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Does Regulation Reduce Productivity? Evidence From Regulation of the U.S. Beet-Sugar Manufacturing Industry During the Sugar Acts, 1934-74*

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ABSTRACT

Since Stigler (1970), economists have recognized that regulation is very often "used" by industry to limit competition. By limiting competition, regulation should keep industry prices "high." But by limiting competition it may have an adverse impact on productivity as well. While regulation's impact on prices is well studied, its impact on productivity is not. This is the main question of this paper: Does regulation reduce productivity? We analyze regulation of the U.S. sugar manufacturing industry during the Sugar Act period, 1934-74. Regulation dramatically reduced competition in this industry in this period. We find that regulation significantly reduced productivity at the factory level, induced the industry to move production location, and led to prices significantly higher than if there had been no regulation.

*The views expressed herein are those of the author and not necessarily those of the Federal Reserve Bank of Minneapolis, the Federal Reserve System, the U.S. Bureau of Economic Analysis or the U.S. Department of Commerce.

1. Introduction

Since Stigler (1970), economists have recognized that regulation is very often “used” by industry to limit competition. By limiting competition, regulation should keep industry prices “high.” But by limiting competition it may have an adverse impact on productivity as well. This is an age-old view, the view that lack of competition will retard innovation and more generally productivity, and Stigler (1957) presents a nice summary of it.

While regulation’s impact on prices is well studied, its impact on productivity is not. This is the main question of this paper: Does regulation reduce productivity? We analyze regulation of the U.S. sugar manufacturing industry during the Sugar Act period, 1934-74. Regulation dramatically reduced competition in this industry in this period. Factories were given sales quotas, farmers were given acreage quotas, and foreign countries were given quotas.

As Stigler (1970) also argued, there was typically more to regulation than limiting competition. Once an industry uses the political process to limit competition, some groups of the industry with more political power may try to insert other regulations to shift the benefits of reduced competition to themselves. Stigler gave examples of how smaller firms typically benefited relative to large firms in appropriating limited production quotas or import quotas. This phenomena was at work here. For “voluntarily” abiding by acreage quotas, farmers were sent checks by the government. Factories were taxed on the sugar they produced (even though they abided by quotas). We’ll call this second feature of regulation a redistribution scheme.

The regulation of the sugarbeet manufacturing industry, then, looks similar to regulation in many industries. A prime consequence of regulation is to limit competition in industry. In the trucking industry, certificates were needed to enter markets. In the banking industry, firms were often limited to single branches. In these and most regulated industries, industry uses the regulatory process to limit competition within the industry (and from without). And this was true in the sugar industry as well.

While regulation in the sugar industry shares features with other industries, its different in a key aspect: it is relatively easy to study the impacts of regulation. Among other things, regulations were not complex, productivity is easy to measure, and regulation was preceded, and followed, by many years of no regulation.

We find that regulation significantly reduced productivity at the factory level, induced the industry to move production location, and led to significantly higher prices than if there had been no regulation. This is a positive analysis, normative analysis will follow.

The outline of paper is as follows. In the next section, we present some background on the industry and regulations during the Sugar Act period. We also sketch some intuition for how the regulations would influence industry productivity, its location and its prices. In Section 3, we present time series evidence on these three variables, productivity, location and prices. In Section 4, we introduce a simple model that we will use to analyze the impact of regulation. It is a model of a factory operating in a non-irrigated area, one where farmers have no control over the sugar content of their beets. In Section 5, we extend the model to an irrigated district, one where farmers can influence sugar content of the beets. In Section 6, we begin our analysis of regulation, asking how the redistribution scheme influenced industry location and productivity. In Section 7, we examine the impact of regulations that limited competition.

2. Overview of Industry and Regulation

We set the stage here. We'll introduce enough notation so that we can show key data in the next section.

A. Overview of Industry.

We denote the output of the industry, that is, white-sugar, by y. For example, y might be 100-pound bags (CWTs) of white-sugar. Factories produce y using factory inputs, like labor, energy, and capital, and sugarbeets that are typically farmed very close to the factory.

We'll let t denote tons of beets. The beets contain sugar. We'll let s denote the tons of sugar contained in the beets, or sugar-in-the-crop as opposed to in-the-bag (i.e., y). The beets typically contain only small amounts of sugar, that is, the sugar content of the beets, $q = s/t$, is on the order of 15 percent. This is a big reason why transportation costs loom large, and beets typically shipped only short distances. Factories pay farmers for beets based on the sugar in the beets s, based on contracts signed before the season opens.

Not all sugar in the beets will be extracted, of course, that is, $y/s < 1$.

B. Overview of Regulation.

From its beginnings in the 1870s until to 1934, the U.S. government's role in the sugarbeet industry was simple: it set a tariff that protected the industry. There was no domestic regulation of the industry.

Government involvement in the industry dramatically changed in the Great Depression, as it did in many industries. In 1934, the government created a very significant regulatory apparatus under the Sugar Acts that would last 40 years, 1934-74. There were two main features of regulation. First, the government undertook programs to control the sales of sugar in the U.S. market. Second, and as is so often the case when the political process is used to control production, some groups in the industry (e.g., the farmers) were able to institute programs to shift some of the benefits of regulation toward themselves and away from other groups (e.g., the factories).

Regarding controlling sales of sugar, there was a program to limit foreign sales into the U.S. market and a program to limit domestic sales. In particular, once the government set a sales-target for a year (sometimes called the "consumption estimate"), it used a formula to divvy this sales between foreign and domestic sources. To control foreign sales, it used quotas. Given foreign sugar had to enter through ports, quotas were easy to enforce. To control domestic sales, an elaborate regulatory apparatus was set up. Manufacturing firms were given marketing allotments. They could not sell more than these allotments. Since there were only about 15 firms, it was also fairly easy to monitor sales of these firms. Still, as another way to control supply, farmers were given acreage allotments stating how many acres they could devote to beets.

As mentioned, the second feature of regulation involved programs "redistributing" benefits of regulation (flowing from limited supply) from factories to farmers. In particular, farmers were sent checks from the government that were based on the sugar s they produced. They were big checks. Also, factories were taxed on the bags of sugar y they produced. The rationale (there always is one) for sending farmers checks was to compensate them for voluntarily abiding by the acreage allotments.

What impact might we expect from these regulations? Let us sketch some arguments, and later establish them in the context of a model. Lets look at this in two steps. First, we'll assume that there is a tariff, and consider the impact of the programs to redistribute benefits. Then we'll consider the impact of moving from a tariff to domestic and foreign quotas.

Assume sugar prices are fixed (at the world price plus the tariff). Again, the redistribution scheme had government sending farmers checks for s, and taxing factories for bags y. Recall, the factory gives farmers checks for s; the government payment is a (big) bonus on the factory check. In effect, the government is telling one part of the manufacturing enterprise to make lots more input (s), and another to make less output (y). Its not inconceivable that this could lead to adverse productivity consequences. Lets sketch some.

In some areas farmers can influence $s = q \cdot t$. How? This is typically achieved at the end of the growing season, using methods that increase s, by increasing t, though decreasing q. These growing methods were available before the Sugar Act, of course, but the government bonus created greater incentives to pursue them. As we discuss below, lowering q will have an adverse effect on factory productivity.

Some areas have higher s (because of better weather conditions, etc.), and the government bonus created greater incentives for farmers to expand there. This lead the industry to shift toward these areas. So, there are two initial effects: factory productivity down, and changes in location.

One might also expect the bonus to influence farmer innovation, and it did. Farmers found more ways to increase s, again typically involving decreases in q.

Next, consider the impact of moving from a tariff to domestic and foreign quotas. Since foreign sugar was subject to quota, the domestic price was decupled from the world price. Consider the pricing strategy of a domestic manufacturing firm. Given the firm had a fixed allotment, it had no incentive to cut price to increase its profit. So, domestic regulations should keep prices high. So, it is not foreign protection that should keep prices high, but foreign protection and domestic regulations in tandem.

One might also expect factories incentives to innovate to be dulled. The return to finding better ways to manufacture sugar and hence lower costs was limited, since firms had fixed allotments. Also, competition was stifled, an negative effect on innovation (perhaps) over and above the influence of a fixed allotment.

Again, the sugar act expired in 1974. The redistribution scheme was ended. The control of domestic sugar sales was ended. Foreign quotas were kept (though the foreign quotas have been reduced over time). Given that there is no control of domestic sales, competition has increased. Another development was the introduction of high fructose corn syrup in the late 1970's, which also increased competition.

3. Productivity and Industry Location over the Century

A. Factory and farm productivity

Figures 1-6 present evidences on factory productivity over time. All the figures show a similar pattern, that productivity is growing until the sugar act begins in 1934, and then productivity begins to decline. So in particular, productivity continues to grow through the Great Depression. In this version of the paper, we show productivity at the factory level for a small set of factories. But these factories are representative of the other factories in the industry.

Figures 1 and 2 show output (y) relative to energy use (b, which is BTU's in Figure 1 and Coal in Figure 2) in four factories, Oxnard (in California, owned by American Crystal), Rocky Ford (in Colorado, owned by American Crystal), Billings (in Montana, owned by Great Western), and Gering (in Nebraska, owned by Great Western). Energy is an important factory input (energy costs are as large as labor costs). As seen, productivity is growing until 1934 then falls. Figure 3 shows output relative to labor input at Oxnard and Rocky Ford Here we only have data beginning in 1929. The pattern here is similar to that in Figure 1 and 2.

Another measure of factory productivity which is more widely available is the recovery rate (y/t). The recovery rate is the output of sugar per ton of beets. In Figure 4, we plot the recovery rate for Oxnard, Billings and Rocky Ford, factories we have introduced before, and a new factory Spreckel's #1 (in California, owned by Spreckel's). The pattern of the recovery rate in the first 3 factories look similar to the other measures of productivity in those factories, increasing until 1934 and then falling.

In Figure 5, we present recovery rate data on 3 Midwestern factories, East Grand Fork, Moorhead, and Crookston, all American Crystal factories, and Sidney (in Montana, owned by Holly). These factories show a decline in recovery rate through the sugar act period, then an increase post-1974.

In Figure 6, we show the national recovery rate. There is a clear relationship between the national recovery rate and the sugar act. In the figure, we also plot the recovery rates of Oxnard, Spreckel's and East Grand Forks. Note that the recovery rates fall faster at the factory levels than the national level. The reason is industry production during the sugar act was shifting from low recovery rate regions (like East Grand Forks) to high ones (like California). We discuss locations in the next section.

We would also like to present data on sugar output (y) relative to farm inputs, but they are harder to obtain. For now, we will present data on sugar output relative to acres. In Figure 7, we show y/a for California. There is a noticeable reduction in the trend growth of output per acre beginning in 1934.

We have not as yet attempted to construct measures of TFP for individual farm/factory units. Our (partial) factory productivity measures (like y/n and y/b) show trend reversal, from positive to negative growth. Our (partial) farm productivity measures (like y/a) show a slow-down in trend. Hence, we are fairly confident that standard measure of TFP growth would show a significant slowdown (or even decline) at the start of the sugar act in 1934.

It would be hard to imagine that TFP growth remained negative throughout the sugar act period. We know factories introduced packaging equipment that led to significant reductions in manning requirements. But certainly, one can imagine TFP stayed significantly below the pre-sugar-act trend. Finally, note that there are estimates of TFP for this industry from 1957 to 1996 from Bartelsman and Gray (in the NBER four digit manufacturing industry data). They estimate that TFP is declining from 1957 until the late 1970's, and then shows significant growth from the 80's on. While this is interesting, we believe their materials deflators may be biased (the quality of materials is declining, but we think the deflators are not adjusted for that).

B. Location of industry

In Figure 8, we plot the shares of harvested acres by various regions in the United States. Years of the sugar act are denoted by the dashed lines. In some states, farmland is typically non-irrigated. This is true of mid-western states. Irrigated farmland itself can usefully be decomposed into areas with extensive rainfall and more arid areas, much of the Great Plains in the former, some of California in the latter. As can be seen, the share of the acres in the Far West rose during the sugar act period at the expense of other areas. What is quite dramatic is the extent to which the Midwest has grown in share of acres since the sugar act was not renewed.

C. Sugar prices

In Figure 9, we present time series on three real sugar prices, US raw (Duty-fee-paid NYC), Midwest wholesale refined, and World raw (Caribbean FOB). As can be seen, US sugar prices moved with the world price before the sugar act. During sugar act, US sugar prices were fairly constant, and did not move with the world price (unless the world price moved above the US price). After the sugar act, US sugar prices have been falling significantly, about 2-3% a year. Note that world prices have been fluctuating up and down during this period, with little or no trend.

4. Model of a Non-Irrigated Factory District

In this section we model the workings of a factory in a non-irrigated factory district before the Sugar Act of 1934. The distinction between the model in this section and the next, the irrigated district case, is that farmers here will not be able to manipulate (or influence) tons t and sugar s per acre. As we'll discuss below, factories in non-irrigated districts did not pay farmers based on the sugar content $q = s/t$ of their individual tons, but rather the district average q, on the theory that farmers had little control over q. We begin by discussing the environment.

A. Environment

For now, consider a one period model.

