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VALIDATING THE CONJECTURAL VARIATION METHOD: THE SUGAR INDUSTRY, 1890-1914

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ABSTRACT

The Conjectural Variations (CV) methodology uses the responsiveness of price to cost determinants under differing demand conditions to infer market power and cost. It thus substitutes demand information for complete cost information. In this paper we use the American sugar refining industry at the turn of the century to assess the efficacy of the CV approach. We do so by comparing direct measures of marginal cost and price-cost markups with the indirect estimates obtained from the CV method. We find that the CV method performs reasonably well. It yields estimates of industry conduct that are close to the direct measure we derive from full cost information, and robust to the choice of the functional form of demand. The conduct parameter is underestimated, but the deviation is minimal in our context. The CV methodology does a better job of detecting differences in conduct arising from different structural regimes (corresponding to the aftermath of entry), but only when the researcher imposes the (a priori known) restriction of cost stability.

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Measuring market power lies at the core of empirical efforts in Industrial Organization. Where there is no market power, there is little that the theory of Industrial Organization can add about firm behavior. On an applied level, the extent of market power is, along with preferences and technology, one of the essential characteristics of an industry. The degree of market power in a given industry or group of industries therefore constitutes important economic data. Moreover, many theories of oligopoly can be formulated as predictions about the determinants of market power. The testing of these theories therefore relies upon the accurate measurement of market power.

Market power has traditionally been measured by the Lerner Index, that is, the relative markup of price over marginal cost ($L \equiv \frac{P-c}{P}$). Were price and marginal cost directly observable, the measurement of market power would be straightforward. In most settings, however, marginal cost has been difficult to observe or estimate. It is in response to these difficulties that the empirical conjectural variations (CV) literature has developed. This approach, which in his 1989 survey Bresnahan christened the "New Empirical Industrial Organization" (NEIO), focuses on the estimation of a conduct measure as an indirect measure of market power. Under maintained assumptions about the structure of demand and marginal cost, comparative static properties are utilized to infer market conduct without directly observing marginal cost.

The NEIO approach has spread, and has been applied to a number of different questions.

One strand of this literature has provided estimates of conduct in a variety of industries. Applebaum (1982) estimated conduct in the Electrical Machinery, Rubber, Textile, and Tobacco industries. Bresnahan's (1981) paper found departures from marginal cost pricing in the automobile industry. Sumner (1981) found statistically significant, although economically small, market power in the cigarette industry. Other studies have estimated conduct in the Canadian food processing industry (Lopez (1984), the interwar Aluminum industry (Suslow (1986)), the coffee roasting industry (Gollop and Roberts (1979), and Roberts (1984)), retail gasoline (Slade (1987)), and the television manufacturing industry (Karp and Perloff

(1989)).[1]

A second strand of literature has used NEIO techniques to test a particular theory of oligopoly behavior. For example, Porter's influential (1983) study of the nineteenth century railroad cartel, the Joint Executive Committee, detected a pattern of equilibrium price wars consistent with the Green-Porter (1984) model. This study has led to a body of research, with contributions by Lee and Porter (1984), Porter (1985), Berry and Briggs (1988) and Ellison (1994).

A third area of research has applied the empirical CV approach to policy questions, such as the effects of deregulation. Spiller and Favaro (1984) found that the removal of entry restrictions in the Uruguayan banking industry resulted in more competitive conduct. Rubinovitz (1993) studied the deregulation of cable television rates, and found that a substantial portion of the ensuing rate increases was due to the exercise of monopoly power.

Finally, the techniques of the "New Empirical Industrial Organization" have spread beyond the field of Industrial Organization, narrowly defined, extending most notably to the characterization of imperfect competition in international markets. For instance, Knetter (1989, 1993) has applied these techniques to explain the failure of exchange rate fluctuations to be fully "passed through" into import prices.

Despite the widespread application of this methodology, a number of objections have been raised about the NEIO approach. First, NEIO studies typically impose strong functional form assumptions on demand, which under static oligopoly models imply even stronger restrictions on the relationship between price and marginal cost. If these assumptions are erroneous, inferences about market power may be incorrect. Second, as Corts (1994) has argued, the NEIO conduct parameter measures the marginal response of price, and hence the markup, to changes in exogenous variables. It thus infers market power from the marginal behavior of the markup, not from the level of the markup, and so may mismeasure the level of market power if firm behavior cannot be represented as a conjectural variations equilibrium.

[1]The measures of market power from these studies are listed in Bresnahan (1989), Table 1, or Carlton and Perloff (1994), p. 363.

For example, supergame models of oligopoly behavior in stochastic demand environments, as in Rotemberg and Saloner (1986), may generate behavior in which the marginal response of price to demand shifters is independent of the discount rate, and hence the price level at some baseline state of demand. More broadly, the NEIO approach has never been "tested", since such an assessment requires that one have at hand an alternate measure of the conduct parameter as a basis for comparison with the NEIO.

The purpose of this paper is to assess the efficacy of the NEIO by making just such a comparison. We utilize conduct estimates from a particular industry setting, the United States cane sugar refining industry at the turn of the century. Three features of this industry make it a particularly attractive setting in which to evaluate the conjectural variations approach.

First, the production technology is simple. Raw sugar is transformed at a fixed, and known, coefficient into the final product, which is refined sugar. We therefore have great confidence in the structural form of marginal cost. Moreover, since we can observe the prices of both raw sugar and refined sugar, and we possess excellent estimates of labor and other costs, we can directly measure a *true* price-cost margin.

Second, the well-defined harvest cycle of raw sugar generates exogenous seasonal fluctuations in the supply, and hence price, of this input. Yearly climatic changes lead to exogenous variation of the raw sugar price as well. These fluctuations help to identify not only demand, but also conduct, in a manner common to several NEIO studies.

We can therefore compare the first, direct measure of conduct computed from the complete information on costs and prices with the second, NEIO estimates of conduct. As a secondary validation of the NEIO method, we can compare its indirect estimates of the cost parameters with our direct ones.

A third feature is that the history of the sugar refining industry involved dramatic structural changes. These include the formation of the Sugar Trust in 1887, subsequent repeated episodes of entry (with consequent price wars), renewed consolidation, an antitrust prosecution and subsequent "voluntary", partial dissolution. These structural changes allow us to assess the efficacy of the NEIO approach under different structural conditions. Moreover, we can examine whether the CV conduct estimates change appropriately with clear changes in structural conditions, and whether the CV approach can, in fact, differentiate those conduct changes from changes in cost.

More formally, we conduct our evaluation of the NEIO in the following manner.

In the empirical conjectural variations literature, the equilibrium oligopoly price is characterized by the following generalization of the monopolist's first order condition:

$$P + \theta Q P'(Q) = c \tag{1}$$

where θ is the conduct parameter, and c is marginal cost. The conduct parameter may be given the interpretation of the share of the inframarginal industry output that the firm takes into account in making its output decision. For monopoly, θ equals one, for symmetric Cournot oligopoly it is the inverse of the number of firms in the industry, and for perfect competition it is zero.

Although θ might be viewed as a general function of demand and supply conditions, some restriction must be imposed on the properties of θ in order for (1) to be empirically operationalized. It is typically assumed to be constant. A less restrictive assumption would allow θ to vary, so long as it is uncorrelated with whatever instruments are used to identify (1). These will typically be current cost or demand indicators.

With complete cost information, it is straightforward to measure θ directly. Rewriting (1),

$$\theta = \eta(P)\frac{P - c}{P} \equiv L_\eta \tag{2}$$

so that θ equals the elasticity-adjusted Lerner index, L_η.

This paper is structured as follows. After an initial survey of the historical background, we assemble the ingredients for both L_η and our CV estimates. In section 2, the technology of sugar production is detailed. In particular, we characterize both the structure and value of marginal cost. In section 3, we estimate the industry demand curve. From this estimate, we recover the elasticity of demand, $\eta(P)$, which coupled with the price-cost data, yields our direct measure of industry conduct, the elasticity-adjusted Lerner Index, which we report in section 4. We also step into the NEIO framework, estimating industry conduct and cost parameters under varying assumptions about the researcher's knowledge of demand and cost conditions. We then compare these estimates with each other and with the elasticity-adjusted Lerner Index.

Under the maintained hypothesis that the elasticity-adjusted Lerner Index truly measures industry conduct, we are able to evaluate the efficacy of the NEIO approach in this specific empirical setting.

We find that the NEIO approach performs reasonably well, although its performance in certain circumstances is cause for further study. In particular, the estimated NEIO conduct parameter was generally close to the elasticity-adjusted Lerner index. This was true for all the demand specifications we employed. The NEIO did underestimate the conduct parameter, but this deviation was minimal in our context. On the other hand, the CV approach turned in a mixed performance in estimating the cost parameters. Finally, imposing information about cost parameters did not affect the estimates of the conduct parameter.

