw sugar) in Puerto Rico was 2.14, while the milling (factory) costs were 0.87, for a total cost of 3.01 cents per pound of raw sugar. In Louisiana, the average farm cost of producing sugarcane (in cents, per pound of raw sugar) was 3.15, and the milling costs were 1.36, for a total cost of 4.51 cents per pound of raw sugar. Louisiana's costs were roughly 50 percent greater than Puerto Rico's. Puerto Rico's cost advantage did not persist: by the early 1960s, Puerto Rico's costs were similar to those of Louisiana.

In Table 4, we present sugarcane statistics for Florida, Louisiana, and Puerto Rico. Columns 1 and 2 are average farm and factory (mill) costs, c_{farm} and c_{fact}. The third column is the sum of the two, $c_{farm}+c_{fact}$. The fourth column is price (i.e., revenue per pound). This is the price received by the factory at the factory door. In the previous notation, this is p_x. Profit per pound of sugar equals column 4 minus column 3, $p_x - (c_{farm} + c_{fact})$. This is the combined (farm plus factory) industry profit. The sixth column is side payments to farmers. The last column is industry profit plus the side payment to farmers, $p_x - (c_{farm} + c_{fact}) + s$.

The statistics for Louisiana are from Campbell (1977). For the years 1964-66, the average farm cost of producing sugarcane was 5.29, and the milling costs were 2.50, so the total costs of production were 7.78 cents per pound of raw sugar. The combined farm plus factory profit in Louisiana for the years 1964-66 was -0.94. The payoff was negative but small.

For Florida, the USDA conducted cost and return surveys in its role of mediating contracts between farmers and factories.[69] Bohall (1977) reports costs and returns for Florida (and Louisiana) in 1973. From this report, we can calculate the cost of production in Florida relative to the cost in Louisiana (for both farm and factory) for 1973. We then use the relative costs in 1973 to estimate Florida's costs for earlier years.

In particular, let $c_{farm,FL}/c_{farm,LA}$ denote the ratio of average farm costs in Florida and Louisiana. For 1973, the ratio was 0.69. Florida's farm costs were only about 70 percent of Louisiana's. To estimate Florida's farm costs for a given year, $c_{farm,FL,t}$, we multiply Louisiana's farm cost in that year, $c_{farm,LA,t}$, by 0.69. With this method we estimate that Florida's farm costs for the period 1964-66 were 3.62.

We do the same for mill costs. Let $c_{mill,FL}/c_{mill,LA}$ denote the ratio of average factory costs. For 1973, the ratio was 0.57. To estimate Florida's mill costs for a given year, $c_{fact,FL,t}$, we multiply Louisiana's mill cost in that year, $c_{farm,LA,t}$, by 0.57. With this method we estimate that Florida's mill costs for the period 1964-66 were 1.41. So the total costs of producing raw sugar was 5.03 cents per pound of raw sugar. The combined farm plus factory profit in years 1964-66 was 1.96.

For Puerto Rico, we estimate total costs of production from statistical reports produced by sugar factories. The factories were declared a public utility by the local government. Among other regulations, factories were required to submit detailed statistical reports to the local government. These reports and estimates are described in the Appendix (see also Requa (1963)). From these reports, we can only estimate the combined farm plus factory costs. For the years 1964-66, the total costs of producing raw sugar were 7.63 cents per pound of raw sugar. The combined farm plus factory profit in years 1964-66 was -0.67.

Table 5 presents area level totals for sugar produced, revenues, costs, profits, and so

[69] However, while we have references to a few of these studies, we have only been able to obtain the study by Bohall (1977).

on. As we said earlier, some areas, such as Florida, have large profits, while others, such as Louisiana and Puerto Rico, have large losses. In the quasi-lump-sum allocation, only Florida operates. We have, in millions of dollars, $R^{qlum}_{cane} = 72.1$, $C^{qlum}_{cane} = 51.9$, and $\Pi^{qlum}_{cane} = 20.2$. Total industry profits are negative. Cartel profits are completely destroyed: rather than profits of $\Pi^{qlum}_{beets} = 20.2$, profits are $\Pi^{prop}_{beets} = -2.5$.

10.3 Size of Deadweight Losses

The loss $DWL^{\sim qlum}$ equals \$22.7 million. Relative to industry revenue, R^{qlum}, the loss was 31.5 percent. For $\kappa = 0.35$, $V^{qlum}_{cane} = 53.9$, and the DWL is 42.1 percent of value added. For $\kappa = 0.45$, $V^{qlum}_{cane} = 48.7$, and the DWL is 47.0 percent of value added. These losses are larger than those in the beet industry. Recall that these are also lower bounds.

11 Costs of Monopoly: Recap and Way Forward

Think of the *economy-wide* cost of monopoly, say Δ, as determined by the cost *within* industries and the *breadth* of monopoly. In symbols,

$$\Delta = \sum_{i \epsilon M} \frac{DWL_i}{V_i} \cdot \frac{V_i}{GDP},$$

that is, the total cost depends on the costs within industries, DWL_i/V_i, and the breadth of monopoly, where breadth depends on the number of industries with monopolies (that is, the size of the set M) and the size of these industries, V_i/GDP. The consensus is that not only DWL_i/V_i, but also the breadth of monopoly, are small.

We have shown that the costs of monopoly in the beet and cane industries were not small. The costs we examined, which are briefly reviewed in Section 11.1, were those from misallocation. But the cartel led to other losses as well. In Section 11.2 we argue that the cartel led to reduced industry productivity growth. TFP growth in North Dakota (and

California) would have been *higher* without the cartel.[70] Losses stemming from reductions in productivity growth may, of course, have swamped the productivity losses from misallocation. Lastly, in Section 11.3, we discuss the breadth of monopoly.

11.1 The Cartel's Impact on Misallocation

The history presented earlier clearly shows a significant misallocation of production in the domestic U.S. sugar industry during the cartel. First, a misallocation occurred across states. Second, a misallocation occurred within states. The cartel also had a negative impact on productivity growth as well, the topic to which we turn next.

11.2 The Cartel's Impact on Technological Progress

While we do not have estimates of the reduced productivity growth at this point, we present three avenues through which the cartel reduced productivity growth.

First, quotas on factory sales decreased the incentive to reduce costs. This effect is present with a *single* firm in the industry. Since a firm cannot expand its production if it successfully lowers its costs, this effect retards research incentives. In this industry, quotas limited incentives for finding new methods to extend a factory's sugar campaign, that is, the number of its slicing days. Slicing days have dramatically increased since the cartel ended. One would expect slicing days to jump once quotas are lifted if the quota had been binding. But slicing days have steadily and significantly increased over the entire post-1970 period.[71]

Second, with *more than one* firm, quotas *reduce the competition* in the industry. This effect can have important (negative) consequences for productivity growth.[72]

Third, recall that the cartel is composed of many members, including the federal and local

[70] We are using TFP here in its more traditional sense. That is, TFP growth measures the growth of productivity over time in a region.

[71] The impact of factory quotas on slicing days might be studied by comparing slicing days in the United States with other countries, both before and after the cartel.

[72] See Dunne, Klimek, and Schmitz (2015), who show competition increased productivity growth in the U.S. cement industry.

governments. Governments often influence how the cartels are structured. We mentioned how state governments had an incentive to forbid renting of farm quotas across state lines and how the federal government pushed for provisions such as side payments to farmers.

In Puerto Rico, local cartel administrators pursued policies that favored small farms and penalized farms for growing, policies that reduced productivity growth. Bridgman et al. (2012) argue that these policies were the primary reason why Puerto Rico did not mechanize farm operations after World War II. This failure to mechanize meant that TFP in the Puerto Rican sugar industry stagnated. Hence, TFP significantly fell over time relative to TFP in other sugar producing areas, ultimately leading to the industry's collapse in the middle 1960s.

11.3 Breadth of Monopoly: United States

Not only can losses from monopoly be large in individual industries, but also many monopoly-type industries together account for a not-insignificant share of U.S. GDP. Earlier we mentioned the dental industry and state dental cartels. These cartels block the use of many different types of non-DDS professionals and lead to economic losses. The law profession acts similarly, prohibiting non-JD professionals from engaging in the simplest tasks. For 100 years the construction industry has had restrictions on the use of technology, leading to economic losses. A very important industry, one with significant elements of monopoly and one that likely leads to large economic losses, is the education industry.