Preferences

Since the sugar industry faced a price that was the world price multiplied by a tariff, $p_y = p_{y,US} = p_{y,world}(1 + \tau)$, until 1934, we'll assume that this factory faces a fixed price for its output.

Endowments

We assume that there is an existing factory, that may or may not be operated. Assume for now that there is only one factory (in the country!).

We next turn to describe technology.

Transport technologies and land distribution

Farmland differs in how "far" it is from the factory. In particular, farms differ in the cost x to deliver a ton from the farm to the factory. Let $A(x)$ denote the total number of acres such that it costs x to deliver a ton. Sugarbeets must be grown in rotation. Hence, let $a(x)$ denote the number of acres where sugarbeets can be grown such that it costs x to deliver a ton. We treat $a(x)$ as a parameter. Obviously it is determined by transportation facilities, cropping patterns, etc. We display this geographical abstraction in Diagram 1.

Farming and harvesting technologies

We assume farmland around the factory does not differ in quality. The production function for one unit of such farmland, say an acre, is

$$(t, s) = \begin{cases} (0,0) & \text{if} \quad n_{farm} < \widetilde{n}_{farm} \\ (\widehat{t}, \widehat{s}) & \text{if} \quad n_{farm} \geq \widetilde{n}_{farm} \end{cases}$$

where n_{farm} is a measure of farm input. Hence, if the farmer uses input $n_{farm} = \widetilde{n}_{farm}$, then he produces $\widehat{t}$ tons of sugar beets with sugar $\widehat{s}$. Hence, the sugar content is $\widehat{q} = \widehat{s}/\widehat{t}$. The input n_{farm} refers to the input of the farmer. For simplicity, we abstract from the input "farm-help". In fact, farm-help was extremely important in this industry. That there are only two inputs (land and labor) is for simplification.

With this technology, the farmer has no control over tonnage and sugar (assuming the minimum level of required inputs are used). Note as well that we don't have any uncertainty. Weather, in fact, did move around tonnage and sugar, something we will consider in the next version.

Let $t(x)$ be number of tons whose cost of delivery is x dollars. Hence, $t(x) = a(x) \cdot \widehat{t}$.

For the harvesting technology, we simply assume the cost of harvesting t tons is $c_{harv} \cdot t$.

Factory processing technology

As beets are delivered to the factory, the factory can process them in bunches, depending on their quality q. While all beets are of the same quality here, let us, to be consistent with what follows in the irrigated section below, consider processing the tons from x, that is, $t(x)$, separately from other tons. We will present the technology and then offer an extended discussion of it.

Factory output is $I(x) \cdot y(x)$. $I(x)$ is an indicator function which states that we must employ enough repair staff to maintain machines or output is zero, that is,

$$I(x) = \begin{cases} 0 & \text{if} \quad n_{repair} < \delta t(x) \\ 1 & \text{if} \quad n_{repair} \geq \delta t(x) \end{cases}$$

where $n_{repair}(x)$ is repair labor. If $I = 1$, then production is

$$y(x) = e[\widehat{q}, n_{prod}(x)/t(x)] \cdot s(x) = e[\widehat{q}, z(x)] \cdot s(x)$$

where $n_{prod}(x)$ is the production labor devoted to processing beets from a distance x, $z(x) = n_{prod}(x)/t(x)$ is the "effort" per ton, and $e[\widehat{q}, 0] = 0$, $e_z[\widehat{q}, z] > 0$, $e_{zz}[\widehat{q}, z] < 0$, $e_z[\widehat{q}, 0] = \infty$ and $e[\widehat{q}, \infty] < 1$. With z fixed, one might imagine that $y/s = e[q, z]$ would increase as q increases. That is, the higher the sugar content, the higher the extraction rate, for fixed z. So, we assume $e_q > 0$. Again, that we only have two factory inputs, $n_{prod}(x)$ and $n_{repair}(x)$, is for simplicity.

The function $e[\widehat{q}, z(x)]$ is an extraction function. Starting with sugar in the crop s, the factory extracts $e[\widehat{q}, z(x)] \cdot 100$ percent, or produces $e[\widehat{q}, z(x)] \cdot s$. The function has constant returns in $(n_{prod}(x), t(x))$, that is, double $n_{prod}(x)$ and $t(x)$, double y. Keeping $n_{prod}(x)$ and $t(x)$ fixed, increasing q increases y for two reasons: s increases, and extraction increases (assuming $e_q > 0$).

Why add repair labor? First, this will mean that the factory will not want to process tons below some minimum quality, an important property to have. Second, note that if the factory starts processing tons of lesser quality, its productivity may well decrease (see below for discussion).

Factory output is then $y = \int I(x) \cdot y(x)$. There is of course a capacity constraint, say, $\int t(x) = T \leq \overline{T}$, but we'll ignore it for now.

B. Planning Solution

Consider a "planner" who maximizes industry surplus, that is industry revenue, $p_y \cdot y$, less industry costs, the sum of factory costs, farm costs and transportation costs, taking as given the output price p_y and the input prices (which are given below). In particular, he takes as given the price of a unit of land, p_L. This is the value of land in its next best alternative.

Think of two stages, the farming and the manufacturing. We'll define value functions at each stage. Let $V_{fact}(\{s(x), t(x)\})$ be the value at the processing stage given we have $t(x)$ tons from distance x, those tons having sugar $s(x)$, where $x \in X$ (where the subscript $''fact''$ is short for factory). Here, as will be shown, total tons $T = \int_{x \in X} t(x)dx$ is a sufficient state variable, that is, we can write the value function as $V_{fact}(T)$. This is because all tons have the same sugar content. Let V_{farm} be the value at the farming stage (where the subscript $''farm''$ is short for farm).

Processing stage

We start at the last stage. Again, we process tons separately. Let $v_{fact}(t(x))$ be value of $t(x)$ tons from x. we have that

$$v_{fact}(t(x)) = \max_{n_{prod}(x), n_{repair}(x)} rev_{plan}(t(x)) - cos_{fac}(t(x))$$

where revenue of the planner is $rev_{plan}(t(x)) = p_y \cdot I(x) \cdot y(x)$ and where factory costs are $cos_{fact} = [n_{prod}(x) + n_{repair}(x)] \cdot p_{n,fact}$, where $p_{n,fact}$ is the cost of factory labor. If we process tons (i.e., $n_{repair}(x) = \delta \cdot t(x)$), then the first order condition for $n_{prod}(x)$ is

$$(1) \qquad p_y e_z[\widehat{q}, z(x)] \cdot \widehat{q} = p_{n,fact}$$

so, $z(x)$ does not depend on x, say $z(x) = z_{plan}$, and $n_{plan}(x) = z_{plan} \cdot t(x)$. Define the constant v_{fact} by

$$v_{fact} = \{p_y e[\widehat{q}, z_{plan}] \cdot \widehat{q} - p_{n,fact} \cdot [z_{plan} + \delta]\}.$$

[We need assumption A1, $v_{fact} > 0$]. Then $v_{fact}(t(x)) = v_{fact} \cdot t(x)$. Hence, $V_{fact}(T) = v_{fact} \cdot \int t(x)dx$.

Farming stage

The planner farms the closest acres first, so the choice of planner is how far to farm, that is, $X_{plan} = [0, x_{plan}]$. The problem is

$$V_{farm} = \max_{x_{plan}} V_{fact}(T) - cos_{farm}(x_{plan}) - cos_{tran}(x_{plan})$$

where $cos_{farm}(x_{plan}) = \int_0^{x_{plan}} \{[p_L + p_{n,farm} \cdot \widetilde{n}_{farm}] \cdot a(x) + c_{harv} \cdot t(x)\}dx$ is farming costs (where $p_{n,farm}$ is alternative value of the farmer's labor), and where $cos_{tran}(x_{plan}) = \int_0^{x_{plan}} x \cdot t(x)dx$ is transport costs, and where $T = \int_0^{x_{plan}} t(x)dx$. The marginal farm, on a per acre basis, is

(2) $$v_{fact} \cdot \widehat{t} = [p_L + p_{n,farm} \cdot \widetilde{n}_{farm}] + [c_{harv} + x_{plan}] \cdot \widehat{t}.$$

[We need assumption A2, $v_m \cdot \widehat{t} > [p_L + p_{n,farm} \cdot \widetilde{n}_{farm}] + c_{harv} \cdot \widehat{t}\}$, that is, at acre $x = 0$, its worth farming]. This gives us the solution for x_{plan}, which is

$$x_{plan} = v_{fact} - [\frac{p_L + p_{n,farm} \cdot \widetilde{n}_{farm}}{\widehat{t}}] - c_{harv}$$

C. Market Solution

Early in the industry's history, there were attempts to run the factory and farms as one integrated unit as above. This arrangement was proved to be inefficient. The industry learned that beets had to be grown in rotation with many other crops. Hence, if the beet factory wanted to own its beet farms, it needed to engage in a wide spectrum of farming activities. Running an integrated operation, perhaps because of managerial diseconomies, was not common.

Rather than integrated production, the industry moved to a model where factories purchased beets from farmers under contracts that were signed before the growing season began. This alternative has dominated. (footnote: mention coops).

Recall we are assuming that there is an established factory (and only one). Hence, on the processing side, there is a fixed factor: the factory. There is another fixed factor: namely, the land close to the factory. Because of these fixed factors, economic profits are earned. Farmers close to the factory, and the factory owners, could likely give good reasons why they deserved the lion's share of economic profits.

Here is how the market worked. Beets were purchased under contracts signed before the growing season began. If both sides signed the contract, then (i) farmer agrees to grow beets on certain amount of acres and (ii) the factory agrees to buy tons from those acres, at price specified in contract (note: the same price applies to each farmer).

The contract (if signed by both parties) pays farmers for each ton of beets. The contract typically pays (per ton of beets)

$$p_B() = \theta \cdot p_y \cdot q_{avg}$$

where $\theta \in [0, 1]$, and where q_{avg} is the average quality delivered over all beets in the factory district. Since all the beets are the same, $q_{avg} = \widehat{q}$. The parameter θ is like the farmer's share of industry revenue. If extraction was perfect, that is, $e = 1$, then $y = s = q \cdot t$, industry revenue is $p_y \cdot y$, and farmer revenue is $\theta \cdot p_y \cdot q \cdot t = \theta \cdot p_y \cdot y$.

In addition, factories also subsidize some of the transportation to the factory. Typically, the contracts call for the factory to pay transportation from railway depots to the factory. Farmers pay transportation from their farm to the depots. This feature is common across areas, and over decades and decades. In our model, if the cost is x, we assume that the factory pays $\sigma \cdot x$, $\sigma \in (0, 1)$.

So, the contract is a (θ, σ) pair.

Outline of Analysis (for given (θ, σ))

To begin our analysis, lets assume that a pair (θ, σ) has been chosen. We ask: How many acres will be contracted? Lets sketch our approach first, then fill in the details.

Given (θ, σ), a farmer can decide if he would like to sign a contract with the factory. Let $x_{farm}(\theta, \sigma)$ denote the "marginal" farmers, that is, those farmers that are indifferent to signing. Farmers at $x < x_{farm}(\theta, \sigma)$ will want to sign. The factory can also decide what farmers it would like to sign contracts with. Let $x_{fact}(\theta,\sigma)$ denote the "marginal" farmer that the factory would like to sign. It would like to sign farmers at $x < x_{fact}(\theta,\sigma)$. The contracted acres, given both sides have to sign, will be the lesser of what the factory wants and the farmers want. That is, the contracted acres are $x_{cont}(\theta,\sigma) = \min[x_{farm}(\theta,\sigma), x_{fact}(\theta,\sigma)]$.

Farmers problem (for given (θ,σ)***)***

Lets assume that at each x, there are $a(x)$ farmers, that is, one farmer per unit of land. We'll assume that the farmer owns the land. For simplicity, we assume the farmer works the land growing sugarbeets or rents out the land, but the rented land cannot be used to grow sugarbeets. Hence, the land rents at price p_L. (We could introduce a rental market for beet land. Beet land would rent for more than p_L. We could calculate beet land rental rates from the farmers profit at x. But a beet rental market would not change the analysis below).

A farmer at x has revenue

$$rev_{farm}(x) = [p_y \cdot \theta \cdot \widehat{q}] \cdot \widehat{t}$$

and costs, $cos_{farm}(t(x))$ and $(1-\sigma) \cdot cos_{tran}(t(x))$. The $x_{farm}(\theta,\sigma)$ is

$$\text{(3)} \qquad [p_y \cdot \theta \cdot \widehat{q}] \cdot \widehat{t} = [p_L + p_{n,farm} \cdot \widetilde{n}_{farm}] + [c_{harv} + (1-\sigma) \cdot x_{farm}] \cdot \widehat{t}$$

where $p_L + p_{n,farm} \cdot \widetilde{n}_{farm}$ is the opportunity cost of the farmer. We denote the $x_{farm}(\theta,\sigma)$ by $x_{farm}(\theta,\sigma)$, which can be written

$$x_{farm}(\theta,\sigma) = \frac{1}{1-\sigma}\{p_y \cdot \theta \cdot \widehat{q} - [\frac{p_L + p_{n,farm} \cdot \widetilde{n}_{farm}}{\widehat{t}}] - c_{harv}\}$$

We plot $x_{farm}(\theta,\sigma)$ in Diagram 2 as a function of θ. Denote the solution to $x_{farm}(\theta,\sigma) = 0$ as $\theta_{\min}(\sigma)$. $x_{farm}(\theta,\sigma)$ is increasing in θ beyond $\theta_{\min}(\sigma)$.