In section 5 we consider the relationship between structure and conduct as an additional means to evaluate the CV approach. We compare the elasticity-adjusted Lerner index with NEIO estimates over different structural regimes. Here, as well, the NEIO estimates closely track the elasticity-adjusted Lerner index, regardless of the demand specification, and all the conduct estimates change in the direction one would expect given the changes in structural conditions. When we allow the CV approach to attribute the price wars to changes in cost instead, however, it erroneously does so, indicating the importance of *a priori* information in distinguishing between conduct and cost changes.

Section 6 concludes.

Table 1: Chronology of the U.S Sugar Industry

1887	Sugar Trust formed
1889-90	Entry by Spreckels
1891	Sugar Trust incorporated as American Sugar Refining Co.
1891-92	Acquisition of Spreckels, others
1892-1896	Small Scale Entry, Cartel Operation
1898	Entry by Arbuckle Brothers and Doscher
1900	End to Arbuckle war
1903	Cuban Reciprocity Treaty
1910	Government files antitrust suit
1914	World War I begins

1 Historical Background

The history of the American sugar industry is admirably chronicled by Eichner (1969) and Zerbe (1969). Although we differ with some of their interpretations, both authors provide invaluable guidance for understanding the industry, and should be consulted for a more detailed chronology than that presented here. For a contemporary chronicle of the sugar industry, nothing compares with Willett and Gray's *Weekly Statistical Sugar Trade Journal.* That trade publication is the source for most of our data and much of our supporting information concerning the industry.

The purpose of this brief overview is to sketch the major structural changes in the industry, as outlined in Table 1. This constitutes important background information.

After several unsuccessful attempts at collusion, the Sugar Trust was formed in December 1887 as a consolidation of 18 firms controlling 80 per cent of the industry's capacity. The 20 plants owned by the original Trust members were quickly reorganized and reduced to 10 plants. Refined prices rose 16%, and entry soon followed.[2] The first entrant was Claus Spreckels who, in December 1889, completed a plant in Philadelphia.[3] That led first to a

[2]The average refined price rose from $ 6.013 (per hundred pounds) in 1887 to $ 7.007 in 1888. From Willett and Gray, cited by Eichner, p. 343.

[3]Spreckels refined sugar on the West Coast, while the Sugar Trust was centered on the more populous East Coast. Spreckel's entry was in retaliation for the Sugar Trust's acquisition of a plant in California the previous spring, which had touched off a price war on the West Coast.

price war, and then to American Sugar acquiring the Spreckel's Philadelphia plant along with those of firms that had remained outside the original Trust.[4] This acquisition campaign was completed by April 1892 and it raised American Sugar Refining's share of industry capacity to 95 per cent.

This earliest episode set the pattern for the subsequent history of the sugar industry: high levels of concentration, punctuated by episodes of entry that engendered price wars and later acquisition by or accommodation with American Sugar.

In the next several years, the degree of concentration slowly declined, as a series of firms entered, each at a relatively small-scale.[5] Five firms entered in all, each with a single plant, with an average capacity of 1340 barrels of refined sugar per day. This was in contrast to the 49,500 barrels capacity of American Sugar Refining and associated "friendly" companies.[6] American Sugar took on the role of the leader of a cartel, and by 1896, contemporary publications indicate that an understanding had evolved between American Sugar and the new, so-called independents.

The next phase of the industry's competition began in 1898. The Arbuckle Brothers constructed a plant, which began limited, initial production in August.[7] Another entrant, the Doscher refinery, began production in November. When fully operational, each of these new plants had a capacity of 3,000 barrels daily. This precipitated a severe price war, marked by pricing at or below cost, shut-down by the independent refiners, and partial exit by one of the new entrants. With the exception of one "respite" in the price war, the war continued until May 1900, when the Doscher refinery merged with two of the major independents, the

[4]The Sugar Trust was reorganized as a corporation, the American Sugar Refining Company (ASRC), in 1891.

[5]Vogt, p. 49 lists the individual refineries, with their capacities and their date of entry.

[6]Vogt, p. 48.

[7]The rivalry between the Arbuckle Brothers and American Sugar Refining preceded their entry into sugar refining. The Arbuckle Brothers were large wholesale grocers and the dominant roasters of coffee in the United States. Their position in coffee was due to a patent on a packaging machine, which enabled them to sell coffee in small packages, rather than in bulk form. From 1892-1896, they applied the same technology to sugar, buying refined sugar from American Sugar Refining and then reselling packaged sugar. In September 1896 Arbuckle Brothers announced their intentions to enter sugar refining. American Sugar entered coffee roasting a few months later by purchasing another firm, and a coffee price war ensued. Construction of the Arbuckle Sugar Refining plant took almost two years.

Mollenhauer and the National, in a transaction organized by the President of the American Sugar Refining Company.

The industry's structural conditions were also significantly influenced by government action, through both the tariff and antitrust.

The tariff structure contained two chief components, the duty on raw sugar, an input, and the duty on refined sugar, the final consumption good. The tariff on refined sugar was important in protecting the U.S. refining industry from foreign, chiefly European, competition. In addition, an important preference was granted toward (raw) Cuban sugar in 1903. Under the Cuban Reciprocity Treaty, Cuban sugar was admitted to the U.S. at a tariff rate of 80% of full duty.

American Sugar's attempts to acquire and maintain dominance did not escape antitrust scrutiny. In 1910 the Federal government filed suit, charging monopolization and restraint of trade, seeking the dissolution of American Sugar. Although this case was not formally resolved until a consent decree was signed in 1922, the government's victories in the American Tobacco and Standard Oil cases in 1911 led American Sugar to initiate partial, "voluntary," dissolution.[8]

[8]There were also earlier antitrust actions. In 1892 the government challenged American Sugar's acquisition of several Philadelphia refineries in the *E.C. Knight Case.* The Supreme Court's decision in 1895 upheld the acquisition.

2 Technology of Sugar Production

The production technology of sugar is quite simple. Raw sugar is transformed at a fixed, and known, coefficient into the final product, which is refined sugar.

In this period, most refined sugar in the United States was derived from sugar cane. Sugar cane was initially processed into raw sugar, a form which can be transported and stored for later refining. The standard grade of raw sugar was "96 degree centrifugals," which is 96% pure sugar, or sucrose, and 4% water and impurities. The sugar content of raw sugar was tested by the polariscope device, which thereby ensured input homogeneity. Most of the raw sugar refined in the U.S. was produced in the tropics, especially Cuba, although Louisiana was an important domestic source. The raw sugar was then "melted," purified, and crystallized by refiners into refined sugar, which is 100% sucrose.[9]

The cane refiners utilized a common technology.[10] In addition to the fixed-coefficient materials cost of raw sugar, variable costs also included labor and other costs. The constant marginal cost of sugar refining, c, can therefore be summarized by:

$$c = c_o + k * P_{RAW} \tag{3}$$

where c represents the marginal cost of producing 100 pounds of refined sugar, c_o represents all variable costs other than the cost of raw sugar itself, and k is the parameter of the fixed-coefficient production technology between raw sugar and refined sugar. This cost structure is a maintained hypothesis throughout this paper. For ease of discussion we speak of the cost of producing 100 pounds, although in some cases we will quote contemporary observers about the cost per pound.

In addition to knowing the structure of marginal cost, we have a precise estimate of k and can place c_o within a narrow range. In what follows, we will sometimes have need of

[9]Paul Vogt, *The Sugar Refining Industry in the United States*, 1908, p. 1.

[10]Claus Doscher of the New York Sugar Refining Co. and Henry Havemeyer of American Sugar Refining Company both testified that the general processes of sugar refining were common to all refiners. June, 1899 testimony, *Report of the U.S. Industrial Commission,* Volume I, Part 2, 1900, p. 100, p. 112, respectively.

these values, in order to substitute them into (3). Since raw sugar was only 96% sucrose, the lowest value of k that is physically feasible is $k = \frac{1}{.96} = 1.041$. In fact, there was some loss of sugar in the refining process, so 100 pounds of raw sugar would yield only 92.5 to 93 pounds of refined sugar.[11] Put otherwise, the production of one pound of refined sugar requires 1.075 pounds of raw sugar, or $k = 1.075$. This technological coefficient, which remained unchanged over our sample period and beyond, [12] will play a crucial role in our formal analysis.

Inferring the value of c_o is less straightforward. Nevertheless, we have a number of different sources of evidence that are consistent with each other. The earliest evidence comes from testimony before the Industrial Commission in 1899.[13] The following is an exchange between Henry Havemeyer, President of American Sugar, (H) and a Congressional questioner (Q):

> H: Now, there has never been any cost of refining that I have ever been acquainted with less than one-half cent a pound, and at the time of the formation of the trust it was three-quarters. Now, you have got the whole business. We maintain that when we reduced the cost we were entitled to the profit ...
> Q: You say you have never know the actual cost of refining to be less than one-half cent?
> H: No, I doubt very much if any refineries can do it.[14]

Havemeyer goes on to agree with his inquisitor that at a margin of 50 cents a hundred, "the refineries are running at a loss" and "dividends can hardly be paid out of profits."