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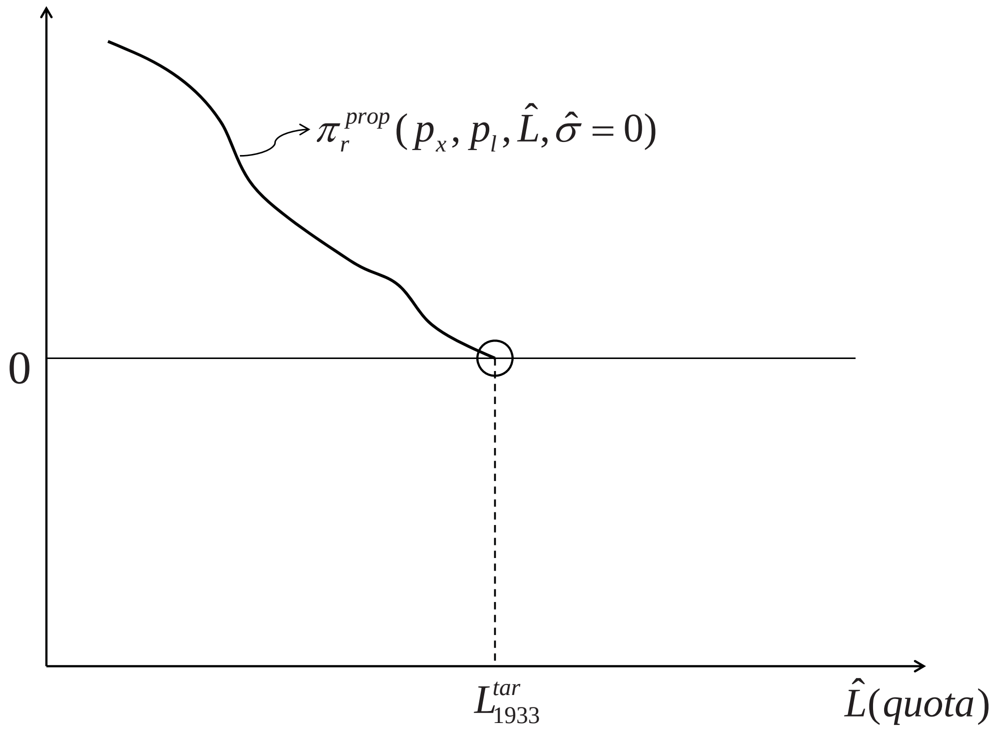
Diagram 1: Average Farmer Profit



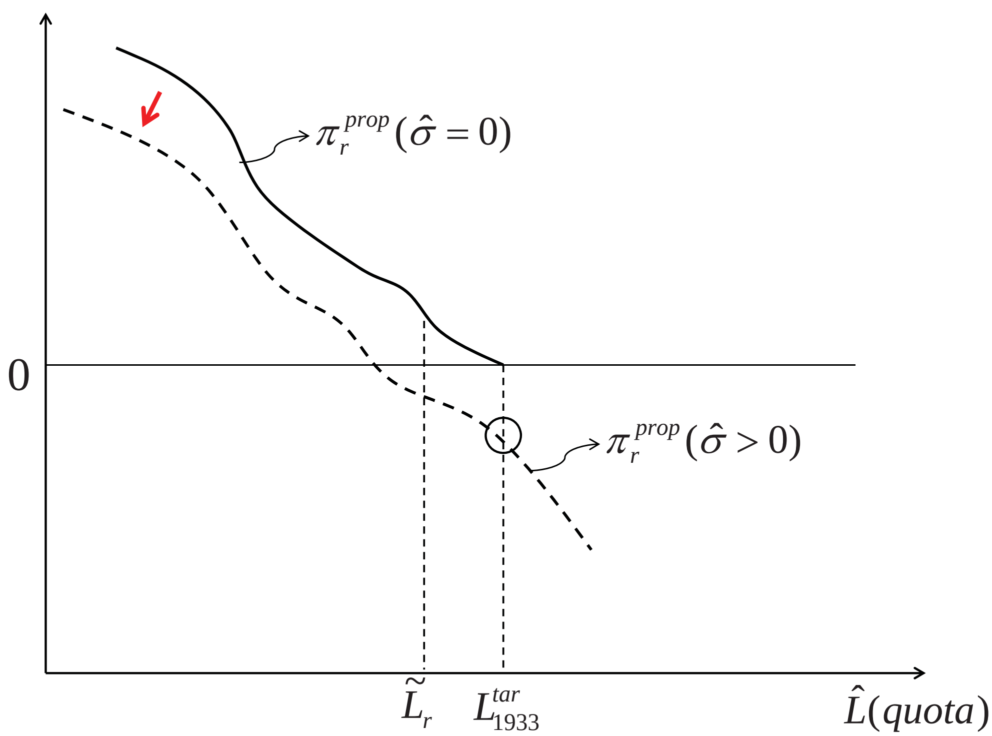


Diagram 2: Average Farmer Profit

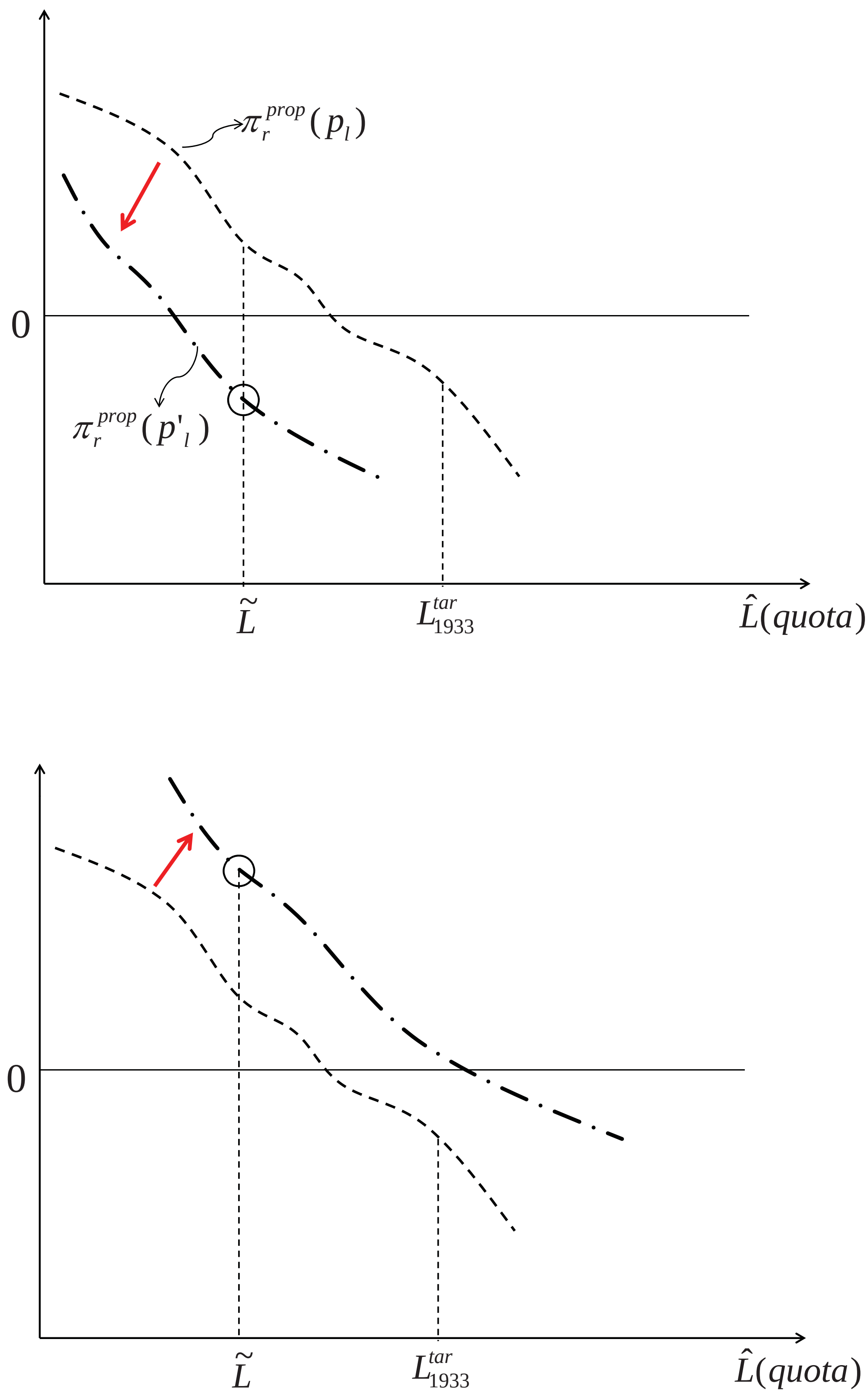


Figure 1: Harvested Acres of Sugar Beets
by States, 1950
(in thousands)