Factory problem (for given (θ,σ)***)***

We process tons separately. Let $\pi_{fact}(t(x))$ be value of $t(x)$ from x. We have that

$$\pi_{fact}(t(x)) = \max_{n_{prod}(x), n_{repair}(x)} rev_{fact}(t(x)) - cos_{fact}(t(x)) - \sigma \cdot cos_{tran}(t(x))$$

where $rev_{fact}(t(x)) = I(x) \cdot p_y \cdot [y(x) - \theta \cdot s(x)]$, that is, if $I = 1$, then the factory sells to market $p_y \cdot y(x)$, and pays farmer $p_y \cdot \theta \cdot s(x)$, and where $cos_{fact}(t(x))$ and $cos_{tran}(t(x))$ are as above. Recall the factory is paying some of the transport. If we process (i.e., $n_{repair}(x) = \delta \cdot t(x)$), then the first order condition for $n_{prod}(x)$ is

(4) $$p_y e_z(\widehat{q}, z(x)) \cdot \widehat{q} = p_{n,fact}$$

so, $z(x)$ is identical to the planner's, that is, $z(x) = z_{plan}$. We have

$$\pi_{fact}(t(x)) = \{p_y[e(\widehat{q}, z_{plan}) - \theta] \cdot \widehat{q} - [z_{plan} + \delta] \cdot p_{n,fact}\} \cdot t(x) - \sigma \cdot x \cdot t(x)$$

For each θ, we can ask: from what distance is the factory willing to purchase beets? That is, we can solve $\pi_{fact}(t(x)) = 0$. Call the solution $x_{fact}(\theta, \sigma)$, which can be written

$$x_{fact}(\theta, \sigma) = \frac{1}{\sigma}\{p_y[e(\widehat{q}, z_{plan}) - \theta] \cdot \widehat{q} - [z_{plan} + \delta] \cdot p_{n,fact}\}$$

We plot $x_{fact}(\theta, \sigma)$ in Diagram 2. Denote the solution to $x_{fact}(\theta, \sigma) = 0$ as $\theta_{\max}(\sigma)$. $x_{fact}(\theta, \sigma)$ is decreasing in θ up until $\theta_{\max}(\sigma)$.

Contracted acres (for given (θ, σ)***)***

Again, contracted acres are $x_{cont}(\theta, \sigma) = \min[x_{farm}(\theta, \sigma), x_{fact}(\theta, \sigma)]$. Contracted acres are the dotted line in diagram 2. Let $\theta = \theta_{plan}$ solve $x_{farm}(\theta, \sigma) = x_{fact}(\theta, \sigma)$. Note that at $\theta = \theta_{plan}$, $x_{cont}(\theta, \sigma) = x_{plan}$. When $\theta < \theta_{plan}$, farmers "determine" contracted acres, when $\theta \geq \theta_{plan}$, the factory does.

Model of (θ, σ) ***choice***

We will model the factory as a monopsonist. Note that the factory could extract all the profits from the farmers by paying all the transportation (that is, choosing $\sigma = 1$), so that all farmers are alike, and then driving θ low enough so that farmers are indifferent between growing beets and renting out land at p_L. We know the factory does not do this (that is $\sigma < 1$ in all contracts), so it cannot be a perfectly price discriminating monopsonist. So, we will model the factory as choosing a uniform θ, subject to the condition that it pays some of the transportation charges (again, the railroad charges).

Before we present this maximization problem, let us consider why the factory does not choose $\sigma = 1$, and a very "low" θ? First, there are other reasons why different farms may be high or low profitability in beets (besides the farm's x value) and these may not be observed by the factory. This may lead the factory to choose $\sigma < 1$. Or there may be pressure from farm groups to keep $\sigma < 1$.

Again, we assume that the factory takes σ as given, and chooses θ to maximize its profits. Denote the factory's profits by $\Pi_{fact}(\theta, \sigma)$. Then

$$\theta_{fact} = \arg\max_{\theta} \Pi_{fact}(\theta, \sigma)$$

$$s.t. \;\; \sigma = \widetilde{\sigma}$$

What can we say about θ_{fact}? Diagram 3 reproduces the contracted acre diagram in its upper half, the bottom half plots profits of the factory and farms. Consider factory profit, $\Pi_{fact}(\theta)$. When $\theta = \theta_{\min}$, the factory gets no tons and the profit is zero. As θ increases, there are two effects. First, farmers deliver beets and profit increases. Second, the payment to infra-marginal farmers increases, and profits fall. Profit reaches a maximum at $\theta = \theta_{fact}$, $\theta_{fact} < \theta_{plan}$. This result is simply that a monopsonist pays less than the efficient level. We also plot total farm profits, $\Pi_{farm}(\theta)$. Note that industry profit, $\Pi_{ind}(\theta) = \Pi_{fact}(\theta) + \Pi_{farm}(\theta)$, equals V_{farm}, at $\theta = \theta_{plan}$.

We have been examining a few issues that might tell us whether our model of the θ choice is a reasonable one. We have been looking at periods when there were significant decreases in the prices of alternative crops in the pre Sugar Act period. In these periods, there would be significant reductions in p_L, the alternative value of the land. In the model, with large decreases in p_L, the curve $x_{farm}(\theta, \sigma)$ would shift out. One might also expect $\theta_{fact}(p_L)$ to decrease in the model. What would happen to contracted acres in the model depends on how much $\theta_{fact}(p_L)$ decreases, and how much $x_{farm}(\theta, \sigma)$ increases. During these periods, sugarbeet factories did increase their purchases of beets, and did reduce θ.

We also have the actual contracts, hence we know θ. We can estimate θ_{fact} and θ_{plan}, and then compare them to the actual θ. θ_{plan} is simple to calculate, and equals

$$\frac{(1-\sigma)(p_y eq - (z+\delta)p_{n,fact}) + \sigma[(p_L + p_{n,farm} \cdot \widetilde{n}_{farm})/\widehat{t} + c_{harv}]}{p_y eq}$$

$$= e(z) \cdot (1 - \frac{cos_{fact}}{rev} + \sigma(\frac{cos_{fact} + cos_{farm}}{rev} - 1))$$

From our work thus far, we estimate θ_{plan} to be about .57. The actual θ's are in the range of $.45 - .48$, quite a bit lower than θ_{plan}. We have not yet estimated θ_{fact}.[1]

5. Model of an Irrigated Factory District

In this section we model the workings of a factory in an irrigated factory district before the Sugar Act of 1934. The distinction between the model in this section and the last, the non-irrigated district case, is that farmers here will be able to manipulate (or influence) tons t and sugar s per acre. Factories in irrigated districts typically paid farmers based on the sugar content $q = s/t$ of their individual tons. We begin by discussing the environment.

A. Environment

The only change in the environment is in the farming technology. The production function for one unit of farmland, say an acre, is

$$(t, s) = \begin{cases} (0, 0) & \text{if} \quad n_{farm} < \widetilde{n}_{farm} \\ (\overline{t} + f(w), \overline{s} + \gamma \cdot f(w)) & \text{if} \quad n_{farm} \geq \widetilde{n}_{farm} \end{cases}$$

where n_{farm} is farmer labor input and w is irrigation effort, where $f(0) = 0$, $f'(w) > 0$, $f''(w) < 0$, and $f'(0) = \infty$. Hence, if the farmer uses input $n_{farm} = \widetilde{n}_{farm}$, then he produces $t(w) = \overline{t} + f(w)$

[1] The reader can skip the next section on the irrigated factory district and move to the section on regulation, if he/she wants to see our analysis of regulation in the non-irrigated factory district.

tons of sugar beets with sugar $s(w) = \overline{s} + \gamma \cdot f(w)$. If $n_{farm} = \widetilde{n}_{farm}$, sugar content of the beets is $q(w) = s(w)/t(w)$, and

$$q'(w) = \frac{f'(w)}{t(w)^2}[\gamma - \overline{q}] \cdot \overline{t}.$$

Hence, if $\gamma < \overline{q}$, $\overline{q} = \overline{s}/\overline{t}$, then irrigation will increase $s(w)$ but decrease $q(w)$.

To be more precise, w is irrigation effort at the end of the growing season. It was well known in the industry that irrigating late in the season would decrease quality, that is, $q'(w) < 0$. Hence, contracts often had clauses that prohibited irrigation after some date, though this was hard to enforce. There is also a large agronomy literature estimating $q'(w)$. Hence, we assume that $\gamma < \overline{q}$, $\overline{q} = \overline{s}/\overline{t}$.

B. Market Solution

The contract in an irrigated district typically paid (per ton of beets)

$$p_B() = \theta \cdot p_y \cdot q_i$$

where $\theta \in [0, 1]$, and where q_i was the sugar content of farmer i's beets (of course, there was testing of many different tons, since each ton may have differed in quality).

Farmer problem (for given (θ, σ))

Consider farmer at x. Let $\pi_{farm}(x)$ be value at x. We have that (assuming $n_{farm} = \widetilde{n}_{farm}$)

$$\pi_{farm}(x) = \max_{w(x)} rev_{farm}(x) - cos_{farm}(x) - \sigma \cdot cos_{tran}(x)$$

where $rev_{farm}(x) = p_y \cdot \theta \cdot s(w)$, where

$$cos_{farm}(x) = [p_L + p_{n,farm} \cdot \widetilde{n}_{farm}] + c_{harv} \cdot t(w) + p_w \cdot w$$

and $cos_{tran}(x) = (1 - \sigma) \cdot x \cdot t(w)$.

The first order condition for $w(x)$ is

$$f'(w)[p_y \cdot \theta \cdot \gamma - (c_{harv} + (1 - \sigma) \cdot x)] = p_w. \tag{5}$$

We assume that $\gamma > c_{harv}/p_y \cdot \theta$, so watering is optimal at $x = 0$. Call the solution $\widetilde{w}(x)$. $\widetilde{w}(x)$ is obviously a function of θ. $\widetilde{w}(x)$ is decreasing in x. Irrigation has benefits and costs. One of the costs is that it leads to extra tonnage that needs to be transported, and this cost is larger the further away a farm is from the factory. Since $\widetilde{w}(x)$ is decreasing in x, $q(\widetilde{w}(x))$ is increasing in x.

We have that

$$\pi_{farm}(x) = p_y \cdot \theta \cdot s(\widetilde{w}(x)) - (c_{harv} + (1-\sigma)\cdot x) \cdot t(\widetilde{w}(x)) - p_w \cdot \widetilde{w}(x) - [p_L + p_{n,farm} \cdot \widetilde{n}_{farm}]$$

Next, solve $\pi_{farm}(x) = 0$ for the $x_{farm}(\theta, \sigma)$. Is there a solution to this equation? Write the equation as

$$x_{farm}(\theta,\sigma) = \frac{1}{1-\sigma}\{p_y \cdot \theta \cdot q(\widetilde{w}(x)) - [\frac{p_L + p_{n,farm} \cdot \widetilde{n}_{farm} - p_w \cdot \widetilde{w}(x)}{t(\widetilde{w}(x))}] - c_{harv}\}.$$

The left hand side is the identity equation in x. Assume the right hand side exceeds 0 at $x = 0$. Since the right hand side decreases in x (until farmer's choose not to water at all), there is a solution, and its unique, denoted $x_{farm}(\theta, \sigma)$. It has the same shape as the non-irrigated case, $x_{farm}(\theta, \sigma)$ increasing in θ beyond $\theta_{\min}(\sigma)$.

Factory problem (for given (θ, σ)***)***

The factory takes as given how sugar content varies with x. That is, if the factory signs with a farmer at x, it knows how the farmer will irrigate. In order to simplify expressions, lets introduce the following notation. Let $\widetilde{q}(x) = q(\widetilde{w}(x))$, $\widetilde{t}(x) = t(\widetilde{w}(x))$ and $\widetilde{s}(x) = \widetilde{t}(x) \cdot \widetilde{q}(x)$. We process tons separately. Let $\pi_{fact}(\widetilde{t}(x))$ be value of $\widetilde{t}(x)$ from x. We have that

$$\pi_{fact}(\widetilde{t}(x)) = \max_{n_{prod}(x), n_{repair}(x)} rev_{fact}(\widetilde{t}(x)) - cos_{fact}(\widetilde{t}(x)) - \sigma \cdot cos_{tran}(\widetilde{t}(x))$$

where $rev_{fact}(\widetilde{t}(x)) = I(x) \cdot p_y \cdot [y(x) - \theta \cdot \widetilde{s}(x)]$, that is, if $I = 1$, then factory sells to market $p_y \cdot y(x)$, and pays farmer $p_y \cdot \theta \cdot \widetilde{s}(x)$, and where $cos_{fact}(\widetilde{t}(x))$ and $cos_{tran}(\widetilde{t}(x))$ are as above. Recall the factory is paying some of the transport. If we process (i.e., $n_{repair}(x) = \delta \cdot \widetilde{t}(x)$), then the first order condition for $n_{prod}(x)$ is

$$(6) \qquad p_y e_z(\widetilde{q}(x), z(x)) \cdot \widetilde{q}(x) = p_{n,fact}$$

so that "effort" depends on x, namely $\widetilde{z}(x) = z(\widetilde{q}(x))$. We have that:

$$\pi_{fact}(\widetilde{t}(x)) = \{p_y[e(\widetilde{q}(x), \widetilde{z}(x)) - \theta] \cdot \widetilde{q}(x) - [\widetilde{z}(x) + \delta] \cdot p_{n,fact}\} \cdot \widetilde{t}(x) - \sigma \cdot x \cdot \widetilde{t}(x)$$

For each θ, we can ask: from what distance is the factory willing to purchase beets? That is, we can solve $\pi_{fact}(\widetilde{t}(x)) = 0$. Is there a solution to this equation? Write the equation as

$$x_{fact}(\theta, \sigma) = \frac{1}{\sigma}\{p_y[e(\widetilde{q}(x), \widetilde{z}(x)) - \theta] \cdot \widetilde{q}(x) - [\widetilde{z}(x) + \delta] \cdot p_{n,fact}\}$$

The left hand side is the identity equation in x. Assume the right hand side exceeds 0 at $x = 0$. The right hand side is increasing and concave in x (until farmer's choose not to water at all, when it does not change in x), and there is a solution, and its unique, denoted $x_{fact}(\theta, \sigma)$.