In interpreting these statements, one must take into account the sugar industry's definition of "the margin." This was the difference between the price of 100 pounds of refined sugar and 100 pounds of raw sugar. Because raw sugar was transformed into refined sugar at less than a one-for-one basis, this "margin" does not represent a true net-of-raw-sugar-costs margin. One needs to know the price of raw to infer that value, which is $P - 1.075 \times P_{RAW}$

[11]Stephen Buynitsky, an official from the Customs division of the Treasury Department testified that "According to the data collected by the special commission of the Treasury department in 1898 the average quantity of refined sugar produced from 100 pounds of sugar testing 96 [degrees] was 92.5 pounds.", June 10, 1899 testimony, *Report of the U.S. Industrial Commission,* Volume I, Part 2, 1900, p. 44.

[12]See U.S. Tariff Commission, *Refined Sugar: Costs, Prices and Profits,* Washington 1920. The evidence there is drawn from government audits of the refiners' books.

[13]The testimony on costs is summarized in Volume I, part 1, pp. 65-66.

[14]Henry Havemeyer, June 14, 1899 testimony, *Report of the U.S. Industrial Commission,* Volume I, Part 2, 1900, p. 112.

(per 100 pounds) and which we denote the "proper margin." A partner in Arbuckle Brothers conveniently provides that price for us:[15] "I think I have answered that question by saying [that the cost of refining is] from 50 to 60 points, or one-half to six-tenths of a cent per pound. In other words, if raw sugar costs $4\frac{1}{2}$ cents a pound, it will cost over 5 cents up to $5\frac{10}{100}$." Subtracting $4\frac{1}{2} \times 1.075$ from a total cost of 5 or $5\frac{10}{100}$, we obtain a value of c_o ranging between 16 and 26 cents (per hundred pounds).

Yet another witness provided a detailed breakdown on the components of c_o: 5 cents for brokerage and government tax, 10 cents for packages, 20 cents for wages, fuel, boneblack, repairs and sunderies, less 10 cents for the value of byproducts, principally syrup, for a total of 25 cents.

At the Hardwick Committee hearings of 1911, the cost of refining was solicited of the refining companies once again. Various people quoted a cost between 60 and 65 cents per 100 pounds, at a time at which raw was selling for $4.00 per 100 pounds. This implies a value of c_o ranging between 30 and 35 cents in nominal terms, or 22 and 26 cents in constant 1898 dollars.[16]

In addition to the testimony presented at these two hearings, evidence from audits conducted by the U.S. Tariff Commission between 1914 and 1919 is also available.[17] Corrected for accounting depreciation (which is *not* included in the previous estimates) and the value of the syrup, the estimated value of c_o for 1914, which is the last year in our sample, is 35 cents in nominal terms, or 25 cents in 1898 dollars.[18]

Firm behavior provides a further check on these numbers. The Industrial Commission hearings were held in the midst of the Arbuckle price war. In several separate instances in that war, the independent refineries, principally the Mollenhauer, shut down or ran at

[15] James N. Jarvie, June 15, 1899 testimony, ***Report of the U.S. Industrial Commission,*** Volume I, Part 2, 1900, pp. 138-139.

[16] Constant dollar prices are computed from the wholesale price index in Hanes (1993).

[17] U.S. Tariff Commission, 1920, p. 33.

[18] To make the figures correspond to the quoted estimates, we subtracted .013 for depreciation and .056 for receipts for by-products from the total refinery cost of .420, to arrive at an estimate of .351. The 1915 and 1916 figures are similar. From 1917 on, the figures increase presumably reflecting changing relative prices consequent of the war. Also, the sugar industry was regulated in those later years.

"minimum capacity".[19] The proper margin during these shut-down periods should give an indication of the value of c_o.[20] Unfortunately, it is impossible to identify a single breakeven margin, as there is a range of margins in which a given firm is sometimes producing and sometimes not. There are several reasons for that. We see prices only on Fridays, whereas descriptions of shut-downs can refer to events earlier in the week. Month long contractual obligations and the value of a reputation for assured supply may lead firms to produce at a current loss.[21] Most importantly, shut-down costs will drive a wedge between the margins at which it is optimal to shut down and start up production, while changing expectations of the future paths of refined and raw prices will make those two margins variable. The reports of firms running at "minimum capacity" indicate that such shut-down costs did, indeed, exist.

Notwithstanding our inability to use the behavior of the independents during the Arbuckles price war to pin down c_o exactly, that behavior does reveal that our more direct estimates of c_o are reasonable. The minimum proper margin above which the refiners always produced is 26 cents. Except for a couple of weeks, these firms never produced at proper margins below 9 cents (constant 1898 dollars).[22]

We therefore take 26 cents as our best estimate of c_o, since that value is supported by the most and best evidence. As a reflection of our uncertainty, however, we will at times make use of 16 cents as a lower estimate. Although proportionate to the level of c_o this range appears large, as a fraction of either total cost or revenue it is small. At 16 cents, non raw-sugar inputs are 4.5 percent of all costs while at 26 cents it is 7.5 percent, using the mean raw price of $3.31 per hundred pounds. The appropriate interpretation of this range is as a reflection of our ignorance, not as a reflection of differences in refining costs among firms. There was general agreement among the witnesses at the Industrial Commission hearings that refiners

[19] See Willett and Gray, *Weekly Statistical Sugar Trade Journal*, November 17, 1898, February 2, 1899, October 5, 1899, January 25, 1900, February 23, 1900.

[20] This is true so long as the independent refiners were not acting strategically. That Arbuckles and ASRC were producing throughout raises the question of predation, but we will set that aside for future work.

[21] The importance of assured supply is revealed in the contest between the Arbuckles and ASRC for retailers in New England.

[22] For example, these refiners shut down when the price of refined sugar was 4.71 dollars per 100 pounds, and the price of raw sugar was 4.30 dollars per 100 pounds. The money from selling a 100 pounds of refined sugar after covering the cost of the required raw sugar was $4.71 - 1.075 \times 4.30 = 8.75$ cents per 100 pounds.

shared the same technology, and a commission merchant for one of the independents testified that "it is possible that the [larger houses] can refine at a smaller margin than the others. ... [but] it can [not] amount to a great deal; I suppose 3 to 5 cents a hundred would represent the difference." Also, the Doscher refinery, which was constructed contemporaneously with the Arbuckle plant and therefore presumably employed the same state-of-the-art technology, significantly curtailed its production in the late stages of the war.[23]

In 1900, the estimated cost of a refinery with a capacity of 3,000 barrels per day ranged from $1,500,000 to $2,500,000.[24] This cost consisted of two components, the plant and machinery, and the land. The plant and machinery was almost entirely specific to the sugar industry, and would have little value in any other use.[25] In contrast, the land was a significant element of the refinery's cost, and it would have considerable salvage value.[26] Because of the need to import raw sugar, the sugar cane refiners constructed their plants on the waterfront. This enabled raw sugar to be unloaded directly into the plant or nearby warehouses. Entry costs were therefore considerably but not completely sunk.

For the period in question, industry production was always well below industry capacity. American Sugar Refining in particular retained substantial excess capacity, possessing excess capacity even in the depths of the Arbuckle price war. This excess capacity can be seen as the legacy of consolidations and acquisitions. As retaining that excess capacity was costly, one wonders whether it might have played a strategic role. However such concerns are beyond the focus of the present paper.

The standard grade of refined sugar was "standard granulated." Like 96 degree centrifugals, "standard granulated" was a homogeneous product.[27] In fact, refined sugar was shipped to grocers in barrels, who in turn packaged the sugar for final consumers without

[23] *Weekly Statistical Sugar Trade Journal*, May 17, 1900.

[24] *Report of the U.S. Industrial Commission,* Volume I, Part 1, 1900, p. 67.

[25] Philip G. Wright, *Sugar in Relation to the Tariff*, 1924, p. 29.

[26] One witness estimated the replacement cost of two particular refineries at $ 1,700,000 each. The land was valued at $600,000 for a waterfront location in Brooklyn, and $250,000 for a location in Yonkers. *Report of the U.S. Industrial Commission*, Volume I, Part 1, 1900, p. 152.

[27] G. Waldo Smith, President, Wholesale Grocers Association of New York City, June 12, 1899 testimony, *Report of the U.S. Industrial Commission,* Volume I, Part 2, 1900, p. 67.

any identification of the manufacturer.[28] Prices therefore tended toward uniformity.