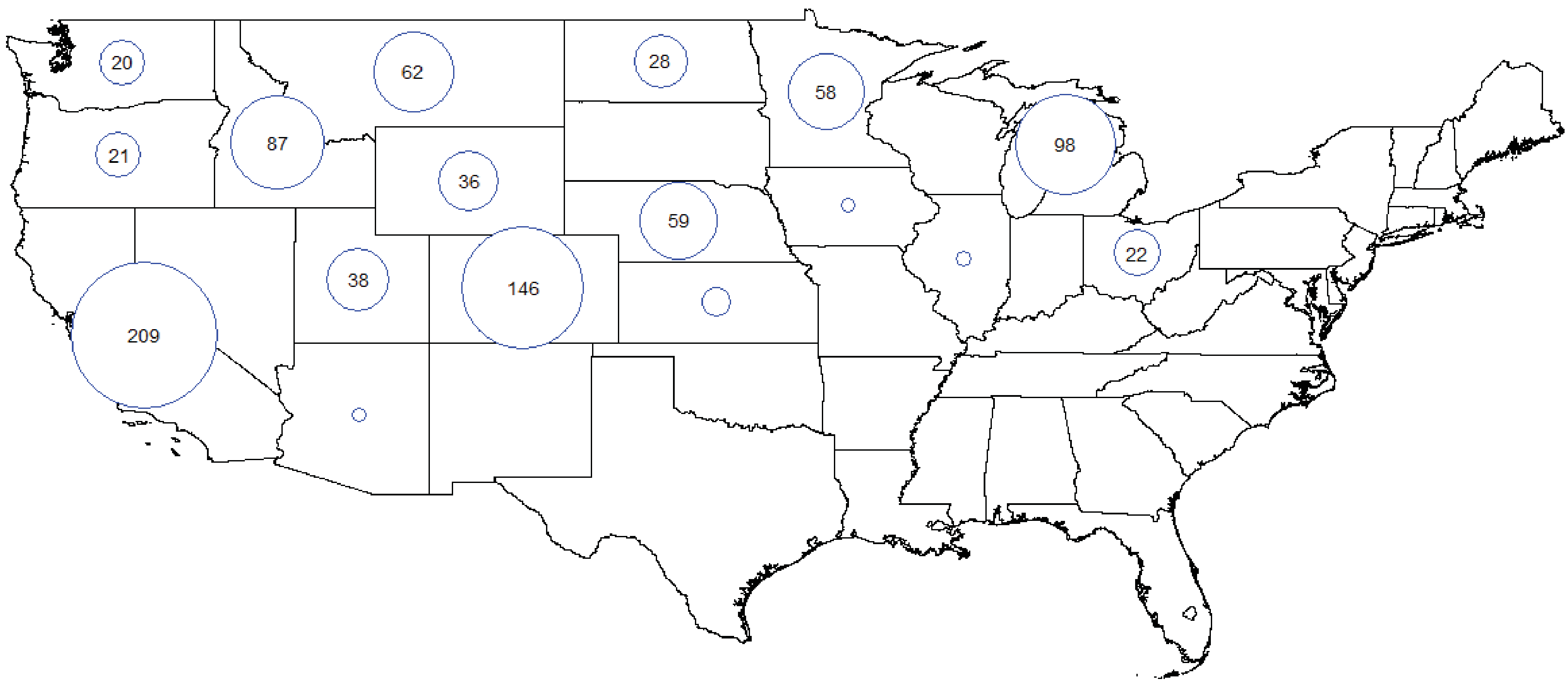


Figure 2: Share of Harvested Sugar Beet Acres by Groups of States

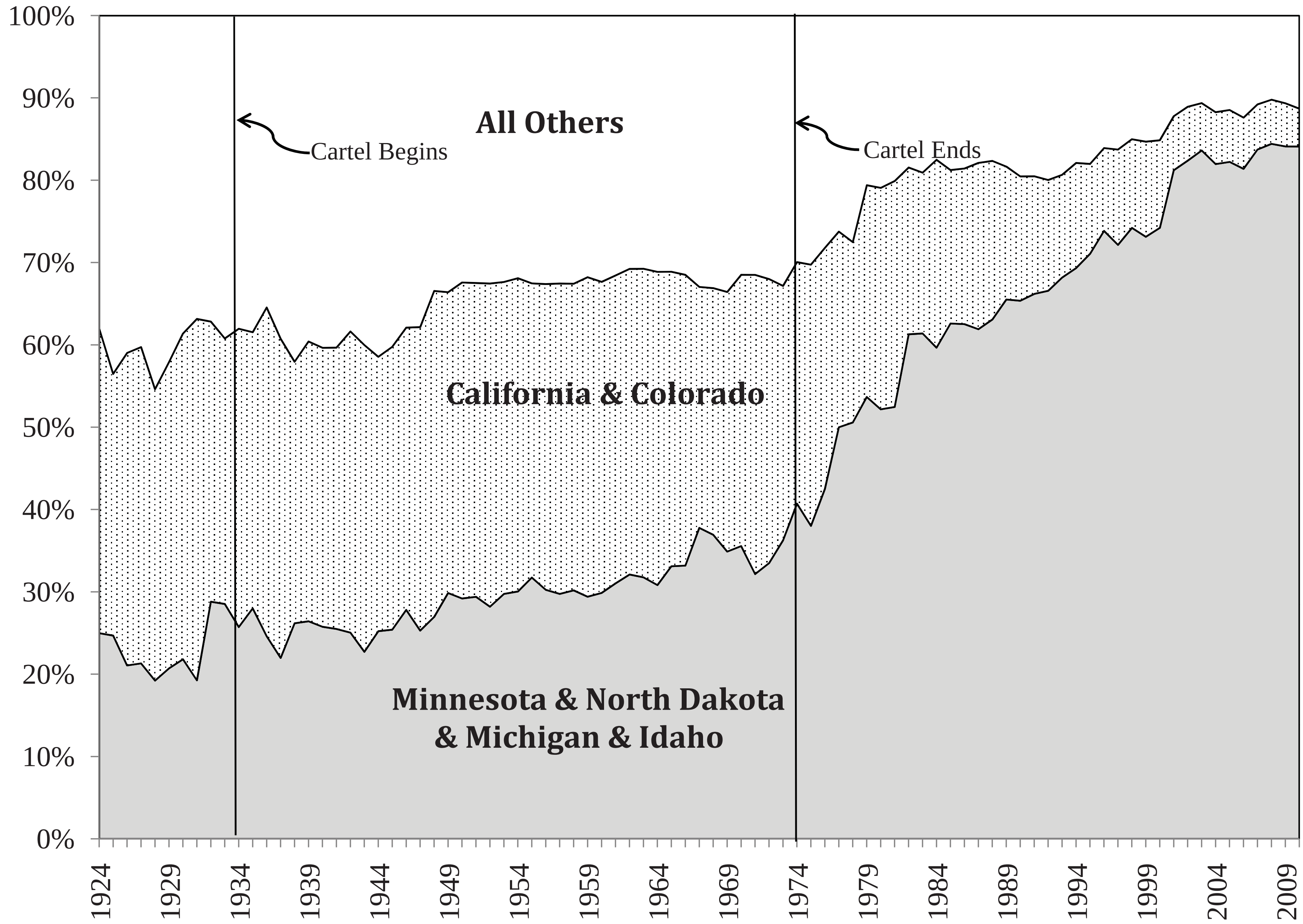
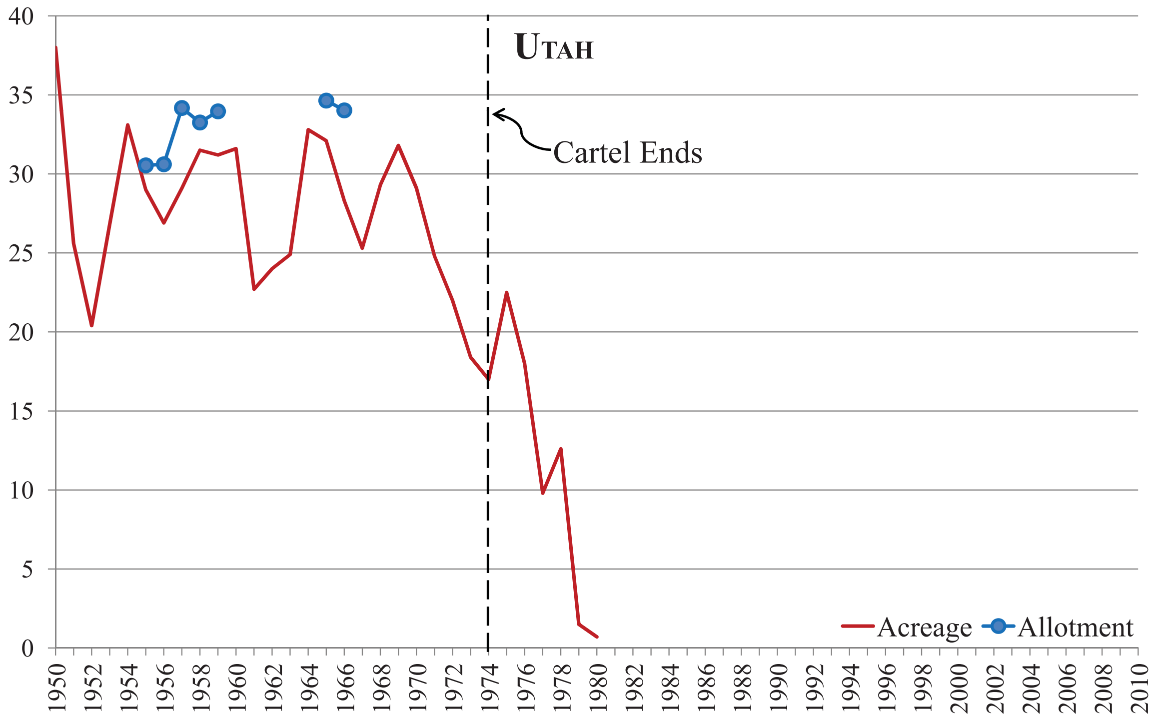