What is the slope of $x_{fact}(\theta, \sigma)$ with respect to θ? We present some conditions under which it is decreasing. Given x, we want $\partial \pi_{fact}(\widetilde{t}(x))/\partial\theta < 0$. Sufficient conditions are:

$$\frac{\partial(\theta \cdot \widetilde{q}(x))}{\partial\theta} > 0$$

and

$$\frac{\partial(p_y e(q, z(q)) \cdot q - [z(q) + \delta] \cdot p_{n,fact})}{\partial q} > 0$$

Under these conditions, $x_{fact}(\theta, \sigma)$ is decreasing in θ up until $\theta_{\max}(\sigma)$.

6. Regulation's Impact: "Redistribution" Scheme

In this section, we begin studying the impact of industry regulation. In this section, we look at the impact of the redistribution scheme by itself. That is, we will assume that the industry faces a tariff (as in the pre Sugar Act period) and then introduce the scheme. We first look at how the scheme influences contracted acres, then productivity and finally innovation.

The distribution scheme works as follows. The government sends the farmer a check equal to $\lambda \cdot s$. The government also taxes the factory an amount $\tau \cdot y$.

A. Contracted acres

In this section, we will show that the scheme increases contracted acres within a non-irrigated district, and will increase it more in non-irrigated districts with higher sugar content and finally will increase it the most in irrigated districts.

Within a non-irrigated district

In the beet contracts, the price used to pay farmers was the net price, that is, the price of sugar net of any taxes, $p_{net} = (p_y - \tau)$. Hence, the farmer's revenue becomes:

$$rev_{farm}(x) = p_{net} \cdot \theta \cdot \widehat{s} + \lambda \cdot \widehat{s} = [(p_y - \tau) \cdot \theta \cdot \widehat{q} + \lambda \cdot \widehat{q}] \cdot \widehat{t}$$

Hence, $x_{farm}(\theta, \sigma)$ becomes:

$$x_{farm}(\theta, \sigma) = \frac{1}{1-\sigma}\{[p_y \cdot \theta + (\lambda - \tau \cdot \theta)] \cdot \widehat{q} - [\frac{p_L + p_{n,farm} \cdot \widetilde{n}_{farm}}{\widehat{t}}] - c_{harv}\}$$

Hence, $x_{farm}(\theta, \sigma)$ expands if $\lambda > \tau \cdot \theta$. As for parameter values, $\lambda \approx 0.8$, $\tau \approx 0.5$, while $\theta \approx 0.45$, so $x_{farm}(\theta, \sigma)$ shifts out in Diagram 2.

The factory revenue becomes:

$$rev_{fact}(t(x)) = I(x) \cdot (p_y - \tau) \cdot [y(x) - \theta \cdot s(x)]$$

The factory has a new effort level, denoted $z_{plan}(\tau)$, which is decreasing in τ. $x_{fact}(\theta, \sigma)$ can now be written

$$x_{fact}(\theta, \sigma) = \frac{1}{\sigma}\{(p_y - \tau)[e(\widehat{q}, z_{plan}(\tau)) - \theta] \cdot \widehat{q} - [z_{plan}(\tau) + \delta] \cdot p_{n,fact}\}$$

$x_{fact}(\theta, \sigma)$ shifts down in Diagram 2.

Whether or not contracted acres expand or contract depends on the initial θ, and whether or not it changes with the redistribution scheme. Recall our model implies $\theta = \theta_{fact}$. At $\theta = \theta_{fact}$, contracted acres is determined by $x_{farm}(\theta, \sigma)$. Hence, if θ does not change, contracted acres expand as $x_{farm}(\theta, \sigma)$ shifts out. This case is drawn in diagram 4 (where we have not drawn the $x_{fact}(\theta, \sigma)$ curve shifting down to keep things simple).

There is a good reason to focus on this case, of $\theta = \theta_{fact}$ not changing. As part of the Sugar Act, the government became involved in the price determination for beets. That is, the Sugar Act gave the government the right to hold meetings and offer advice on the determination of θ and other contract aspects. Hence, the government frowned on reductions in θ.

It is also worthwhile thinking about the factory incentives assuming the government was not effective in frowning on reductions in θ_{fact}. If the factories were free to choose θ_{fact}, there would be a new $\theta_{fact}(\tau)$. Suppose $x_{farm}(\theta, \sigma)$ still determines contracted acres. Then there are two effects, first, a lower $\theta_{fact}(\tau)$ would tend to lower contracted acres, but the shifting $x_{farm}(\theta, \sigma)$ would tend to increase contracted acres.

Across Non-Irrigated Districts

In this section, we ask how acreage expansion would compare across non-irrigated districts with different $\widehat{q}$. Before we do that, we address a key point. Why would two factory districts with different sugar contents coexist? In other words, why isn't one district lower cost than the other, so that factories within that district would be replicated?

There are increasing costs in each district. A major reason for increasing costs, especially before 1950's, was the difficulty of acquiring farm labor. Sugarbeet farming was a labor intensive process. Factories had to look far and wide to supply farms with labor.

So, how do contracted acres change in two districts as we change $(\lambda - \tau\theta)$? Note that λ and τ are the same across districts. Typically, θ's were very close. Hence, we can treat $(\lambda - \tau\theta)$ as a parameter common across factories. We have that:

$$\frac{\partial x_{farm}}{\partial(\lambda - \tau\theta)} = \frac{\hat{q}}{1 - \sigma}$$

So, x_{farm} shifts out more in the higher sugar content area. So, assuming $\theta = \theta_{fact}$, and this doesn't change, the areas with higher $\widehat{q}$ would expand more. The percentage change in acres in a district, where x_{farm} and x'_{farm} denote the initial and new levels of acres, is given by:

$$\frac{\int_{x_{farm}}^{x'_{farm}} a(x)dx}{\int_0^{x_{farm}} a(x)dx}$$

so that if we assume $a(x)$ and x_{farm} are the same across the two factories, the share of acres in the high sugar content district increase.

Across non-irrigated and irrigated Districts

In the irrigated districts, $x_{farm}(\theta, \sigma)$ satisfies:

$$x_{farm}(\theta, \sigma) = \frac{1}{1-\sigma}\{[p_y \cdot \theta + (\lambda - \tau \cdot \theta)] \cdot q(\widetilde{w}(x)) - [\frac{p_L + p_{n,farm} \cdot \widetilde{n}_{farm} - p_w \cdot \widetilde{w}(x)}{t(\widetilde{w}(x))}] - c_{harv}\}$$

Recall $\widetilde{w}(x) = \widetilde{w}(x, \lambda - \tau\theta)$. There are two effects on $x_{farm}(\theta, \sigma)$ as we change $(\lambda - \tau \cdot \theta)$.

First, there is the direct effect fixing $\widetilde{w}(x)$, which is the same effect as in non-irrigated districts. This effect is:

$$\left.\frac{\partial x_{farm}}{\partial(\lambda - \tau\theta)}\right|_{\widetilde{w} \text{ fixed}} = \frac{q(\widetilde{w}(x))}{1-\sigma}$$

where this derivative is evaluated at $x = x_{farm}$. In irrigated districts, average sugar content of the beets is typically larger than the sugar content in non-irrigated areas. For example, in California sugar content averaged about 18%, while in Minnesota it averaged about 12%. Moreover, we know that sugar content is increasing as we move away from the factory, so that the sugar content of $x = x_{farm}(\theta, \sigma)$ is higher than the average. Hence, the sugar content of $x = x_{farm}(\theta, \sigma)$ in irrigated districts is significantly higher than the sugar content in non-irrigated districts.

Second, the farm at $x = x_{farm}(\theta, \sigma)$ has the option of changing its irrigation policy, which has another effect on the profits at $x = x_{farm}(\theta, \sigma)$. The farm at $x = x_{farm}(\theta, \sigma)$ would only change its policy if it increases profits, which in fact it would. So the second effect is in the same direction.

Hence, marginal acres expand more in irrigated districts than in non-irrigated.

B. Productivity

In this section, we examine the impact of the redistribution scheme on productivity in both non-irrigated and irrigated districts.

For factory productivity, let's focus on labor productivity. This can be written as

$$\frac{y}{n} = \frac{y}{n_{prod}} \frac{n_{prod}}{n} = \frac{e(z) \cdot q}{z} \frac{z}{\delta + z}$$

where $n = n_{prod} + n_{repair}$, and where recall that production worker effort per ton z depends on q and $p_{net} = p_y - \tau$, $z(p_{net}, q)$.

We will also look at measures of farm productivity, like

$$\frac{y}{a} = \frac{y}{s} \cdot \frac{s}{a} = e(z) \cdot \frac{s}{a}$$

and

$$\frac{y}{w} = \frac{y}{s} \cdot \frac{s}{w} = e(z) \cdot \frac{s}{w}$$

Non-irrigated districts

Consider factory productivity first. In these districts, p_{net} falls but q is unchanged, and extraction $e(z)$ falls. Because $e(z)$ is concave, $e(z)/z$ increases as z falls. Hence, this effect has a positive impact on y/n_{prod}. However, $z/(\delta+z)$ falls, having a negative impact on y/n. Differentiating the expression for y/n above with respect to τ, we have

$$\frac{\partial(\frac{e(z) \cdot q}{\delta + z})}{\partial \tau} = z'() \cdot q \cdot \frac{e'(z)(\delta + z) - e(z)}{(\delta + z)^2}$$

Notice that if $\delta = 0$, the derivative is positive, since $z'() < 0$, and $e'(z)z - e(z) < 0$. This is the effect from $e(z)$ being concave. Notice as well that if δ is big enough, the derivative is negative, this is the effect coming from the repair staff.

Consider farm productivity next. Since $e(z)$ is falling, y/a falls.

Irrigated districts

Consider factory productivity. The redistribution scheme leads to increases in $\widetilde{w}(x)$, hence decreases in $\widetilde{q}(x)$. Examining the expression above for labor productivity, we see that there is a direct negative effect of lowered q (that is holding z fixed). There is another direct negative effect (holding z fixed) if quality enters the extraction function, that is, $e = e(q, z)$. Beyond these effects, we have the effect sketched above as z changes.

Consider farm productivity. Regarding y/a, there are two effects. First, $e(z)$ falls, tending to reduce productivity. Second, s increases tending to increase productivity. Regarding y/w, $e(z)$ falls, tending to reduce productivity. Recall, s/w is given by

$$\frac{s}{w} = \frac{\overline{s} + \gamma f(w)}{w}$$

Since w increases, s/w falls.

C. Innovation

The redistribution scheme could have many influences on innovation. Here, we consider its impact on farmer innovation.

Given the redistribution scheme, farmers had a great incentive to learn ways to increase sugar per acre. In particular, farmers in non-irrigated areas which had little control over sugar per acre before the Sugar Act gradually discovered ways to influence sugar per acre. They learned ways to fertilize towards the end of the growing season, which had impacts that were similar to late irrigation. Because farmers in non-irrigated districts learned how to manipulate s, there were introduction of contracts that tested individual farmer beets in some of these districts. In fact, the most sophisticated testing today occurs in North Dakota and Minnesota.

7. Regulation's Impact: Restriction of Competition

In this section, we consider the impact of regulations that limited competition. We continue to keep the redistribution scheme in place, and replace the tariff with sales quotas for factories, acreage quotas for farmers and quotas for foreign countries.[2] We consider the impact on prices and productivity.

A. Prices

During the Sugar Acts, prices were no longer determined by the world price (plus the tariff). At the beginning of each year, the government determined the amount of sugar sales it wanted. Note that given this quantity, it could fairly closely estimate the price of sugar in the United States. The government then divided this quantity of sugar among the various producers.

Consider the incentives of a firm in setting its price given its sales quota. The firm had very little incentive to lower its price below the estimated sugar price. A lower price would not bring any additional sales, just lower revenue. In this way, regulations kept prices high.

Looking back on the price figure, we see that real sugar prices in the United States were fairly constant during the Sugar Act, but have come down significantly since then. Hence, it was not only foreign protection that kept prices high during the Sugar Act, but also the domestic regulation of the industry.