In addition to sugar cane, refined sugar can also be made from beets. The domestic and European beet sugar producers constituted two competitive fringes to the industry of interest, the United States cane sugar refiners. Most of the sugar produced in the U.S. was refined cane sugar, although domestic beet sugar grew in importance during this period. Domestic beet sugar supplied less than 1% of U.S. consumption until 1894. This rose to 5% by 1901, and constituted 15% in the years 1908-1914.[29]

European beet refiners provided an additional competitive threat. Europe, and especially Germany, was the center of the world's production of raw and refined beet sugar. Although very little refined sugar was imported into the United States, the threat of imports from Europe affected U.S. prices, at least in some time periods.[30]

There is considerable testimony that in the early years following the formation of the Trust, imports were impeded; the threat of imports caused American Sugar Refining to set the price of refined sugar so that no refined sugar would be imported. Henry Havemeyer of American Sugar Refining Company acknowledged this strategy in Congressional testimony in 1888 and 1894.[31] For later years, evidence suggests that imports of refined sugar were either impeded or blockaded. This difference is linked to changes in the international market for *raw* sugar, the essential input to refined sugar. In short, the Cuban Reciprocity Treaty of 1903 and productivity gains in the Cuban sugar cane industry lowered the New York price of raw sugar relative to the German price of raw beet sugar. This in turn affected the costs of American and German refiners, and hence the competition between them.

Although we acknowledge the influence of these competitive fringes, they are not formally incorporated into our analysis. This is entirely appropriate given our task. We wish to

[28]James Jarvie, partner in Arbuckle brothers, June 15, 1899 testimony, *Report of the U.S. Industrial Commission,* Volume I, Part 2, 1900, p. 146-147. Arbuckle brothers introduced the practice of selling refined sugar to grocers in labelled 2 lb. and 5 lb. packages. Yet even they sold most of their sugar in barrels.

[29]Truman Palmer, *Concerning Sugar*, Looseleaf service, 1929, p. E-54-A,B.C.

[30]Truman Palmer, *Concerning Sugar*, Looseleaf service, 1929, p. E-54-B. Statistics derived from Willett and Gray.

[31]Eichner, p. 96.

compare "overall" or average measures of conduct, which therefore include the discipline of potential foreign competition and domestic beet sugar.

3 Demand

If we are to make statements about the ability of the sugar industry to price near the monopoly price, then it is essential that the monopoly price that we construct be reliable. This requires, in turn, that our estimates of the demand curve be convincing. Three issues arise: the frequency of data, the choice of instruments, and functional form.

We have the luxury of having weekly data available. The advantage of using high frequency data lies in the additional degrees of freedom, albeit tempered by higher serial correlation. But the more frequent the data, the more likely we are to estimate a misleadingly low elasticity of demand. In the presence of grocer or consumer switching costs, the short run elasticity may be much smaller (in absolute value) than the long run elasticity. Focusing on the former would lead us to estimate a much higher monopoly price than is optimal for a forward looking monopolist, and thus, at observed prices, a much lower degree of market power. We compromise by using quarterly data, although qualitatively the coefficient estimates are similar when we use monthly data.

An alternative approach would be to employ weekly data and explicitly model the dynamic problem facing the monopolist. This alternative seems inappropriate for this paper, a validation study. The typical NEIO study employs low frequency data and does not explicitly model dynamic demand issues. Any estimates or conclusions resulting from our use of a dynamic specification might reasonably be viewed as hinging on the particulars of that specification. Employing quarterly data is both a simpler and more robust solution to our dynamic concerns.

For prices, we use quotations from Willett and Gray's *Weekly Statistical Sugar Trade Journal.* Unfortunately, actual consumption data are not available. Instead, we have estimates of meltings (production) from Willett and Gray. Because of final good inventorying and early policies of production to order (with a one month lag), meltings do not correspond exactly to consumption. Meltings should serve as a reasonable proxy, however. Extensive inventorying of refined sugar was avoided because of the risk of "deterioration of the refined sugar which might become lumpy or undergo slight chemical changes," requiring "the sugar to be reprocessed or sold at a discount."[32]

A second issue that we must address is the choice of instruments. We do not use the price of raw sugar as an instrument, because, at 25 percent of the total world consumption, U.S. consumption is too large a fraction of the total market to regard that price as uncorrelated with U.S. demand shocks.

Instead, we use imports of Cuban raw sugar as a supply instrument. Cuba was a low cost source of raw sugar for the U.S. both because it was the closest source to the East Coast refiners, and because after 1903 it enjoyed a preferential tariff. As Column (1) of Table 2 indicates, the vast majority of Cuban exports (and production) was imported into the United States. This fraction never fell below eighty-five percent, and exceeded 98 percent in every year between 1900 and 1909. Column (2) of the same table shows total Cuban sugar production. Table 3 expresses Cuban imports as a share of total U.S. imports. This fraction is much smaller and more variable than the earlier one. Taken together, the three time series indicate that Cuban production, and not total U.S. imports, drove Cuban imports to the United States. We use Cuban imports rather than production because only the former is available to us at quarterly frequencies.

It is clear that Cuban imports were an inframarginal source of raw sugar for the United States, at least in the short run. The next best alternative destination for Cuban sugar was London. Shipping costs were considerably higher to London than to New York, and so the delivered price offered in London for Cuban sugar would have to exceed the New York price by a considerable amount in order for sugar to be sent to London. That cost differential was increased by Reciprocity in 1903. In addition, there appear to have been substantial switching costs to selling other than in New York. There are contemporary comments that because all facets of the Cuban industry, including shipping schedules, were directed toward the U.S. market, sending Cuban sugars to another destination "would always involve inconvenience and costs, and these considerations would lead to acceptance by Cuban

[32]Myer Lynsky, *Sugar Economics, Statistics, and Documents*, 1938, p. 84.

Table 2: Cuban Production and Exports

YEAR	PERCENT OF TOTAL CUBAN EXPORTS SENT TO U.S.	TOTAL CUBAN SUGAR PRODUCTION
1892	89.2	976,000
1893	94.6	815,894
1894	94.3	1,054,214
1895	92.8	1,004,264
1896	96.9	225,221
1897	99.2	212,051
1898	97.4	305,543
1899	99.95	335,668
1900	99.98	283,651
1901	99.99	612,775
1902	99.99	863,792
1903	98.32	1,003,873
1904	99.59	1,052,273
1905	+99.99	1,183,347
1906	99.64	1,229,736
1907	99.57	1,444,310
1908	+99.99	969,275
1909	99.99	1,521,818
1910	94.26	1,804,349
1911	99.88	1,469,250
1912	92.64	1,800,000 *
1913	90.01	
1914	86.74	
1915	88.58	

Statistics for 1900-1915 are reported by fiscal year, and taken from United States Tariff Commission, *Effects of the Cuban Reciprocity Treaty of 1902*, GPO: 1929, p. 65. The figures prior to 1899 are calendar years, and are from Willett and Gray.

Table 3: Sources of Shipments of Sugar into continental U.S., 1900-1915

YEAR	PER CENT OF TOTAL RECEIPTS FROM		
	CUBA	US TERRITORIES	FULL DUTY COUNTRIES
1900	17.6	13.8	68.7
1901	22.9	17.3	59.8
1902	25.0	23.3	51.7
1903	45.9	19.6	34.5
1904	60.0	22.5	17.5
1905	43.0	24.7	32.3
1906	54.2	23.9	22.0
1907	57.7	22.3	20.1
1908	46.9	32.2	20.8
1909	49.5	27.6	23.0
1910	60.8	32.1	7.1
1911	59.8	33.7	6.4
1912	52.7	39.3	8.0
1913	65.4	31.2	3.4
1914	72.2	27.5	0.3
1915	65.6	30.1	4.2

Statistics are reported by fiscal year, and taken from *Foreign Commerce and Navigation of the United States*, reprinted in U.S. Tariff Commission, *Effects of the Cuban Reciprocity Treaty of 1902*, 1929, p. 66.

exporters of what might otherwise be considered unacceptable bids for their sugar."[33] So even very low realizations of American demand for Cuban raw sugar would be unlikely to divert Cuban sugar from the United States. For these reasons, we conclude that Cuban imports were exogenous to American demand for raw sugar in the short run.

The extent of any potential endogeneity of Cuban imports with respect to American demand over the long run depends upon the sources of the variation in Cuban production. These are, first, the seasonality of the annual harvest cycle, second, yearly climatic variations, third, the Spanish-American War, which impeded both the production of raw sugar and its transport to the United States, and fourth, a secular increase in the planting of sugar cane. The sources of the first three types of variations are clearly exogenous to American demand.[34] The last, however, may have been a response to growing American demand. More generally, any planting in the (correct) anticipation of American demand will introduce a correlation between Cuban imports and shocks to American demand. We do not think that the resulting bias will be significant for a number of reasons. First, with respect to the secular increase in the planting of sugar cane, much of that was in response to the Reciprocity Treaty of 1903, which can be properly regarded as exogenous to demand.[35] Second, as we include a time trend in demand, any potential endogeneity bias can only arise out of anticipated deviations from that trend. Third, Cuban sugar cane yields a harvest for five years, and require almost no tending, so that the "capital stock" is relatively fixed.