Figure 3A: Allotments and Harvested Acres (in Thousands), by State



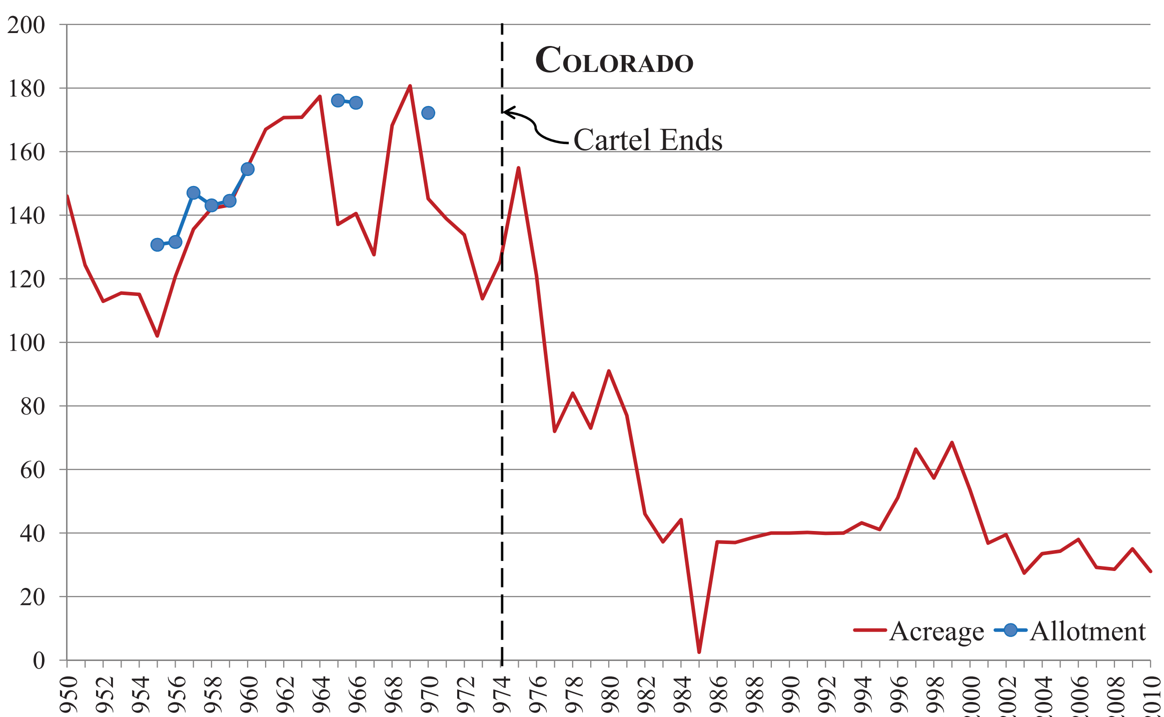


Figure 3B: Allotments and Harvested Acres (in Thousands), by State

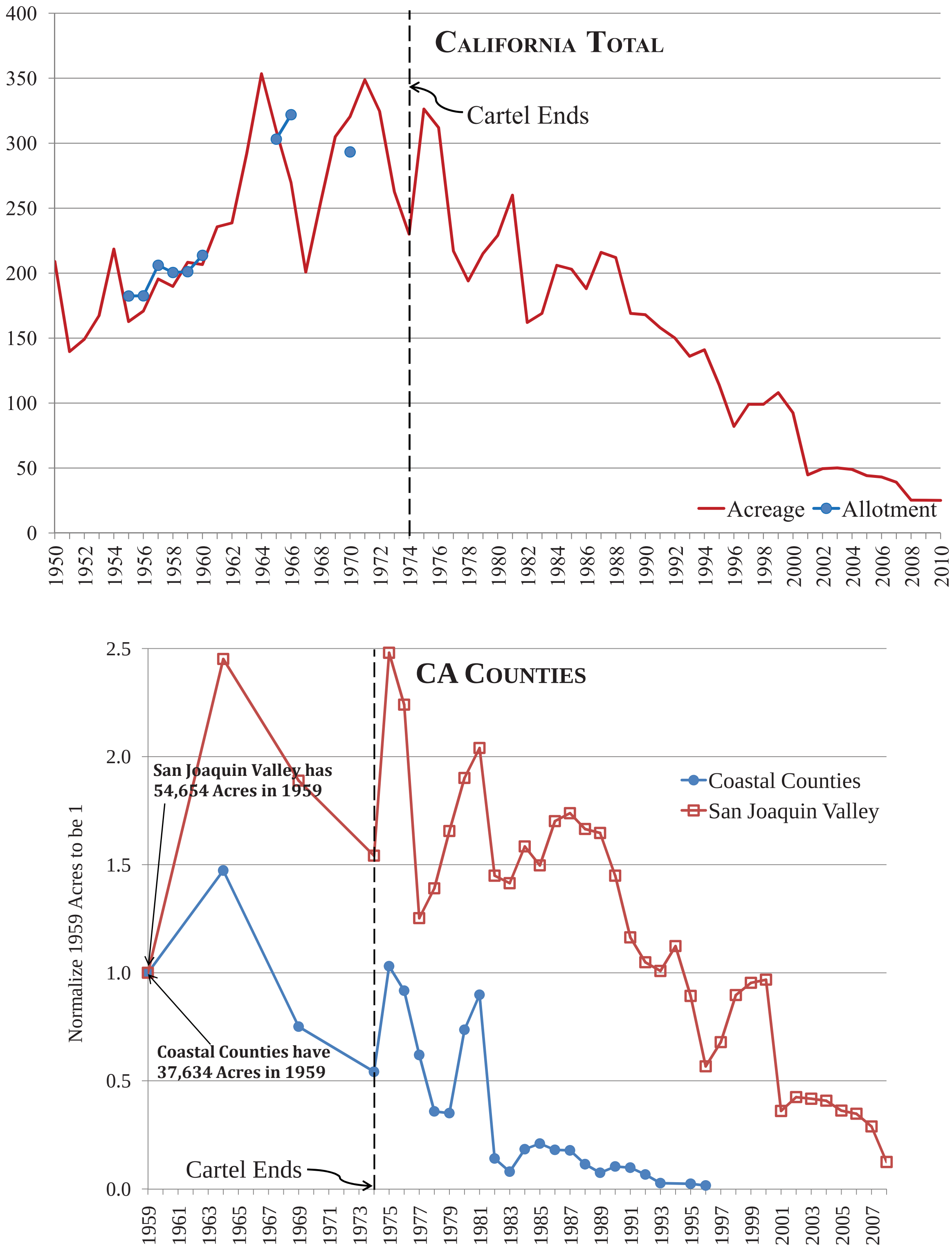
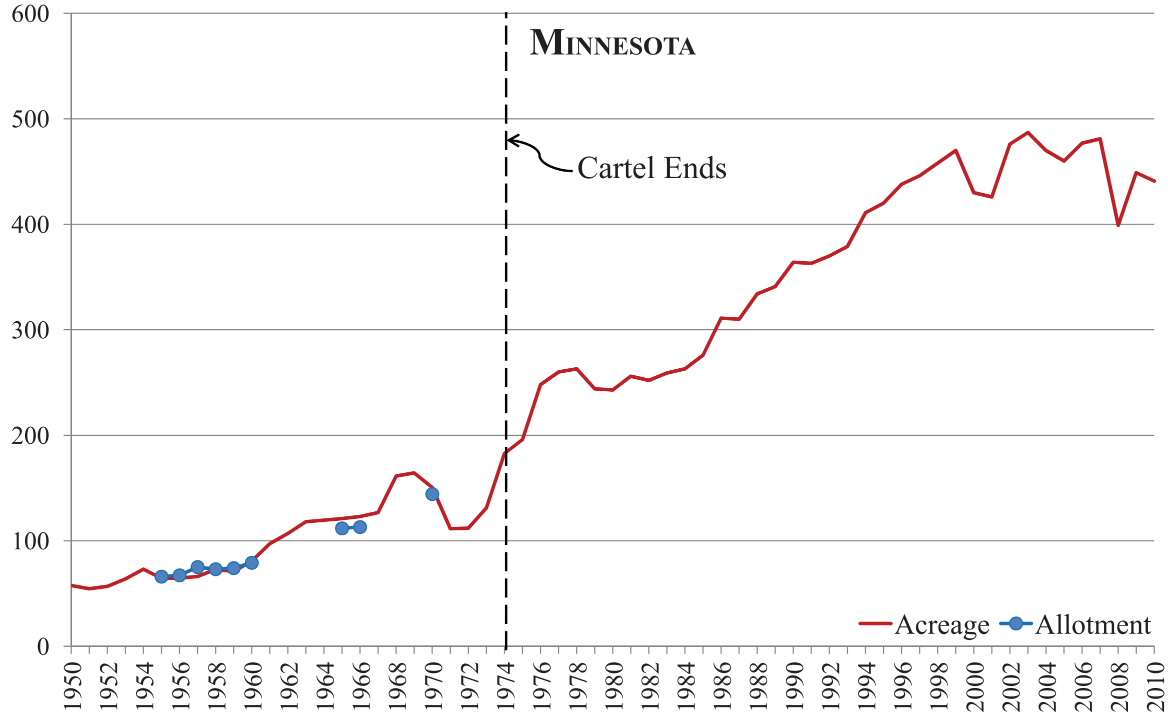