Another big development post-1974 was the introduction of high fructose-corn-syrup. HFCS clearly introduced greater competition for sugar in this period. Hence, it would be more accurate to say a lack of domestic competition in the Sugar Act period kept prices high, and increased domestic competition after 1974 have led to falling prices.

B. Productivity

We have seen that the redistribution scheme led, at least qualitatively, to many of the productivity changes observed in the industry. So, is there any reason to believe that reduced competition during the Sugar Act period reduced factory productivity? And that the increased competition

[2] Note that acreage restrictions on farmers were not in effect in all years. Hence, the analysis above asking how the redistribution scheme influenced contracted acres is relevant, and applies to these years when farmers could adjust acres.

since 1974 increased it? Another way to ask the question, a bit more skeptically, is: Why would significantly falling sugar prices since the end of regulation have led to productivity gains at the factory level?

Let us answer this two ways. First, let us mention literature that has shown that increased competition that led to lower prices has raised factory productivity in some industries. Second, lets present evidence for this industry that at least suggests its true here as well.

Schmitz (2005) shows that there was a dramatic increase in competition in the U.S. and Canadian iron ore industry in the early 1980s. The prices received by these industries plunged. Yet TFP at individual mines soared. He shows that changes in work practices led to most of the dramatic increases in TFP.

How about this industry? We will present back of the envelope evidence that suggests competition may have led to significant TFP gains in this industry. We do this by examining the pattern of factory extraction rates. For most factories, extraction rates fell during the Sugar Act, and have increased since.

For the sake of discussion, assume the extraction function takes the form

$$e(z) = 1 - \exp(-A_e \cdot z),$$

where A_e is factory TFP. Then, solving the factory's optimization problem, one finds that the extraction rate chosen by the factory is

$$e(z) = 1 - \frac{p_n}{A_e p_{net} q}.$$

So, the extraction rate depends positively on $p_{net} \cdot q = (p_y - \tau) \cdot q$. Higher sugar prices and higher sugar content lead to increases in extraction.

During the Sugar Act, p_y did not change much, but $p_y - \tau$ fell as taxes increased. Also, q decreased. So, $p_{net} \cdot q$ fell over time, primarily because q was falling. Hence, holding A_e fixed, we expect factory extraction to decrease, and it did.

After the Sugar Act, taxes τ were reduced, but sugar prices began to fall, precipitously. Sugar content began to increase. On balance, $p_{net} \cdot q$ was falling faster in the post 1974 period than it was during the 1934-1974 period. Hence, holding A_e fixed, we expect factory extraction to decrease faster in the post Sugar Act period than before it. But extraction rates have actually increased!

The only way to square these facts, at this back of the envelope level, is for A_e to grow much faster post 1974 than during the Sugar Act period. Hence, it seems that we will not be able to explain significant features of factory productivity by appealing to the redistribution scheme alone. We will have to understand the impact of competition on TFP and other measures.

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Figure 1

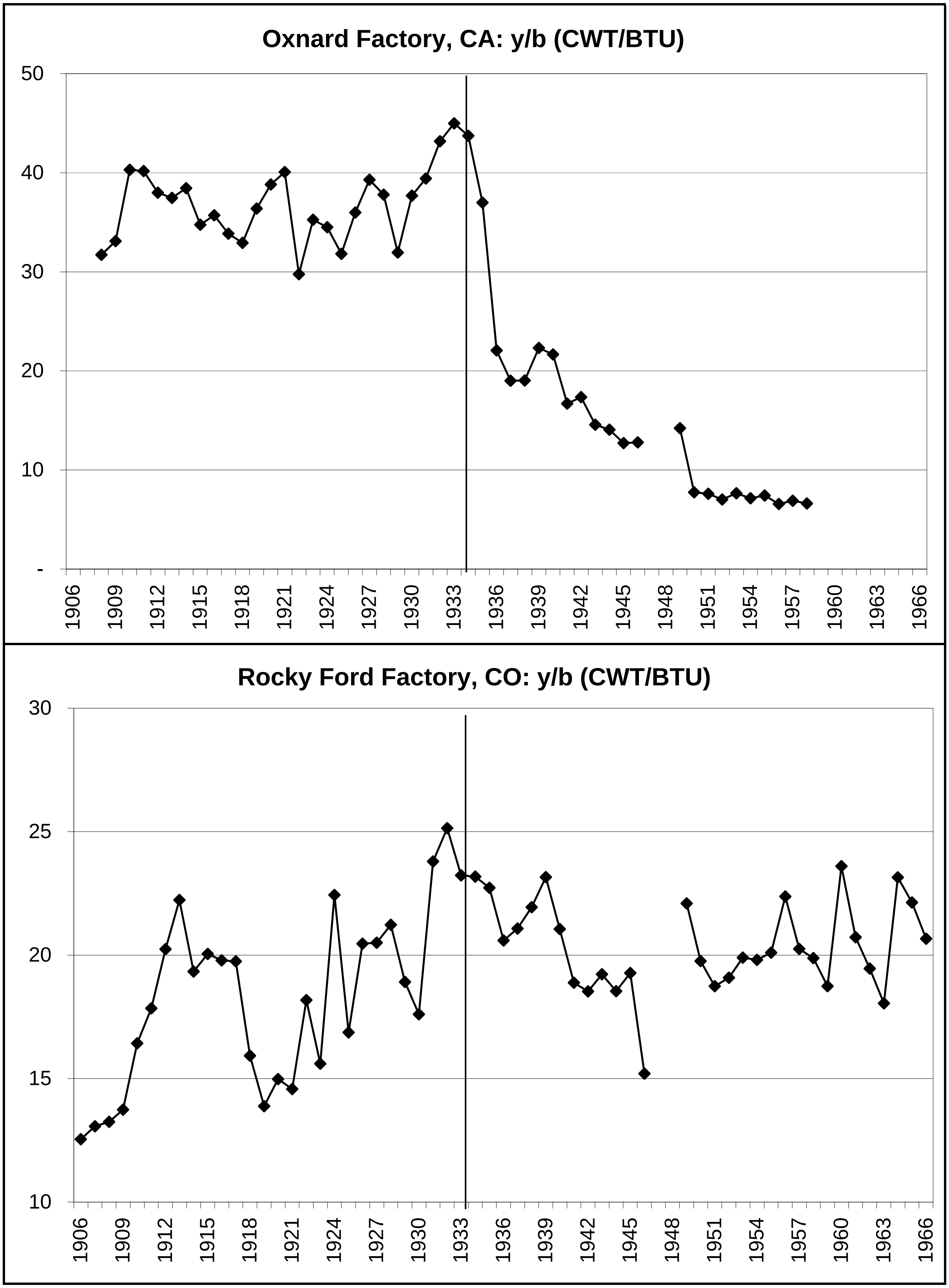

Oxnard Factory, CA: y/b (CWT/BTU)
50
40
30
20
10
-
1906
1909
1912
1915
1918
1921
1924
1927
1930
1933
1936
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966
Rocky Ford Factory, CO: y/b (CWT/BTU)
30
25
20
15
10
1906
1909
1912
1915
1918
1921
1924
1927
1930
1933
1936
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966

Figure 2

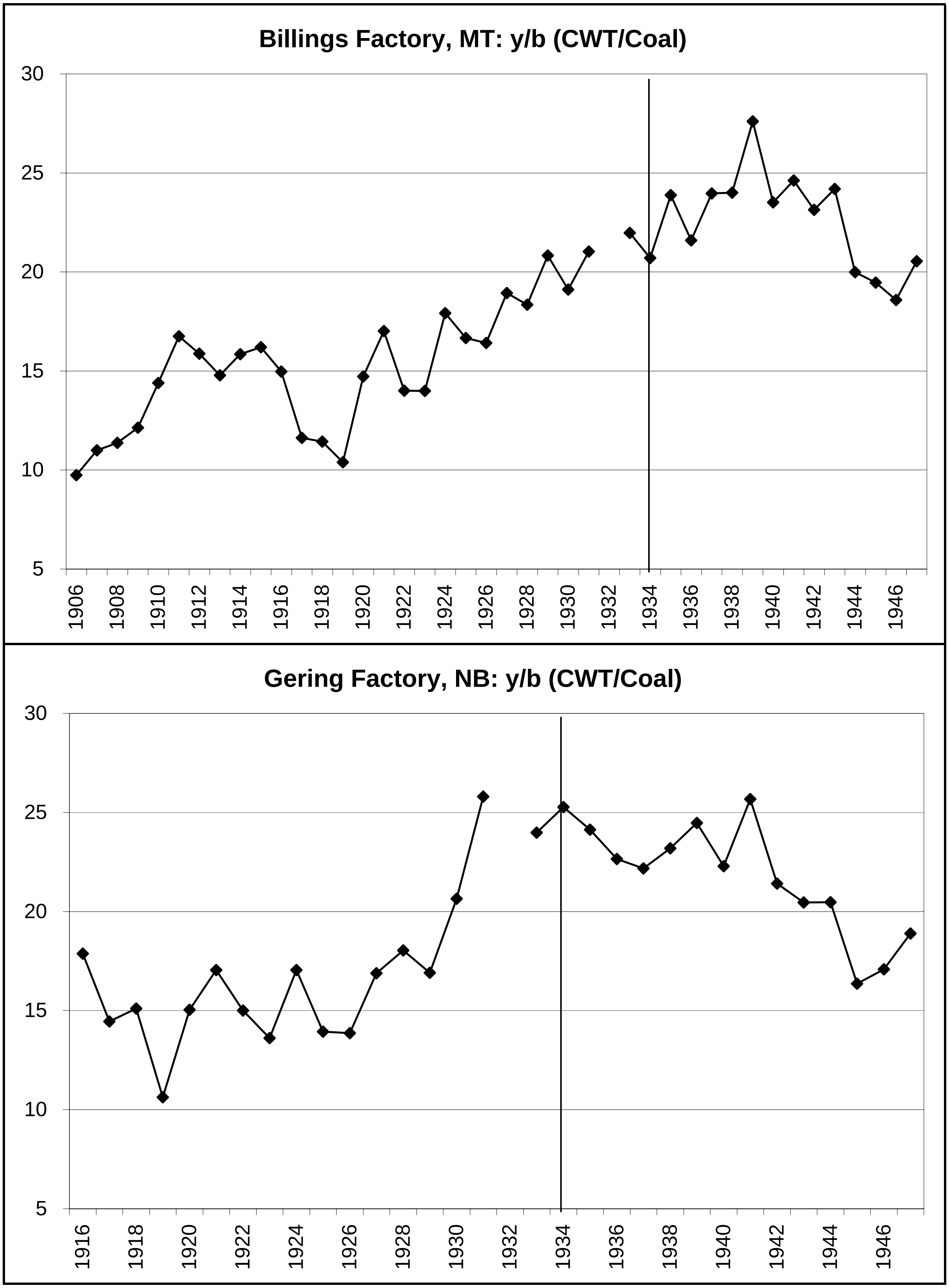
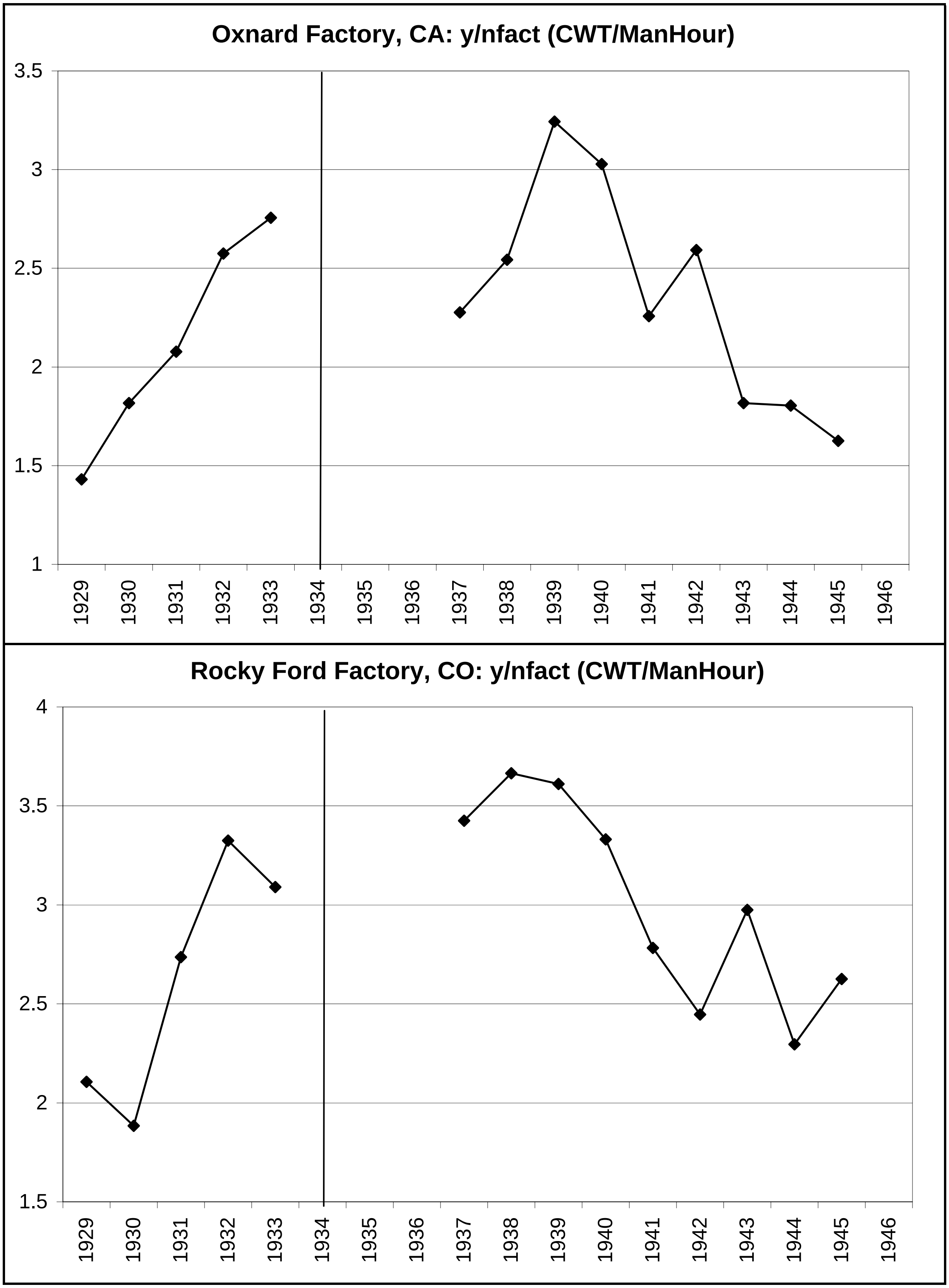