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[33]U.S. Tariff Commission, *Effects of the Cuban Reciprocity Treaty,* p. 72.

[34]We do not deny that revolutions may have economic causes. But we are unaware of any claim that the Cuban Revolution, which precipitated this war, was itself precipitated by a shock to American demand!

Geerligs, 1912 discusses the very dramatic and persistent effects of the Cuban revolution and Spanish-American War: "In the following year, 1895, however, the last rebellion against Spain broke out; after much calamity and devastation it ended in the Spanish-American War, and ultimately in the establishment of the Cuban Republic. This period of disturbance and strike is the worst in the entire history of Cuba ... Owing to the destruction of the factories, the burning over of cane fields, and the extermination of draught cattle, it became almost an impossibility to carry on the sugar industry; and in spite of the strict regulations issued by the Spanish authorities to go on grinding as long as it was feasible, the production in 1897 went down to as low a figure as 212,051 tons. It goes without staying that the industry recovered only slowly when the period of misery and destruction had come to an end, and was followed by a time of quiet." H.C. Prinsen Geerligs, *The World's Cane Sugar Industry*, Norman Rodger, Manchester, 1912, p. 173.

[35]See Dye (1994) for a discussion of technological and organizational improvements in Cuban sugar cane production.

There is one further concern about the exogeneity of Cuban imports to American demand. Suppose that there is a negative shock to American demand this quarter, which in turn lowers this quarter's price for raw sugar. Might not this negative shock induce Cuban raw sugar suppliers to shift some raw sugar exports into the next quarter, when raw sugar prices might be higher? Although this would be a plausible scenario for many industries, it is highly unlikely in our context. The key issue is whether a shock to U.S. demand would induce raw sugar storage and speculation to take place **in Cuba**. If the induced storage activity took place *in New York* or any other U.S. port, then Cuban imports remain exogenous to shocks to American demand. In fact, storage of raw sugar *in Cuba* for speculative purposes was dominated by harvesting the raw sugar at the time dictated by weather conditions and shipping it to New York, where it could be stored more cheaply. The following discussion works through the reasoning.

The willingness of Cuban suppliers to engage in storage and speculation activity depends upon the storage technology at their disposal. Cuban planters and raw sugar factories possessed two options. First, after processing the sugar cane into raw sugar, that raw sugar could be stored in warehouses in Cuba. Except for temporary storage at docks awaiting transportation to the United States, Cuban raw sugars were not warehoused in Cuba during this period since the continual hot weather posed deterioration risks which were absent in New York.[36] Moreover, since New York City was one of the world's central sugar markets, numerous experienced brokers there were well positioned to exploit any arbitrage opportunity that might arise in the raw sugar market.

A second storage option for a Cuban planter would be to delay harvesting the sugar cane, postponing grinding into raw sugar, and thereby store the sucrose in the cane. This second option was unattractive for several reasons. First, if sugar cane is not harvested close to its

[36]Suitable Cuban storage facilities were constructed in the early 1920s. Prior to that time, however, "the planter in Cuba, having little cash and meagre storage facilities, was compelled to ship his product as fast as it was made, sometimes unsold; consequently, ... he was forced to accept what price he could secure; he was not able to hold his sugar for a possibly higher market." Philip Reynolds, *The Story of Cuban Sugar*, United Fruit Co., 1924, p. 52.

peak condition, or ripeness, some sucrose is lost.[37] Second, the Cuban harvest season was dictated by weather conditions, in particular the onset of the rainy season. Geerligs (1912) explains: "Grinding is undertaken exclusively in the dry weather, so that it must be put off till the ground is well dried. Hard roads are of rare occurrence in Cuba, and the cane, as a rule, has to be carried by ox carts from the fields ... As long as the soil is dry the heavy carts ... can easily do the work; but comparatively light showers, i.e. of two inches, cause the ground to become so soft that the vehicles get stuck deeply in the earth, transportation becoming an impossibility. Consequently, grinding should be begun immediately rain is over, [sic] i.e., in December, as the work has to be stopped when the next showers come, which may happen either as early as April or not before July. Further on ... it will be shown of how much importance this uncertainty as regards the duration of the rainy season may be for the sugar production of that island."[38] As a result, a Cuban farmer contemplating postponing harvest in hopes of securing a better price would run the significant risk that the rainy season would begin before he had the chance to harvest all the cane. That would not be a total loss, as a portion of the cane would be available for harvest the following season, in December,[39] but delaying harvest was a very crude tool for trying to arbitrage month to month, let alone quarter to quarter, price differences.[40]

The foregoing discussion has worked through the reasons why a negative shock to U.S. demand would not induce a postponing of Cuban imports into later in the season. Similar considerations account for why a *positive* shock to U.S. demand, and hence the price of

[37]Reynolds, p. 27. Sugar cane has three distinct phases in a given season. First is the *growing* stage in which the sugar cane expands its green vegetative growth. Second is the *ripening* stage as the cane converts and stores sucrose. Third is the *harvest* stage in which the cane is harvested.

In practice, the Cuban harvest extended before and after the period of maximum sucrose content in order to lengthen the grinding season in the face of capacity constraints in the raw sugar factories. Yet these capacity constraints also served to check the ability of the planter to choose his harvest date. During the grinding season, the raw sugar factories ran day and night. Reynolds, p. 30.

[38]Geerligs, p. 178.

[39]Willett and Gray, *Weekly Statistical Sugar Trade Journal*, June 14, 1906, p. 2.

[40]A few centrals, or raw sugar factories, favorably situated in Santiago province, continued grinding through September which accounts for why Cuban imports continue through the rainy season. Willett and Gray, June 21, 1906, p. 2. Yet even these centrals would lose sucrose by delaying the harvest beyond the point of peak sucrose content.

raw sugar, would not induce an expedited harvest. The harvest and grinding could not begin until the roads were dry, and even if grinding could occur earlier, the farmer would substantially reduce the sugar content of his crop by premature cutting.[41]

A final point on this exogeneity issue is to recall that we estimate demand using quarterly data, and this frequency should further attenuate the likelihood that Cuban suppliers shifted imports from one period to another in response to U.S. demand shocks.

Any demand estimation must involve some functional form assumption.[42] The typical "new empirical industrial organization" paper employs either a linear or a log-linear demand curve. The implied monopoly pricing rules (under constant marginal cost) are very restrictive. For the log-linear case, the monopoly price is proportional to marginal cost; in the linear case, every dollar increase in marginal cost increases the monopoly price by fifty cents. When studying an industry in which marginal costs do not vary much over time, and most variation is in demand (as in studies of the Joint Executive Committee in the late nineteenth century railroad industry, for example), the a priori restrictions that these choices of functional form place on the monopoly pricing rule may not be important. But most of the variation in the sugar industry originates from the supply side. We are therefore interested in comparing the demand and conduct estimates from a variety of commonly employed functional forms. This will allows us to assess whether these functional form assumptions affect inferences about market power.

A more general form of the demand curve is

[41] The extent of loss would depend upon particular climatic conditions, but the following may indicate the order of magnitude involved. A contemporary study in South Africa found that the sucrose content of the sugar cane there, over 7 months of the grinding season, was the following: 9.5% on May 14, 11.8% on May 28, 13.7% on June 26, 14% on July 23, 14.5% on August 20, 15% on September 1, 14.3% on October 1, 12.8% on October 29, and 11.9% on November 26. Thus, near the peak sucrose content, the percentage loss by cutting a month early is not so substantial. But it is precisely at that time that the raw sugar factories would be grinding at capacity. In the early part of the harvest, when grinding capacity might be slack, a extra month would raise the sucrose content by 15 to 20 percent. And harvesting one *quarter* prematurely would have a sizeable adverse effect. Francis Maxwell, *Economic Aspects of Cane Sugar Production*, Norman Rodger, 1927, p. 45.

[42] It is rare in empirical industrial organization for there to be sufficient observations to make use of nonparametric estimation.

$$Q(P) = \beta(\alpha - P)^{\gamma} \tag{4}$$

where P is the price of refined sugar. This specification includes, as special cases, the quadratic demand curve ($\gamma = 2$), linear ($\gamma = 1$) and the log-linear ($\alpha = 0$, $\gamma < 0$), as well as, in the limit, the exponential demand curve ($\alpha, \gamma \to \infty$, and $\frac{\alpha}{\gamma}$ constant). Here β measures the size of market demand, γ is an index of convexity, and, when γ is positive, α is the maximum willingness to pay.

The implied monopoly price under constant marginal cost c, $p^M(c)$, satisfies

$$p^M(c) = \frac{\alpha + \gamma c}{1 + \gamma} \tag{5}$$

and so is affine in the marginal cost. The elasticity of the industry demand curve, η, is

$$\frac{-\gamma P}{P - \alpha}$$

which, at the monopoly price, equals

$$\frac{(\alpha + \gamma c)}{\alpha - c}$$

so that the condition that the (absolute value of the) elasticity exceed one at the monopoly price can be written as $\gamma > -1$ for $\alpha > c$, and $\gamma < -1$ otherwise.