Figure 3C: Allotments and Harvested Acres (in Thousands), by State



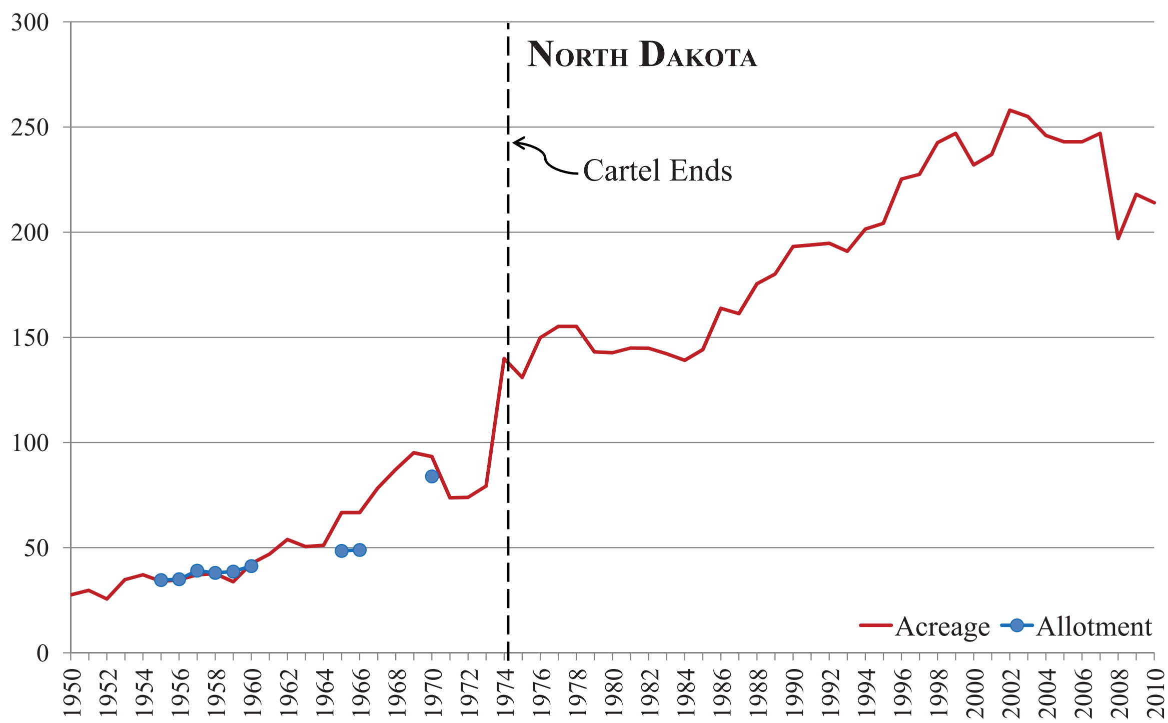


Figure 4: Harvested Acres of Sugar Beets
by States, 2010
(in thousands)

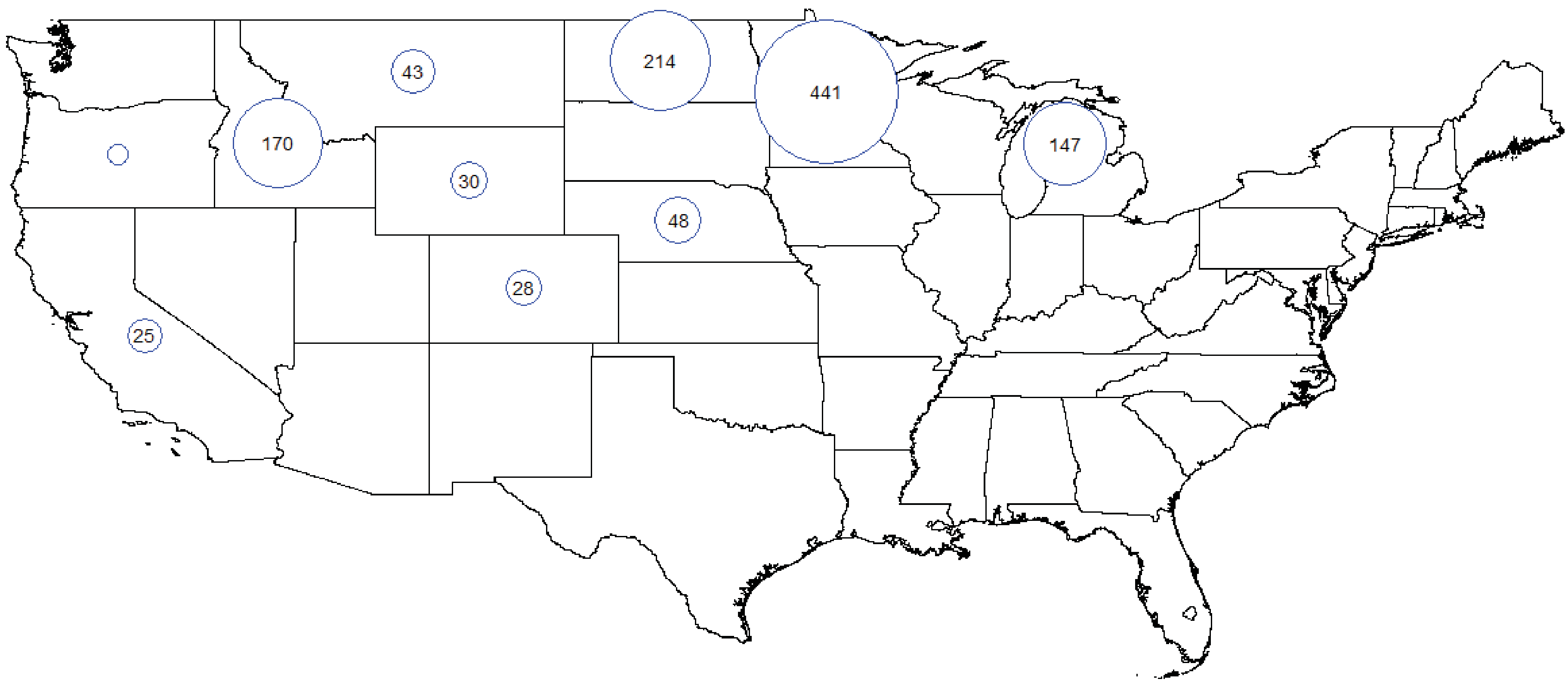


Figure 5: Cane Sugar Production (Raw Value)
by States, 1950
(in thousand short tons)