Billings Factory, MT: y/b (CWT/Coal)
30
25
20
15
10
5
1906
1908
1910
1912
1914
1916
1918
1920
1922
1924
1926
1928
1930
1932
1934
1936
1938
1940
1942
1944
1946
Gering Factory, NB: y/b (CWT/Coal)
30
25
20
15
10
5
1916
1918
1920
1922
1924
1926
1928
1930
1932
1934
1936
1938
1940
1942
1944
1946

Figure 3



Oxnard Factory, CA: y/nfact (CWT/ManHour)
3.5
3
2.5
2
1.5
1
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
Rocky Ford Factory, CO: y/nfact (CWT/ManHour)
4
3.5
3
2.5
2
1.5
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946

Figure 4

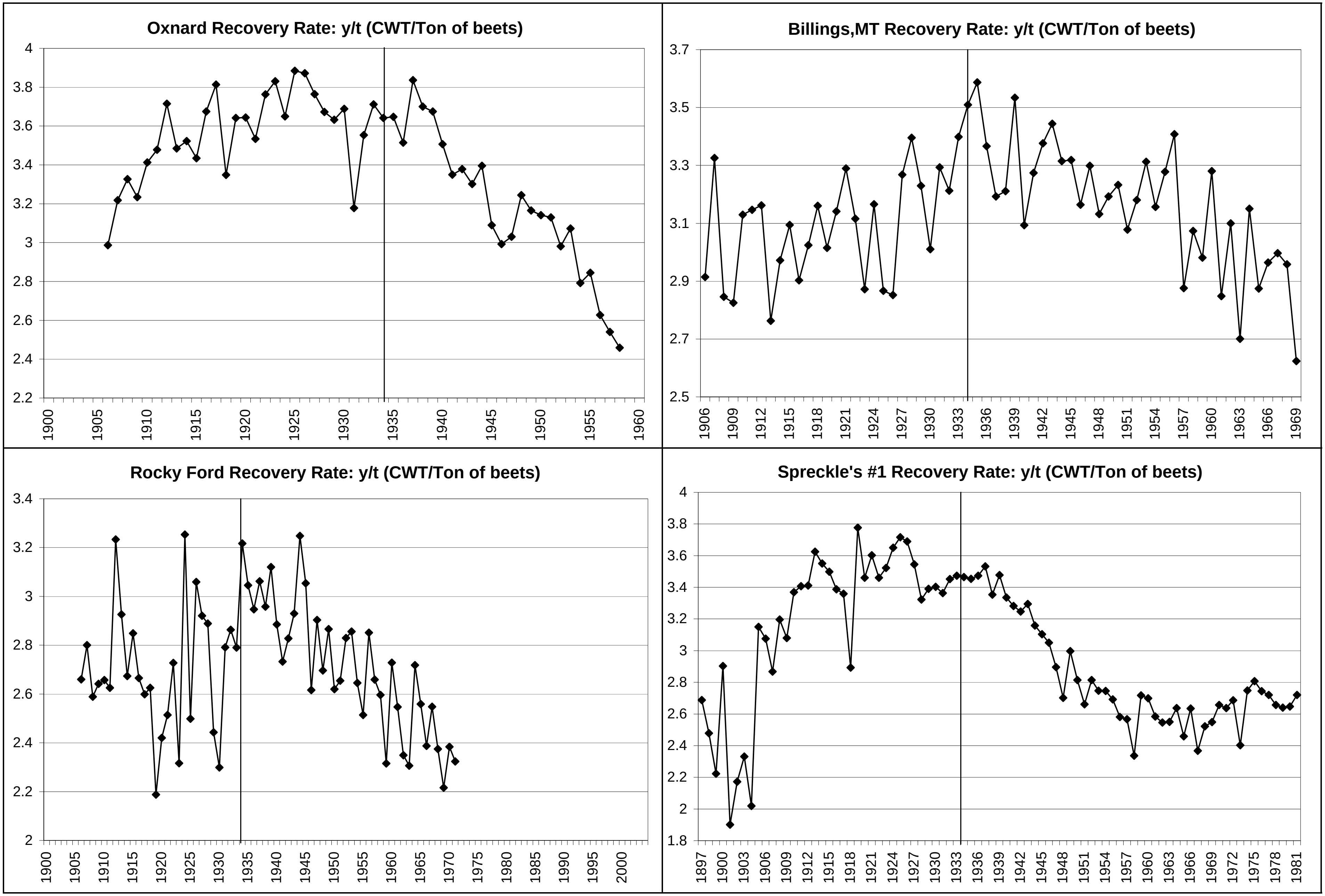

Oxnard Recovery Rate: y/t (CWT/Ton of beets)
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960
Billings,MT Recovery Rate: y/t (CWT/Ton of beets)
3.7
3.5
3.3
3.1
2.9
2.7
2.5
1906 1909 1912 1915 1918 1921 1924 1927 1930 1933 1936 1939 1942 1945 1948 1951 1954 1957 1960 1963 1966 1969
Rocky Ford Recovery Rate: y/t (CWT/Ton of beets)
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000
Spreckle's #1 Recovery Rate: y/t (CWT/Ton of beets)
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1897 1900 1903 1906 1909 1912 1915 1918 1921 1924 1927 1930 1933 1936 1939 1942 1945 1948 1951 1954 1957 1960 1963 1966 1969 1972 1975 1978 1981

Figure 5

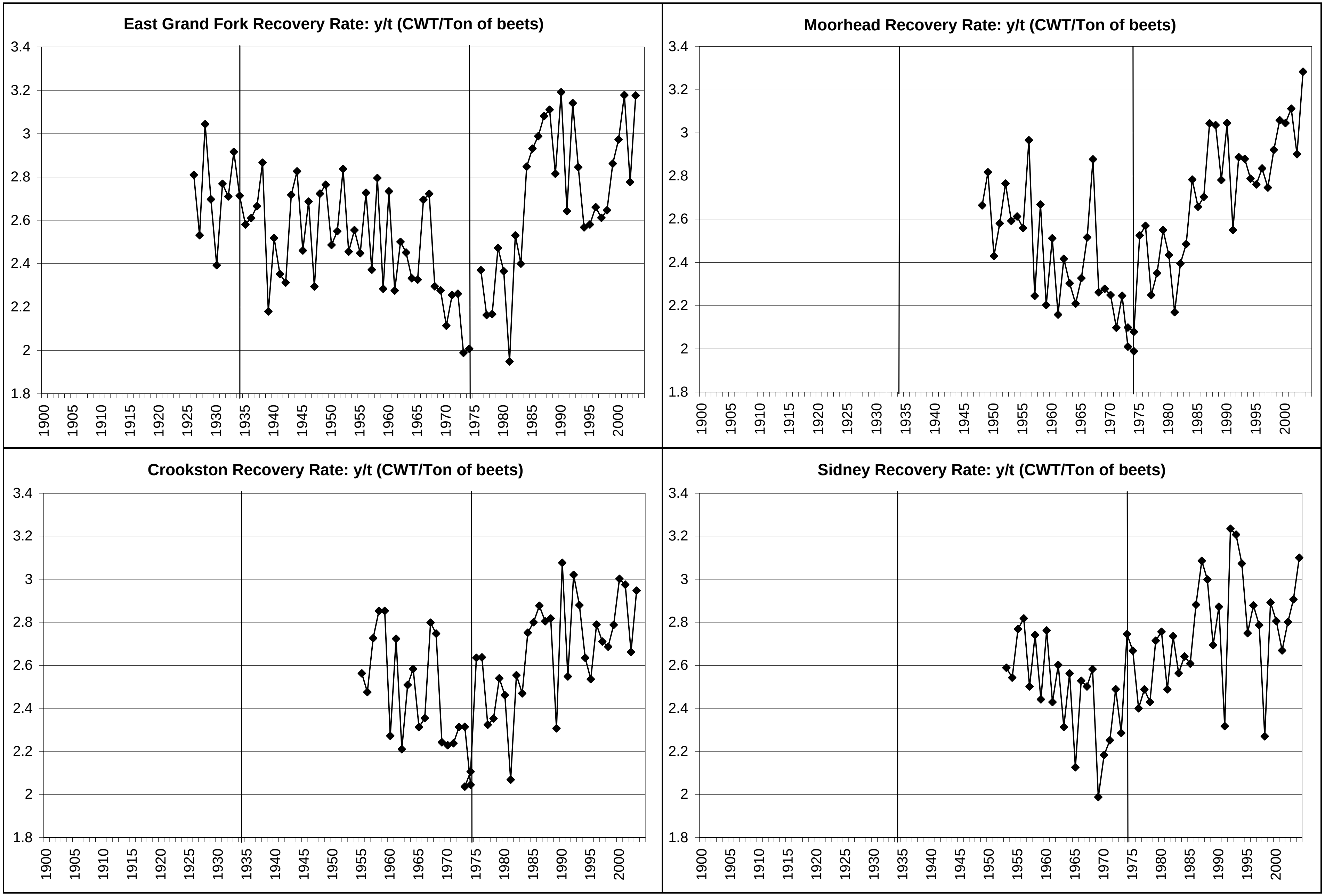
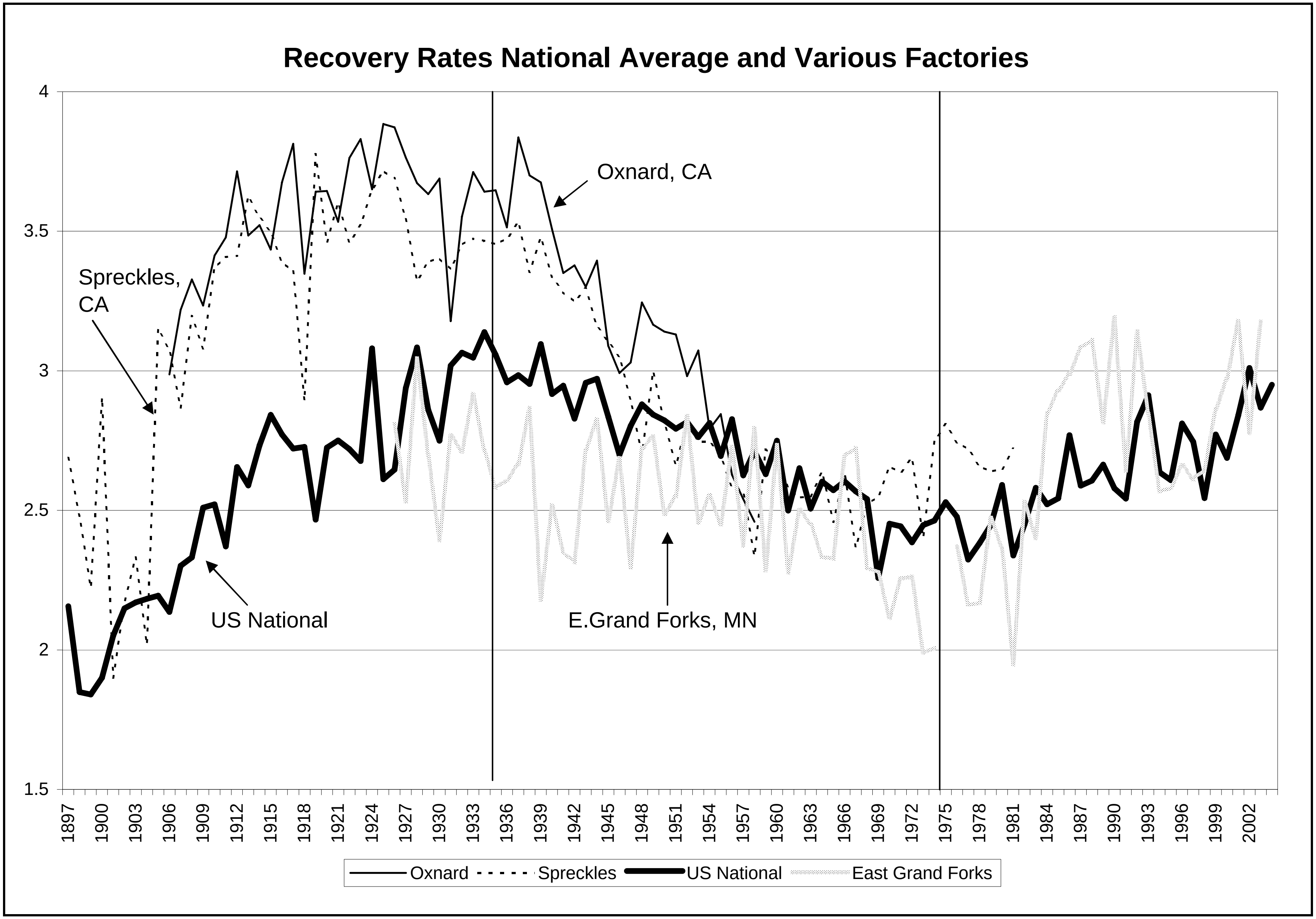
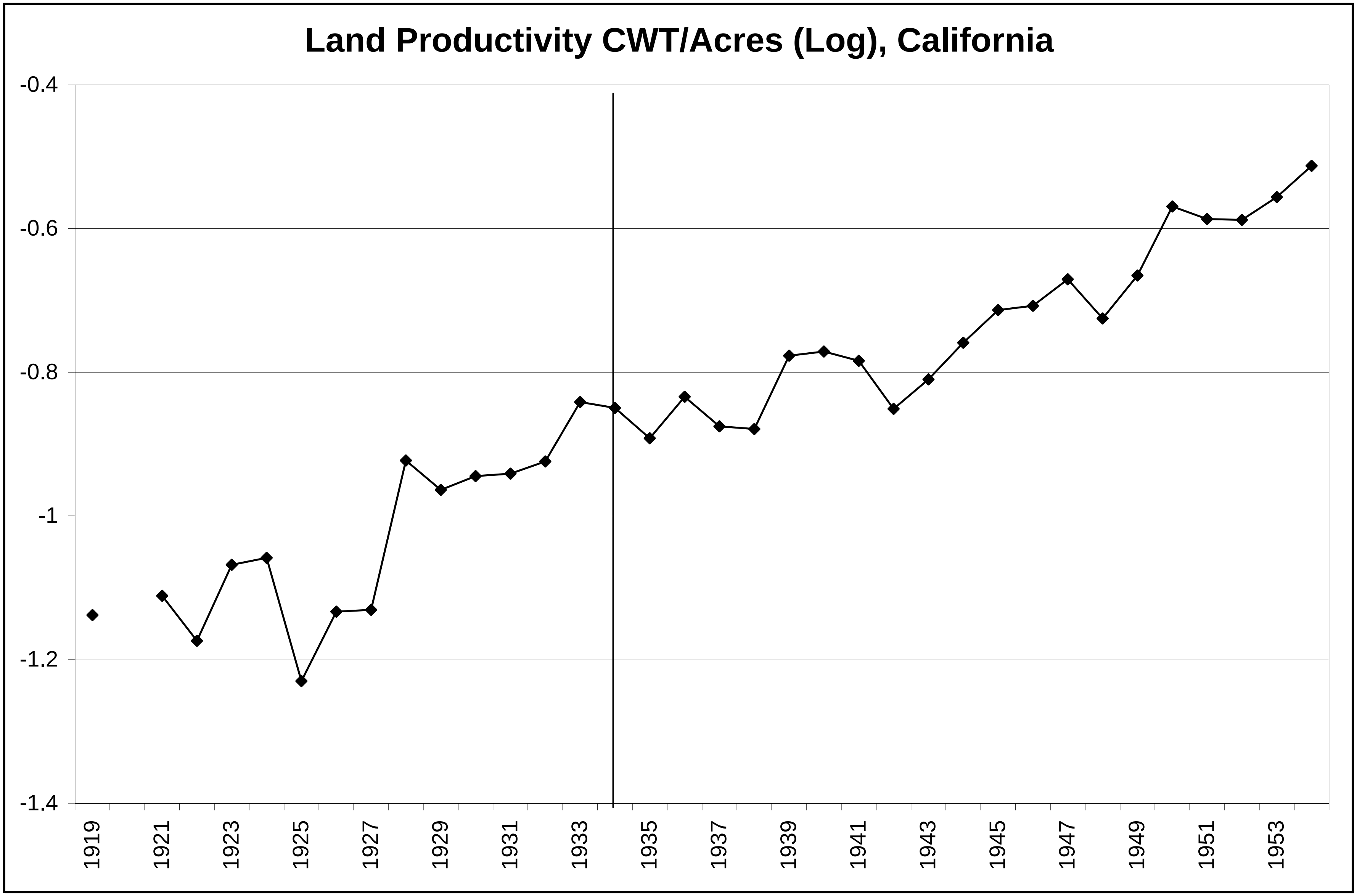