There is a seasonal pattern to demand that arises from the complementarity between sugar and fruit. Sugar is used as an input in fruit canning. The high demand season starts at the end of May, with the first appearance of strawberries in the New York area, and reaches its peak in September. To account for this part of demand we introduce the dummy variable High Season, which takes the value of one for the third quarter, and zero otherwise.[43] We

[43]This specification excludes the early strawberry crop from the High Season, but results from demand estimation on monthly data, with the months of June through September classified as High Season, yield qualitatively similar results to those reported here.

Table 4: Sample Statistics

	Full Sample		Low Season		High Season	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Refined Price	4.03	.62	3.99	.63	4.14	.58
Raw Price	3.30	.59	3.28	.61	3.36	.53
Proper Margin	.48	.19	.46	.18	.53	.21
Meltings	4.43	1.11	4.20	1.04	5.11	1.07
Cuban Imports	2.18	1.73	2.28	1.88	1.87	1.13
Number of Obs.	97		73		24	

All prices are reported in dollars per hundred pounds. All quantities are reported in hundreds of thousands of long tons.

allow both β and either α or γ to depend on this dummy variable. This specification allows high demand to both increase demand proportionately and change the monopoly price.

In order to explore the sensitivity of demand and conduct estimates to functional form assumptions, we estimate demand for four common functional forms: the quadratic, the linear, the log-linear, and the exponential. The corresponding equations, excluding seasonal and time effects, are as follows:

$$\text{Quadratic:} \quad \ln M = -\ln(\beta) + 2\ln(\alpha - P) + \epsilon \tag{6}$$

$$\text{Linear:} \quad M = \beta(\alpha - P) + \epsilon \tag{7}$$

$$\text{Log-Linear:} \quad \ln M = -\ln(\beta) + \gamma \ln(P) + \epsilon \tag{8}$$

$$\text{Exponential:} \quad \ln M = -\ln(\beta) + \frac{\gamma}{\alpha} P + \epsilon \tag{9}$$

We include a linear time trend in $\log(\beta)$, to account for an increasing population. The error term ϵ represents proportional shifts in demand, that is, variations in β, and hence does not affect the monopoly price. Equation (6) is nonlinear in α, and so its estimation utilizes nonlinear instrumental variables, as defined in Amemiya (1985, p. 246).

Table 4 reports the summary statistics of the data. The refined and raw prices and the proper margin are expressed in dollars per hundred pounds, in constant 1898 dollars.[44] Meltings and Cuban Imports are measured in hundreds of thousands of long tons. The sample covers the period January 1890 through June 1914. The sample omits one quarter during the Spanish American war in which Cuba imports were zero. Including this quarter has small effects on the demand parameters; conditional on those parameters, it has negligible effects on the estimates of the pricing rule in the next section.

Table 5 presents the estimates of the demand parameters for the full sample. The results from the four demand specifications are reported in four quadrants. Within each of these quadrants, the right hand column reports the coefficients and their standard errors, while the left hand side lists the demand parameters that account for these coefficient estimates. (The reported standard errors are heteroskedasticity-robust, and are corrected for serial correlation for 4 lags, by the method of Newey-West.) For example, quadrant (1) presents the results for the quadratic. In interpreting these results, one should note that in this single specification, price enters negatively, as $\ln(7.27 - P)$.

For all four demand specifications, the estimates are reasonable. The demand curve is downward sloping in both the high and low seasons. The high season shifts out the demand curve over the range of observed prices and makes it more inelastic. The high season dummy interacted with price is statistically significant, and that interaction term and the intercept dummy are jointly significant at nearly the 5% level for the quadratic, and at even lower levels for the remaining specifications.

The one seeming anomaly is the coefficient on the time trend, which indicates that demand is falling, although no estimate differs from zero at conventional levels of significance. With a growing population and increasing per-capita income, we would have expected a positive coefficient on the time trend. It is possible that the encroachment of beet sugar, which increased from essentially a zero fraction of the U.S. market in 1894 to fifteen percent by 1910, is responsible.

If we drop the time trend from the specification, we can estimate demand separately for

[44]Prices are converted into constant dollars by the wholesale price index in Hanes (1993).

Low and High Season. Table 6 presents those results, which offer a more direct comparison of the demand curves across the two seasons. These results are very nearly identical to those in Table 5. First, High Season shifts out the demand curve over the range of observed prices. Second, demand is more inelastic in the High Season than in the Low. Equality of the two coefficients across the seasons can be rejected at the 5% level for the quadratic specification, and can be rejected at less than 1% for the other specifications. We use the coefficient and standard error estimates from Table 6 as ingredients in all our subsequent analysis.

Table 7 presents our initial analysis. The monopoly pricing rules for both High and Low seasons are shown in the first two rows of the table. By comparison to Table 4 it is evident that the (blockaded) monopoly prices are much higher than the actual observed prices, for any of the four demand specifications. The next two rows present the generalized pricing rules for both seasons, as a function of the conduct parameter θ.

Having estimated demand, we can now turn to comparing estimates of the industry's conduct. The results we have obtained so far, however, foreshadow some of our final conclusions. Observed prices are well below monopoly levels; any market power is moderate or minimal. A comparison of Tables 4 and 6 helps cast light on the ability of the CV approach to estimate that market power correctly. Demand is less elastic in High Season, and refined prices rise, albeit minimally, during High Season. The small sensitivity of refined prices to this change in the elasticity of demand will cause the CV approach to infer a small, but non-zero, value of θ. We now turn to these derivations and comparisons more formally.

Table 5: Demand for Refined Sugar, Full Sample

	(1) Quadratic ($\gamma = 2$)		(2) Linear ($\gamma = 1$)		(3) Log-Linear ($\alpha = 0$)		(4) Exponential ($\gamma, \alpha \to \infty$)	
Price	α_L	7.27	β_L	-2.49	γ_L	-2.16	$(\frac{\gamma}{\alpha})_L$	-.58
		(1.39)		(.85)		(.76)		(.21)
High Season × Price	$\alpha_H - \alpha_L$	3.25	$\beta_H - \beta_L$	.98	$\gamma_H - \gamma_L$	.94	$(\frac{\gamma}{\alpha})_H - (\frac{\gamma}{\alpha})_L$	.28
		(2.06)		(.52)		(.50)		(.13)
High Season		-1.16	$(\beta\alpha)_H - (\beta\alpha)_L$	-2.79		-1.04		-.86
		(.52)		(2.13)		(.69)		(.54)
Constant		-.97	$(\beta\alpha)_L$	14.85		4.72		3.73
		(35.46)		(109.81)		(22.76)		(25.39)
Year − 1902.5		-.0086		-.022		-.004		-.0054
		(.018)		(.056)		(.012)		(.013)
$\chi^2_{(2)}$ Test		4.91		22.73		23.40		20.77

The reported $\chi^2_{(2)}$ statistic is for the joint test that both High Season and High Season × Price have zero coefficients.

Table 6: Demand for Refined Sugar, by Season

	(1) Quadratic ($\gamma = 2$)		(2) Linear ($\gamma = 1$)		(3) Log-Linear ($\alpha = 0$)		(4) Exponential ($\gamma, \alpha \to \infty$)	
	Low Season [$N = 73$]							
Price	α_L	7.72	β_L	-2.30	γ_L	-2.03	$(\frac{\gamma}{\alpha})_L$	-.53
		(.87)		(.48)		(.48)		(.12)
Intercept		-1.20	$\beta\alpha_L$	13.37		4.18		3.52
		(.47)		(1.90)		(.65)		(.48)
	High Season [$N = 24$]							
Price	α_H	11.88	β_H	-1.36	γ_H	-1.10	$(\frac{\gamma}{\alpha})_H$	-.26
		(2.03)		(.36)		(.28)		(.07)
Intercept		-2.48	$\beta\alpha_H$	10.74		3.16		2.70
		(.54)		(1.57)		(.40)		(.29)
$\chi^2_{(2)}$ Test		6.90		28.18		29.17		25.96

The reported $\chi^2_{(2)}$ statistic is for the joint test of equality of the coefficients on Price and the Intercept across seasons.

Table 7: Demand for Refined Sugar, Derived Estimates

	(1)	(2)	(3)	(4)
	Quadratic	Linear	Log-Linear	Exponential
$P^M(c)$: $HS = 0$	$2.57 + .67c$	$2.91 + .5c$	$1.97c$	$1.89 + c$
$P^M(c)$: $HS = 1$	$3.96 + .67c$	$3.96 + .5c$	$10.1c$	$3.85 + c$
$P(c;\theta)$: $HS = 0$	$\frac{7.72\theta}{2+\theta} + \frac{2}{2+\theta}c$	$\frac{5.82\theta}{1+\theta} + \frac{1}{1+\theta}c$	$\frac{2.03}{2.03-\theta}c$	$1.89\theta + c$
$P(c;\theta)$: $HS = 1$	$\frac{11.88\theta}{2+\theta} + \frac{2}{2+\theta}c$	$\frac{7.88\theta}{1+\theta} + \frac{1}{1+\theta}c$	$\frac{1.10}{1.10-\theta}c$	$3.85\theta + c$
η at Full Sample Mean:				
$HS = 0$	2.18	2.24	2.03	2.13
$HS = 1$	1.03	1.04	1.10	1.05

4 The Conduct Parameter

Recall that the conduct parameter was derived from equation (1), the generalization of the monopolist's first order condition:

$$P + \theta Q P'(Q) = c$$

where θ is the conduct parameter, and in most applications is assumed to be constant.