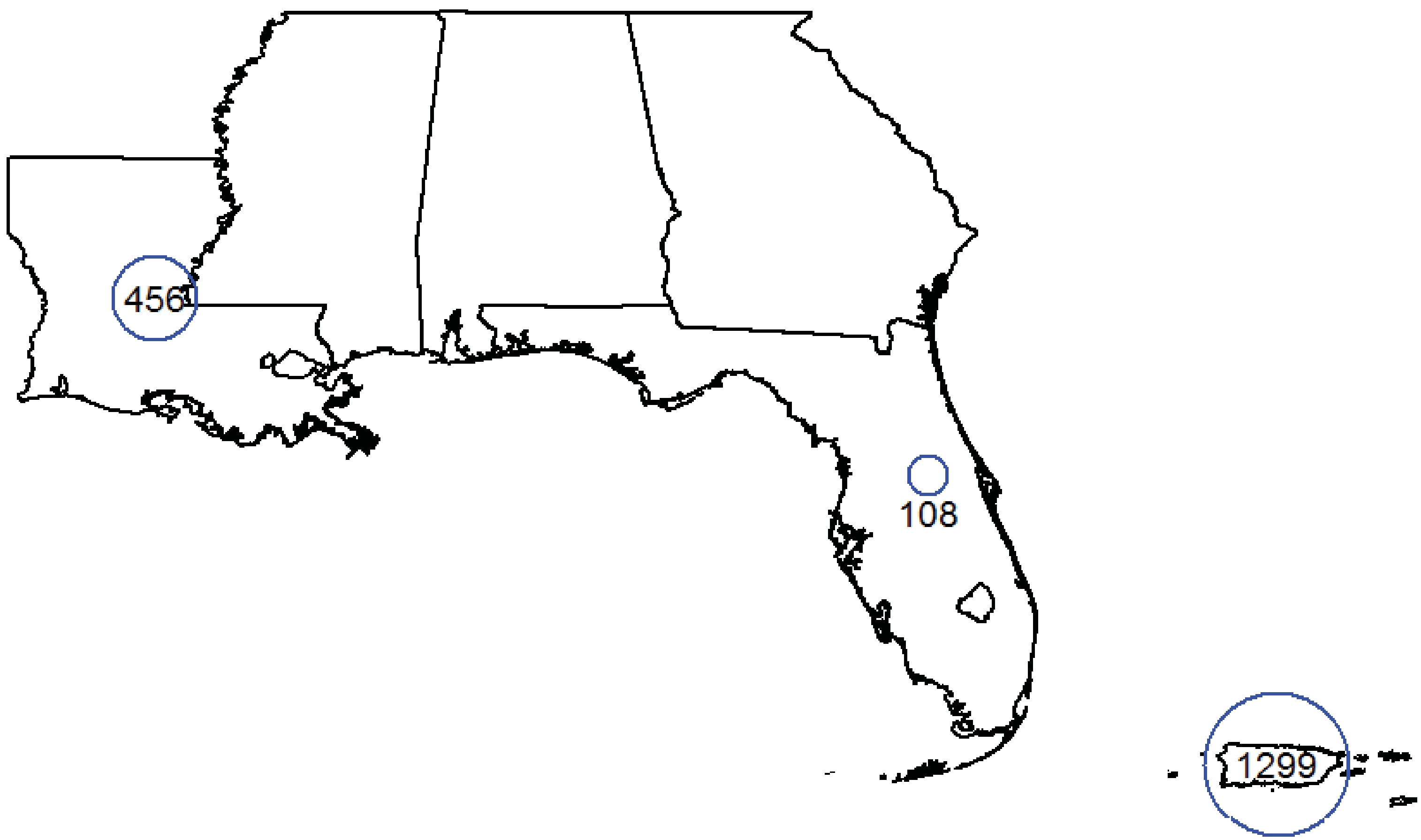


Figure 6A: Sugar Quota and Production
Puerto Rico

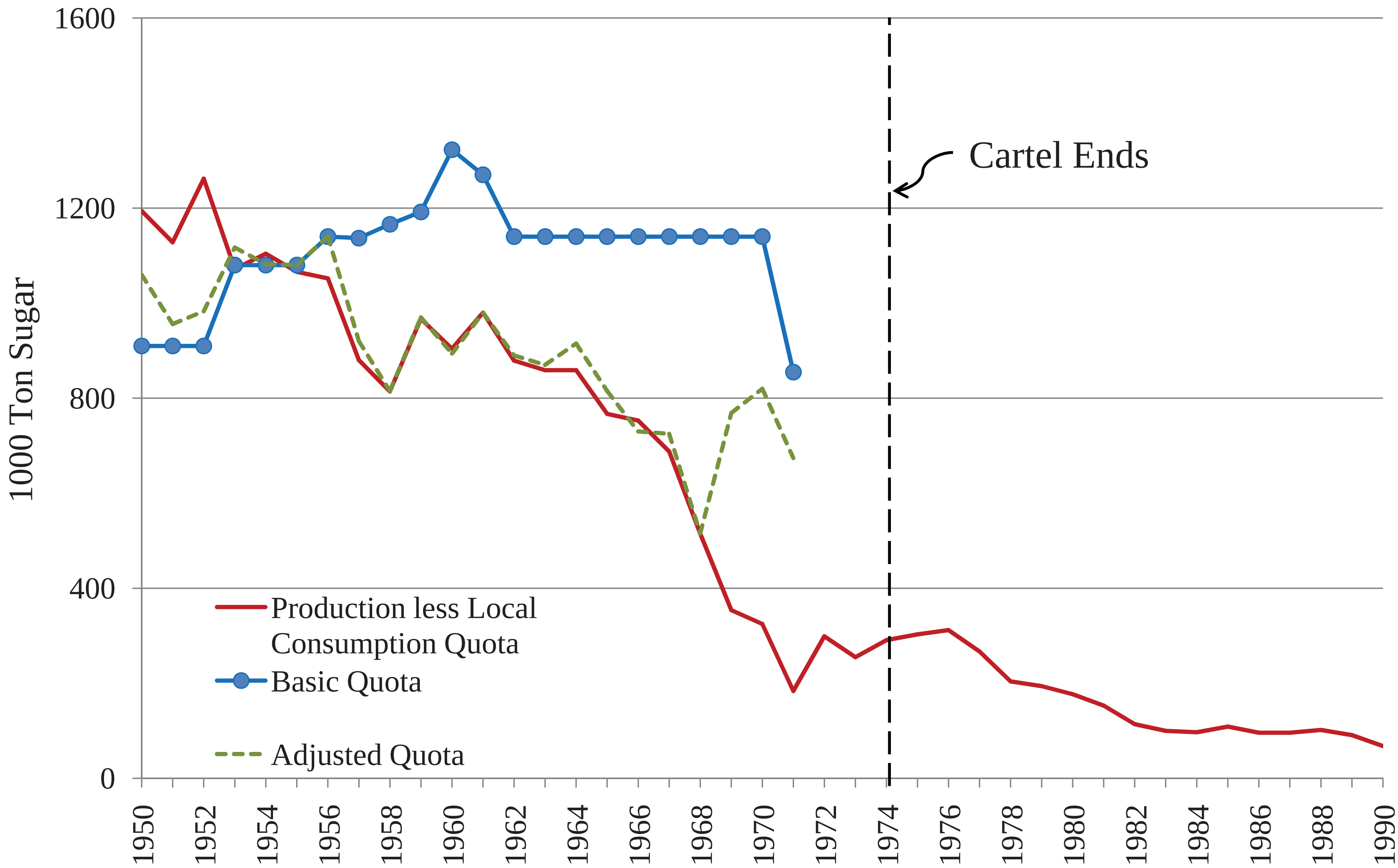


Figure 6B: Harvested Acres and Allotment, Louisiana

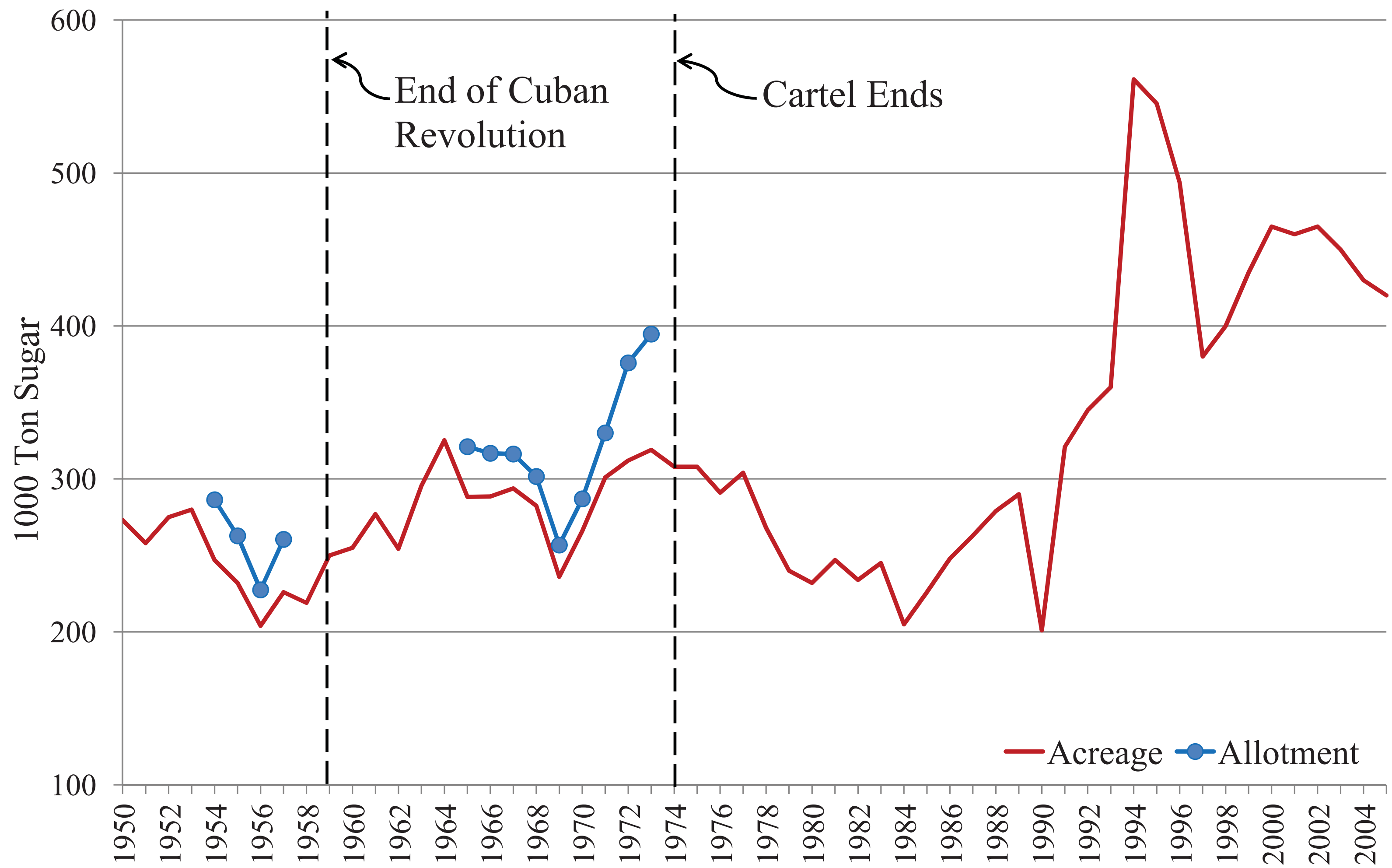


Figure 6C: Harvested Acres and Allotment, Florida

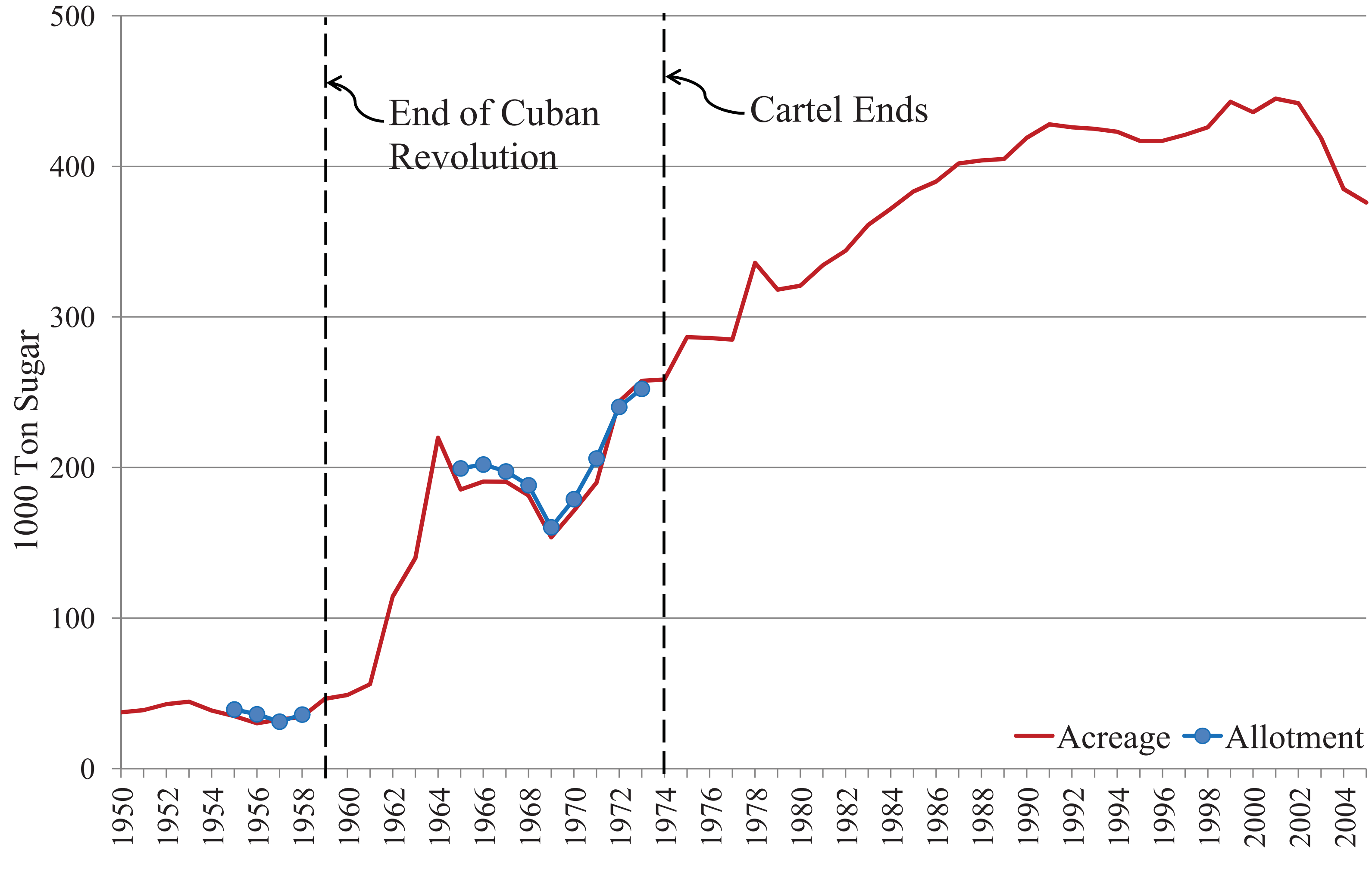


Figure 7: Share of Cane Sugar Production, by Region

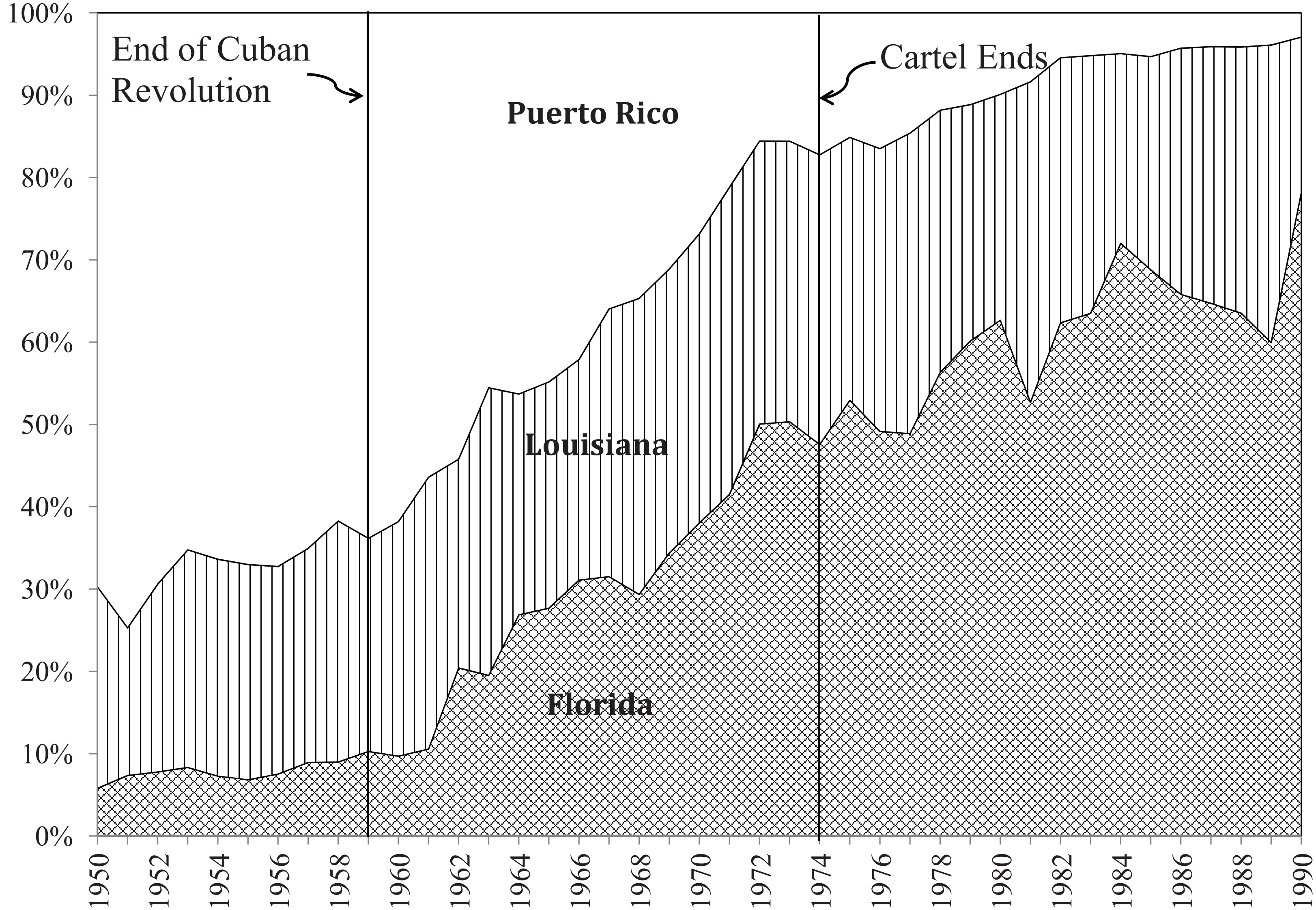


Table 1: U.S. Sugar Beet Industry
Key Statistics from Farming Sector, by State
(Current Dollars)

	1921-1923 Average			1964-1966 Average		
	Revenue per Acre	Costs per Acre	TFP	Revenue per Acre	Costs per Acre	TFP
MN	–	–	–	136.63	103.48	1.32
ND	–	–	–	135.86	103.28	1.32
MT	101.8	80.89	1.26	186.56	142.19	1.31
ID	106.00	97.90	1.08	225.92	196.11	1.15
MI	69.99	78.01	0.90	183.79	162.28	1.13
WA	–	–	–	293.51	291.29	1.01
UT	95.55	97.97	0.98	203.86	219.63	0.93
WY	83.22	82.31	1.01	178.91	194.88	0.92
CO	91.19	88.44	1.03	202.36	230.69	0.88
CA	87.43	85.34	1.02	251.49	291.17	0.86
NE	95.87	80.98	1.18	–	–	–
OH	73.45	70.14	1.05	–	–	–
Industry	87.88	85.98	1.02	254.73	294.32	0.87

Sources: Bridgman, Qi and Schmitz (2015), "Appendix to: Cartels Destroy Productivity: Evidence from the New Deal Sugar Manufacturing Cartel."

Note: In the table above, "–" indicates that data is not available.

Table 2: U.S. Sugar Beet Industry
Key Statistics from Farming Sector, by State
1964-1966 Average
(dollars per ton of Sugarbeets)