East Grand Fork Recovery Rate: y/t (CWT/Ton of beets)
Moorhead Recovery Rate: y/t (CWT/Ton of beets)
Crookston Recovery Rate: y/t (CWT/Ton of beets)
Sidney Recovery Rate: y/t (CWT/Ton of beets)
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000

Figure 6



Recovery Rates National Average and Various Factories
4
3.5
3
2.5
2
1.5
Oxnard, CA
Spreckles,
CA
US National
E.Grand Forks, MN
1897
1900
1903
1906
1909
1912
1915
1918
1921
1924
1927
1930
1933
1936
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
Oxnard
Spreckles
US National
East Grand Forks

Figure 7



Land Productivity CWT/Acres (Log), California
-0.4
-0.6
-0.8
-1
-1.2
-1.4
1919
1921
1923
1925
1927
1929
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953

Figure 8

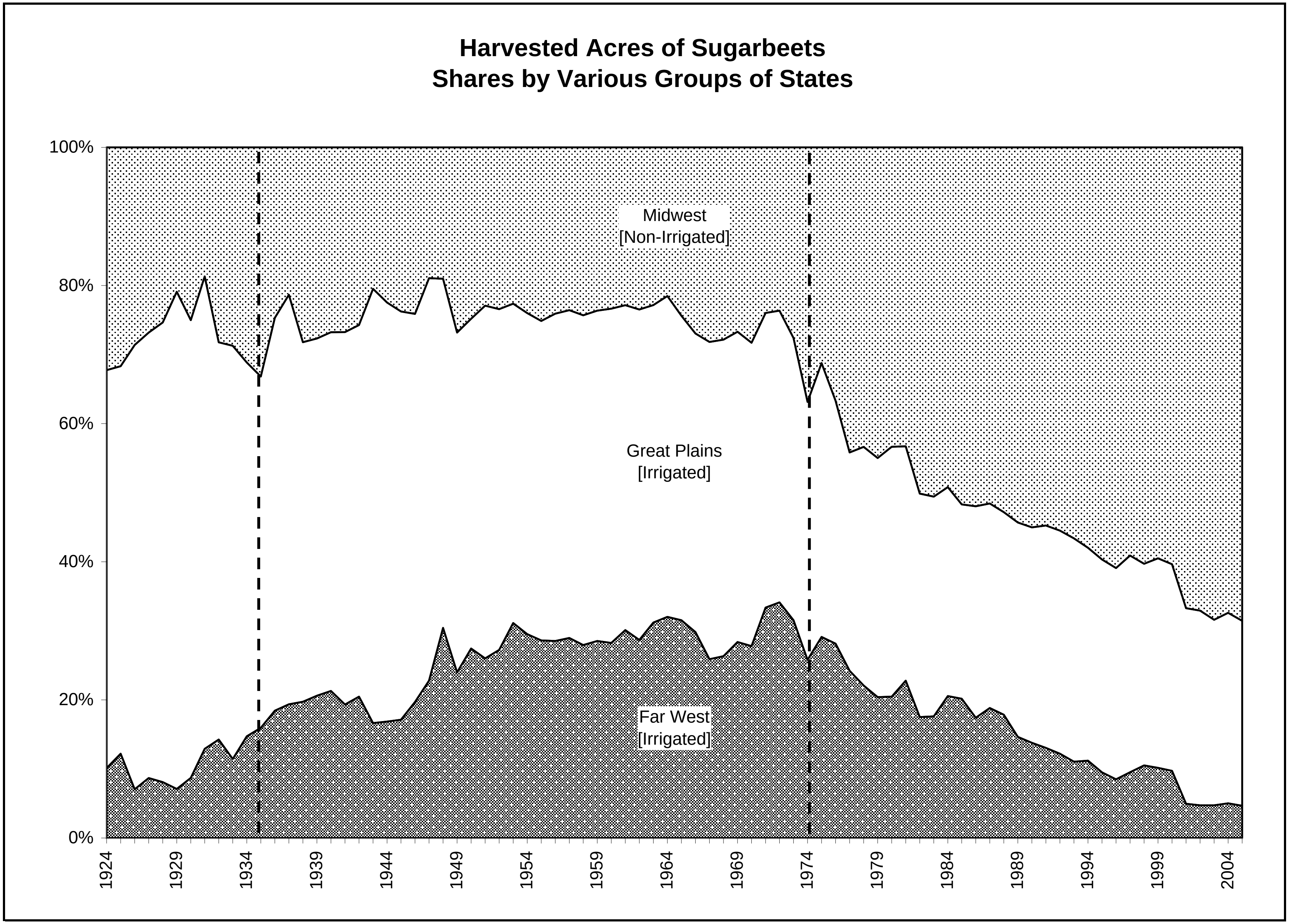
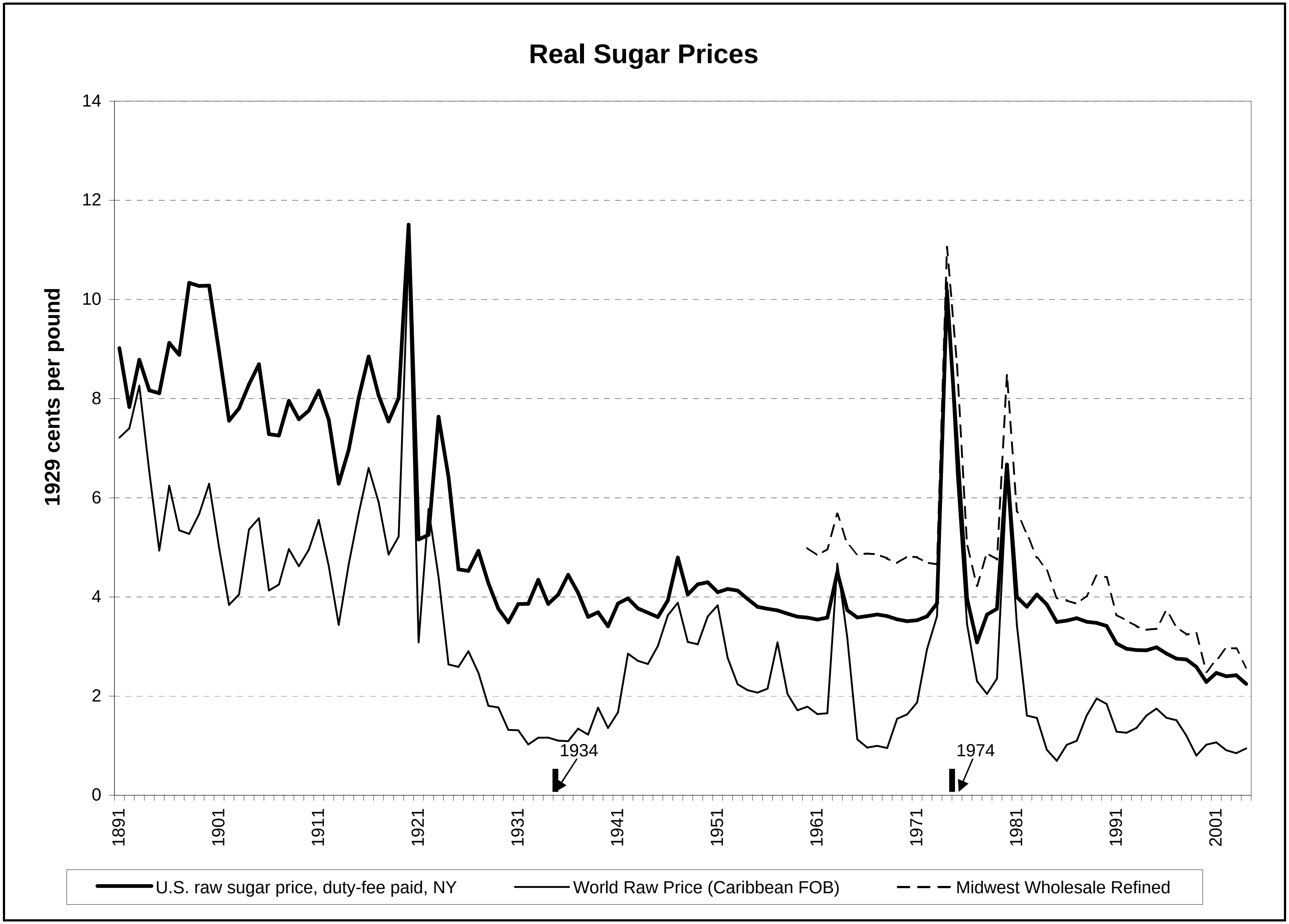
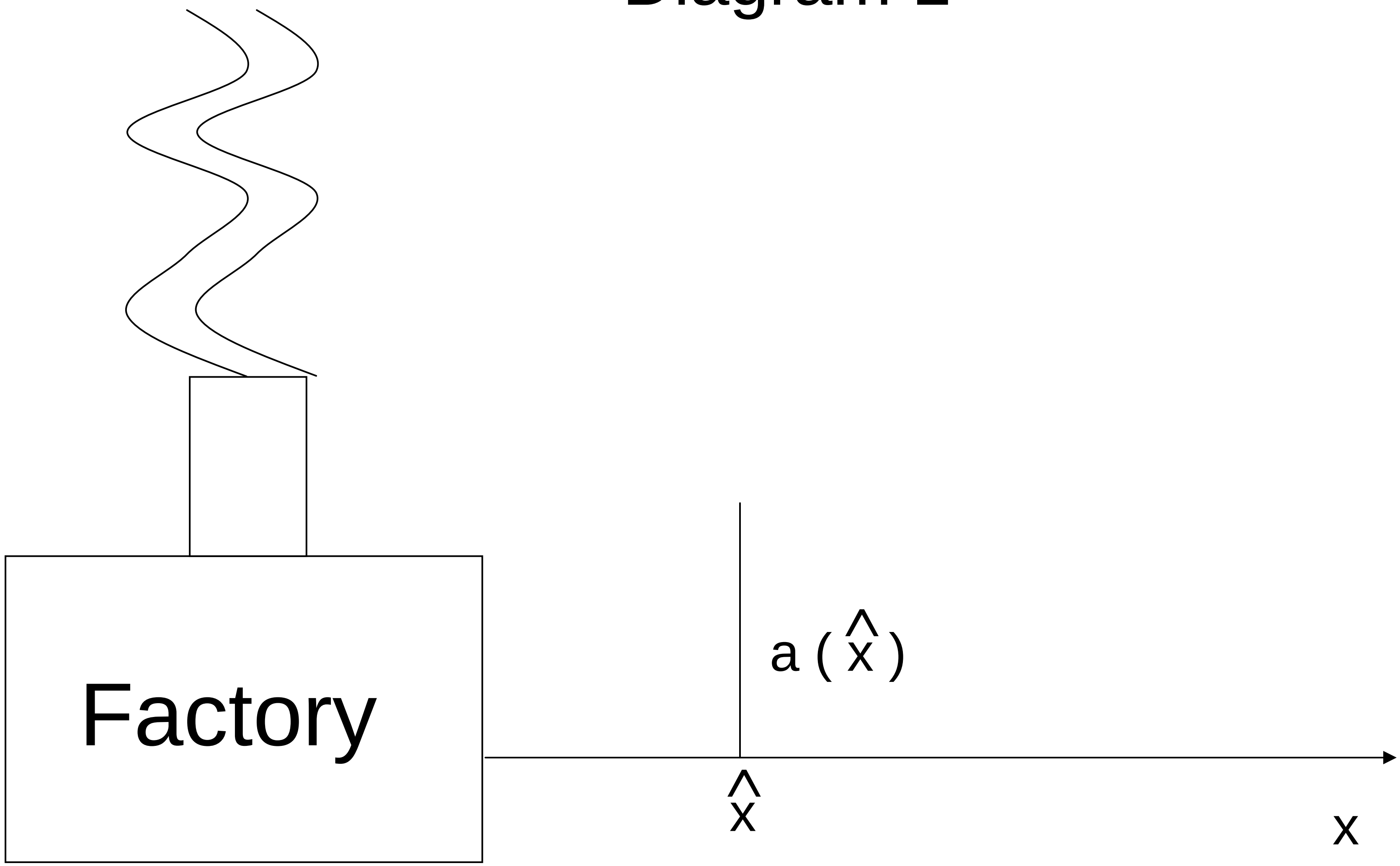