Given the demand curve we specified in (4), the pricing rule generalizes to

$$P(c) = \frac{\theta\alpha + \gamma c}{\gamma + \theta} \tag{10}$$

A framework for organizing our comparison of alternate estimates of θ is to consider varying the information set that the econometrician possesses concerning the industry, and the restrictions that the econometrician imposes. These comparisons are all made within the context of a set of maintained hypotheses concerning the structure of industry demand and costs. For the sugar industry, there are two maintained assumptions. First, demand is described by the appropriate form of equation (4), (i.e., one of equations (6)-(9)), including possibly different values for γ, α, or $\frac{\gamma}{\alpha}$ in High and Low Season. Second, marginal cost c is characterized by equation (3):

$$c = c_o + k * P_{RAW}$$

where c_o represents all variable costs other than the cost of raw sugar itself, and k is the parameter of the fixed-coefficient production technology between raw sugar and refined sugar.

Maintaining these hypotheses, the comparisons can begin. As our benchmark, consider the full set of information we have available. We have estimated the demand curve, and have recovered the elasticity of demand, η. In our case, we have excellent information on components of marginal cost. In particular,

$$c = c_o + 1.075 * P_{RAW} \tag{11}$$

Table 8: Lerner Index and Adjusted Lerner Index

Lerner Index	(1) Mean	(2) S.D.	(3) Standard Error	(4) Standard Error
unadjusted	.054	.045	.0046	—
quadratic	.099	.097	.010	.024
linear	.107	.118	.012	.028
log-linear	.095	.083	.008	.021
exponential	.097	.089	.009	.022

We consider $k = 1.075$ to be certain. Although we do not know c_o as precisely, we have the reasonable range of estimates from 16 to 26 cents, from both testimony and firm behavior, as we have noted previously. Moreover, misspecification of c_o should have a minor impact, since the price of raw sugar accounts for most of the price of refined sugar. For our reported calculations, we will use $c_o = .26$, since that value arises most often in the testimony. Moreover, since it is the upper bound of our range, it serves as a useful benchmark. (In practice, the use of $c_o = .16$ does not change the results materially, as we show later in this section.)

With complete price and cost information, and a specific functional form for demand, we simply compute the price cost margin and multiply it by the appropriate estimated elasticity of demand to form our direct measure of θ – the elasticity adjusted Lerner index, L_η. Table 8 presents summary statistics of this measure. For comparison, we present the (unadjusted) Lerner Index itself in the first row. The adjusted Lerner indices are presented in the subsequent rows, with the values of η taken from the corresponding demand curves presented in Table 6. We present two sets of standard errors. The first set, in column (3), is the usual standard error for a mean, and ignores the fact that η is estimated. The second set, in column (4), accounts for that estimation. Doing so more than doubles the standard error.[45]

For all four demand curves, the mean L_η is close to .10. We use this value as our direct

[45]The standard errors adopt the general method of moments, in which we add to the moments implicit in the IV estimates of Table 6, the additional moment condition $\sum_i L_{\eta i} - \bar{L}_\eta = 0$, where $\bar{L}_\eta$ is our estimate of the mean adjusted Lerner Index.

Table 9: Lerner Indices by Year

	Lerner Index				American Sugar Refining Co.'s
	Unadjusted		Elasticity Adjusted (log-linear)		
Year	Mean	Std. Dev.	Mean	Std. Dev.	Market Share
1887					79.0
1888					75.0
1889					66.0
1890	.00	.01	.00	.02	67.7
1891	.05	.04	.09	.08	65.2
1892	.11	.07	.19	.13	91.0
1893	.12	.03	.22	.08	85.7
1894	.10	.05	.17	.11	77.0
1895	.09	.03	.16	.04	76.6
1896	.09	.05	.14	.05	77.0
1897	.10	.01	.17	.06	71.4
1898	.03	.04	.05	.07	69.7
1899	-.02	.02	-.05	.04	70.3
1900	.02	.04	.03	.06	70.1
1901	.08	.01	.14	.03	62.0
1902	.08	.03	.13	.06	60.9
1903	.07	.04	.12	.07	61.5
1904	.04	.04	.07	.08	62.3
1905	.06	.03	.11	.06	58.1
1906	.05	.03	.09	.07	57.3
1907	.06	.03	.11	.08	56.8
1908	.05	.01	.08	.02	54.3
1909	.02	.02	.04	.05	50.4
1910	.02	.01	.04	.02	49.2
1911	.04	.03	.08	.07	50.1
1912	.04	.02	.07	.05	45.5
1913	.03	.02	.05	.02	44.0
1914	.02	.02	.05	.05	43.0
Average	.05	.05	.09	.08	63.1

The market share figures are from Willett and Gray. American Sugar's average market share is calculated only over the years 1890-1914.

Table 10: Lerner Index Seasonality

	Quarter I		Quarter II		Quarter III		Quarter IV	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
unadjusted	.048	.042	.065	.042	.064	.047	.038	.047
quadratic	.096	.091	.142	.104	.071	.057	.083	.117
linear	.102	.106	.162	.138	.075	.063	.086	.134
log-linear	.097	.085	.132	.085	.071	.051	.078	.096
exponential	.097	.087	.136	.092	.071	.055	.081	.106

estimate of θ, the deviations in the actual values presented in Table 8 being negligible in both the economic and statistical sense. An estimate of .10 corresponds to the conduct one would expect from a static, 10-firm symmetric Cournot oligopoly. We can reject the hypothesis of perfectly competitive conduct, and we can also reject the hypothesis of monopoly pricing.

The variation in L_η is easily accounted for. As Table 9 shows, L_η declines over the sample period,[46] in line with the decline in American Sugar Refining Company's market share. That table also shows the impact of the two major price wars, the one in 1890-1891, following entry by Spreckels, the other in 1898-1900, following that of the Arbuckle Brothers. The latter episode even includes some negative values, indicating pricing below our measure of marginal cost.[47] Table 10 shows that there is also seasonality in L_η. Conduct is least competitive in the second quarter and most competitive in the third quarter (the High Season). This result is suggestive of models of dynamic oligopoly in which the anticipation of future improvements in demand conditions is helpful to collusion, and the opposite harmful,[48] although the equality of the unadjusted Lerner Index in those two seasons also suggests that it might only be an artifact of our identification of the High Season only and always with the third quarter.

[46]The table reports L_η from the log-linear specification. The other three demand specifications yield a similar time series.

[47]Willett and Gray explicitly identify pricing below marginal cost in their *Weekly Statistical Sugar Trade Journal*. For example, on October 20, 1898, they report: "The present difference between raw and refined sugar is reduced this week to 47 cents per 100 pounds, which is the lowest difference made during the old Philadelphia fight [of 1890-1892]. Anyone familiar with the amount of raw sugar of 96 degree test, which is required to produce 100 pounds Granulated of 100 degree test does not require to be told that there is an actual loss to refiners at 47 cents difference." Refined prices subsequently fell further.

[48]See Rotemberg and Saloner (1986) and Haltiwanger and Harrington (1991).

Dynamic oligopoly is of course inconsistent with the assumptions of the CV methodology, which include a zero correlation between θ and observable demand determinants. The proper test of a methodology is not the correctness of its assumptions, however, but its success or failure in doing what it is meant to do. So noting that there is some evidence against the static representation of pricing that underlies the CV methodology, we go on to see whether or not that methodology exceeds the limitations of its assumptions and nonetheless manages to reproduce the full information estimates of θ.

Overall, the relatively low values of L_η suggest a more competitive environment than one would expect from the industry's concentration. A reasonable initial explanation is that industry pricing was constrained by threats of (domestic) entry, or of foreign imports. We intend to explore this issue in future work.

Now consider alternative levels of information available to the econometrician employing the conjectural variations approach. Substituting 3 into 10 yields the following reduced-form equation:[49]

$$P = \frac{\alpha\theta + c_o\gamma}{\gamma + \theta} + \frac{\gamma}{\gamma + \theta} k P_{RAW} \tag{12}$$

We respecify this equation as

$$\mathrm{E}[\{(\gamma + \theta)P - \alpha\theta - c_o\gamma - \gamma k P_{RAW}\}Z] = 0 \tag{13}$$

where Z is the vector of instruments: the log of Cuban imports, the High Season dummy, and a constant. We instrument with Cuban imports because of the potential endogeneity of the price of raw sugar. Whether the source of the error in equation (12) is cost or market power, that error will be negatively correlated with the raw sugar price – increases in it will lead to increases in the price of refined sugar, and so decreases in the quantity demanded of raw sugar and in the latter's price.