	Price (p)	Cost (c)	Markup ($p-c$)	TFP (p/c)	Side-Payment (s)	Payoff ($p+s-c$)
MN	11.84	8.97	2.87	1.32	2.30	5.17
ND	11.89	9.04	2.85	1.32	2.36	5.21
MT	12.91	9.84	3.07	1.31	2.49	5.56
ID	12.91	11.20	1.70	1.15	2.43	4.14
MI	11.46	10.12	1.34	1.13	2.24	3.58
WA	12.35	12.26	0.09	1.01	2.28	2.37
UT	12.85	13.84	-0.99	0.93	2.41	1.42
WY	12.77	13.91	-1.14	0.92	2.46	1.32
CO	12.81	14.60	-1.79	0.88	2.43	0.63
CA	12.24	14.17	-1.93	0.86	2.00	0.07
Industry	12.39	12.55	-0.16	0.99	2.25	2.09

Sources: Bridgman, Qi and Schmitz (2015), "Appendix to: Cartels Destroy Productivity: Evidence from the New Deal Sugar Manufacturing Cartel."

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Table 3: U.S. Sugar Beet Industry
Key Statistics from Farming Sector, by State
1964-1966 Average
(acres and tons in thousands, dollars in thousands)

	Total Tons	Total Revenue	Total Cost	Profits	Total Side-pay	Payoffs	Harv. Acres	Profits per Acre
MN	1,398.4	16,554.9	12,538.4	4,016.5	3,214.5	7,231.0	121.2	33.1
ND	702.7	8,355.1	6,351.4	2,003.7	1,654.8	3,658.5	61.5	32.6
MT	909.5	11,740.7	8,948.5	2,792.2	2,260.3	5,052.5	62.9	44.4
ID	2,630.6	33,955.1	29,474.8	4,480.3	6,401.5	10,881.8	150.3	29.8
MI	1,230.2	14,102.6	12,452.1	1,650.5	2,757.1	4,407.6	76.7	21.5
WA	1,339.9	16,554.1	16,428.9	125.2	3,049.8	3,175.0	56.4	2.2
Sub-total	8,211.2	101,262.6	86,194.1	15,068.5	19,338.1	34,406.6	529.0	28.5
UT	492.9	6,333.4	6,823.3	-489.9	1,189.8	699.9	31.1	-15.8
WY	768.5	9,816.5	10,692.5	-876.1	1,892.3	1,016.2	54.9	-16.0