Harvested Acres of Sugarbeets
Shares by Various Groups of States
100%
80%
60%
40%
20%
0%
Midwest
[Non-Irrigated]
Great Plains
[Irrigated]
Far West
[Irrigated]
1924
1929
1934
1939
1944
1949
1954
1959
1964
1969
1974
1979
1984
1989
1994
1999
2004

Figure 9



Real Sugar Prices
1929 cents per pound
14
12
10
8
6
4
2
0
1934
1974
1891
1901
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001
U.S. raw sugar price, duty-fee paid, NY
World Raw Price (Caribbean FOB)
Midwest Wholesale Refined

Diagram 1



x = cost of delivering
a ton to factory

Diagram 2

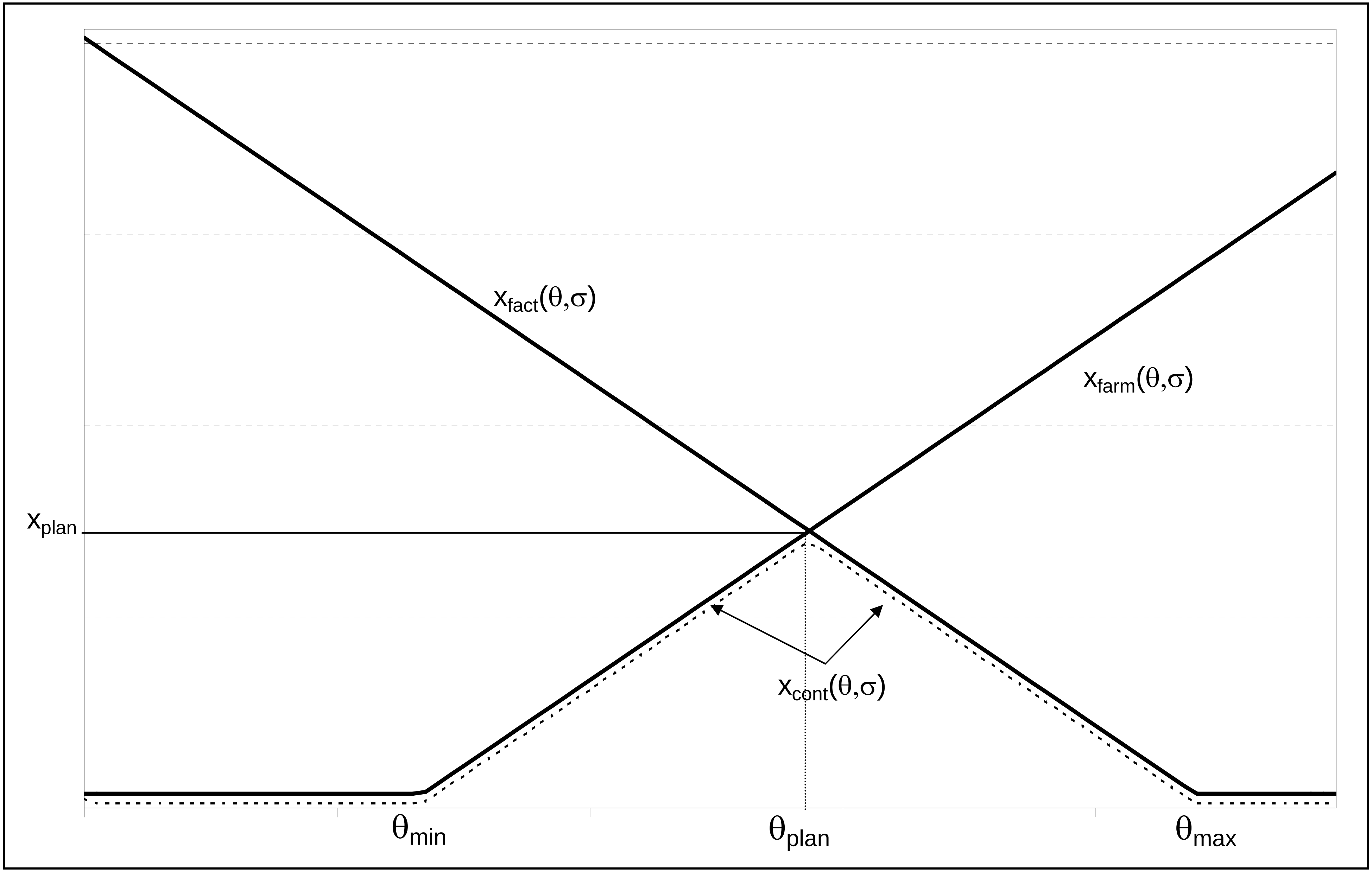
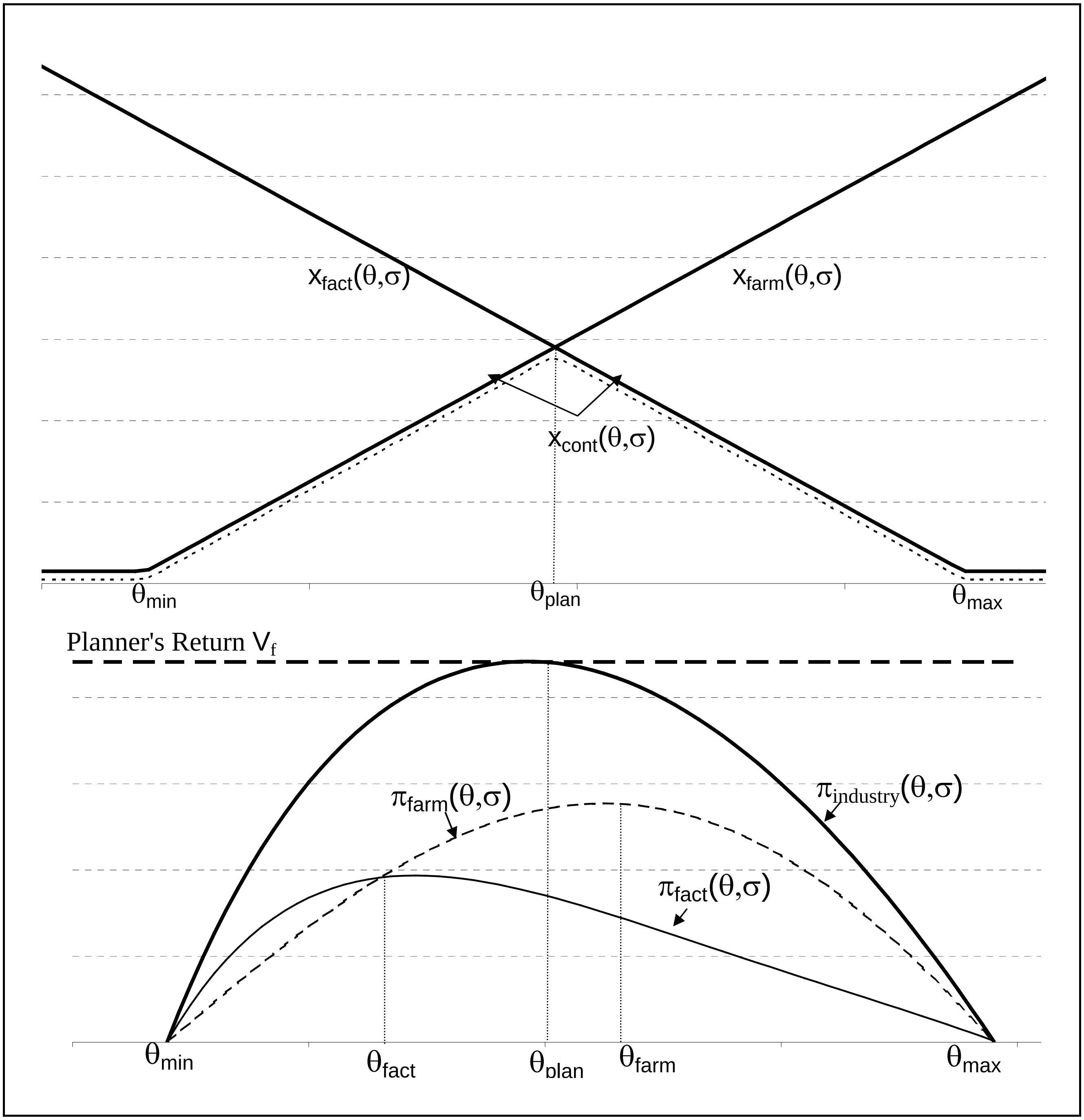

$x_{fact}(\theta,\sigma)$
$x_{farm}(\theta,\sigma)$
x_{plan}
$x_{cont}(\theta,\sigma)$
θ_{min}
θ_{plan}
θ_{max}

Diagram 3



$x_{fact}(\theta,\sigma)$
$x_{farm}(\theta,\sigma)$
$x_{cont}(\theta,\sigma)$
θ_{min}
θ_{plan}
θ_{max}
Planner's Return V_f
$\pi_{farm}(\theta,\sigma)$
$\pi_{industry}(\theta,\sigma)$
$\pi_{fact}(\theta,\sigma)$
θ_{min}
θ_{fact}
θ_{plan}
θ_{farm}
θ_{max}

Diagram 4