CO	2,395.9	30,691.5	34,987.2	-4,295.8	5,811.6	1,515.8	151.7	-28.3
CA	6,391.5	78,205.5	90,543.2	-12,337.8	12,782.9	445.1	311.0	-39.7
Industry	18,260.0	226,309.3	229,240.4	-2,931.0	41,014.6	38,083.6	1,077.6	-2.7

Sources: Bridgman, Qi and Schmitz (2015), "Appendix to: Cartels Destroy Productivity: Evidence from the New Deal Sugar Manufacturing Cartel."

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Table 4: U.S. Sugar Cane Industry
Average Costs and Profits, by Area, 1964-1966 (avg.)
(cents per pound raw sugar)

	Farm Costs	Mill Costs	Farm + Mill Costs	Price	Profit	Side-Payment	Payoff
FL	3.62	1.41	5.03	6.99	1.96	0.48	2.43
LA	5.29	2.50	7.78	6.84	-0.94	0.73	-0.21
PR			7.63	6.96	-0.67	0.67	0.00

Sources: Bridgman, Qi and Schmitz (2015), "Appendix to: Cartels Destroy Productivity: Evidence from the New Deal Sugar Manufacturing Cartel."

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Table 5: U.S. Sugar Cane Industry
Key Statistics, by Area, 1964-1966 (avg.)
(Sugar Production in Million Pounds, Cost and Profit in Million Dollars)

	Production	Revenue	Costs	Profits	Side-Payments	Payoffs
FL	1,032.46	72.13	51.94	20.19	4.91	25.11
LA	1,121.62	76.75	87.31	-10.55	8.20	-2.35
PR	1,824.06	127.01	139.19	-12.19	12.19	0.00
Industry	3,978.14	275.89	278.44	-2.54	25.30	22.75

Sources: Bridgman, Qi and Schmitz (2015), "Appendix to: Cartels Destroy Productivity: Evidence from the New Deal Sugar Manufacturing Cartel."

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