The coefficients in this equation depend on the parameter of interest, θ, but also upon demand and cost parameters. Consider variations in the researcher's knowledge of demand

[49]The appropriate form of this equation for the exponential demand curve is $P = \frac{\alpha}{\gamma}\theta + c_o + kP_{RAW}$

and cost, in turn. Demand is relatively straightforward. One can replace α and γ with estimated values from a demand equation, and/or impose restrictions on α and γ. Keep in mind that, depending on the specification, either γ or α, or their ratio, will take different values in the different seasons.

On the cost side, there is a hierarchy of information structures. First, both k and c_o may be unknown to the researcher. Second, k may be known but c_o unknown. This situation corresponds to the work on the cigarette industry by Sumner (1981), Sullivan (1985), and Ashenfelter and Sullivan (1987), which uses excise taxes as a component of marginal cost, with $k = 1$. In each of these cases, the researcher substitutes any known cost parameters into (13), and recovers estimates of the unknown cost parameters jointly with estimating θ. Third and finally, both k and c_o may be known. In this case, L_η is directly observed.[50]

For each of the standard demand cases, and for each of the first two information cost structures, we estimate (13) by Non-Linear Instrumental Variables. When k is unknown, we instrument with the log of Cuban imports, High Season, and a constant. When $k = 1.075$ is known, we instrument with High Season and a constant. Demand parameter estimates are those from Table 6, which includes a seasonal variation.

Table 11 reports the results. The table's layout requires some explanation. The left hand side lists the conduct and cost parameters. Across the top are the 4 demand specifications. The final column (9) reports the direct measure of cost parameters we used in our Lerner Index analysis, along with the associated measure of θ. Rather than reporting a tight range for θ from our Lerner Index analysis, we simply report .10. Within each demand specification, each column represents a particular information structure regarding costs, with more information being incorporated into the estimation as one moves to the right across columns. So, for example, under the quadratic demand function, column (1) is the situation in which the cost parameters c_o and k are unknown, and hence their estimates are reported along with that for θ. In column (2), k is known to be 1.075, and c_o and θ are estimated.

[50]We do not explore the fourth possibility since in the context of this industry it seems to be an unlikely combination.

The standard errors are heteroskedasticity-robust and serial correlation-robust. They are constructed according to the Newey-West procedure, with 4 lags, and take into account that the demand parameters are themselves estimated. The variance-covariance matrix of (θ, c_o, k) is W_2+V, where W_2 is the Newey-West estimate and $V = D^{-1\prime}(C'W_1C)D^{-1}$ in which W_1 is the Newey-West estimate of the variance-covariance matrix of the demand parameters, D is the matrix of derivatives of the moment conditions from equation (13) with respect to (θ, c_o, k), and C is the matrix of derivatives of those same moment conditions with respect to the demand parameters. We are assuming no correlation between the demand and pricing rule errors, as is appropriate to our interpretation of these errors.

Now to the results themselves. We draw four main conclusions.

First, the Conjectural Variation approach performs reasonably well in estimating θ, the parameter of primary interest. Under all four demand specifications, and the two information structures, the estimated θ is close to the Elasticity-adjusted Lerner Index. Monopoly $(\theta = 1)$ would be rejected under all specifications, as would, more generally, any θ exceeding .11. On the other hand, the researcher would be unable to reject the hypothesis of perfect competition, and the point estimates are quantitatively quite close to perfect competition. Moreover, although the point estimates are quantitatively close to the direct value of .10, θ is underestimated in all the specifications, an issue to which we return shortly.

Second, the estimates of θ are very robust to changes in the demand specification. This is especially noteworthy given that L_η itself is relatively insensitive to the demand specification. This has implications for evaluating the CV approach as applied in practice. The CV methodology has often been criticized as being sensitive to demand specifications. That criticism is clearly unearned here. A researcher utilizing the CV approach to estimate θ would doubtless be reassured by the robustness of the estimates. As we see, this confidence would largely be warranted.

Third, the CV procedures turn in a mixed performance in estimating the cost parameters. In all 4 cases, k is underestimated, although in each case one could not reject the hypothesis that $k = 1.075$. In contrast, c_o is overestimated, in one case by more than 50 cents.

Fourth, information about cost does not materially improve the estimates of θ. Moving from the specification in which both cost parameters are unknown to the specification in which k is known moves estimates of θ only slightly toward our direct measure, if at all. Less importantly for our purposes, imposing information about k improves the estimate of c_o and that estimate's precision.

These comparisons have been made under the assumption that $c_o = .26$. As we indicated earlier, we believe that this is the best estimate of c_o. But since testimonial and other evidence suggested a range of possible values, we will reevaluate our results by setting c_o equal to .16, the lower bound in our range of estimates. Because our CV estimates do not make use of this value, the results reported in Table 11 do not change. Our benchmark conduct estimates from the elasticity adjusted Lerner Index do change from the values in Table 8, however, but not substantially. The mean value of index would be .14 for the log-linear and exponential demand specifications, .15 for the quadratic, and .16 for the linear. Thus we can take .15 as summary statistic for L_η, as compared to .10 under the assumption that $c_o = .26$. Since the NEIO underestimates the conduct parameter, using a higher benchmark level of market power makes the NEIO look worse. But this degradation is not substantial. The value $\theta = .10$ roughly corresponds to the conduct one would expect from a static, symmetric 10-firm Cournot oligopoly, while 7 firms playing the same Cournot game would give rise to $\theta = .15$. Both in terms of statistical significance and economic importance, both values of L_η would lead to the rejection of perfectly competitive behavior, and also the rejection of monopoly behavior. Thus, even if we employed $L_\eta = .15$ as our benchmark, we would retain our main conclusion: the NEIO performs reasonably well in estimating θ, although it does underestimate that parameter. Moreover, our other conclusions about the NEIO remain undisturbed: the NEIO estimates, like the Lerner Index measures, are not sensitive to functional form; the CV approach would still turn in a mixed, albeit somewhat worse, performance in estimating cost parameters, and information about these cost parameters would not materially improve estimates of θ.

To understand why we obtain these estimates, it is instructive to consider a reparameterization of (12) that is linear in its parameters. Because the demand curve differs by season, so will this "reduced form." For all but the log-linear specification, this linear "reduced form" corresponds to the regression of the refined price on a constant, High Season dummy, and the price of raw, as in column (3) of Table 12. For the log-linear specification, the interaction between the price of raw and the High Season is added (since γ differs by season), as in column (2) of the same table. In interpreting these reduced form results, it is useful to refer back to the theoretical pricing rule equation (12),[51] and the implied monopoly and oligopoly pricing rules we obtain from our demand estimates, as reported in Table 7. These pricing rules are characterized by two components, a constant, or intercept, and a slope, the sensitivity of the refined price to the raw price.

It is easiest to consider first any of the demand specifications other than the log-linear. As column (3) of Table 12 shows, price increases by only 8 cents in the high demand state. This is small relative to the predicted increases in the theoretical monopoly price from the demand estimates in Table 7, and thus results in the low value of θ estimated in the nonlinear IV regressions. For example, the demand estimation of the exponential specification implies an increase of $1.96 = $3.85 – $1.89 in the monopoly price in the high demand state, and as the intercept in the pricing rule equals $\theta[\alpha/\gamma] + c_o$, this implies a θ of .04 = .08/1.96. The estimate of k is then obtained from the coefficient on the raw price. For the exponential specification, this coefficient is just k itself, as the refined price increases one for one with cost; for the quadratic and linear, the refined price increases less than one for one with cost, but given the low value of θ, not that much less. Since the coefficient on the raw price is only 1.01, k gets underestimated. Given that we underestimate θ, some element of cost, that is, either k or c_o, must be overestimated to rationalize the difference between the refined and raw price. So c_o is overestimated.

Now consider the log-linear demand specification, and so column (2) of Table 12. The lower demand elasticity in the high season predicts a higher marginal markup in that season, and, indeed, there is a positive significant coefficent on the interaction term between High

[51] The appropriate form of that equation for the exponential demand curve is $P = \frac{\alpha}{\gamma}\theta + c_o + kP_{RAW}$

Season and Raw Price. However, by the same token, the intercept, which is $c_o\gamma/(\gamma+\theta)$, ought to be higher in the high season as well, whereas the coefficient on the High Season dummy is negative and significant. Using the coefficients on the raw price and its interaction only, one would estimate a θ of .46; using only the constant and the coefficient on High Season, one would obtain the nonsensical value of 2.09. The N.L.I.V. estimation constrains the ratios of the slopes and intercepts of the pricing rule to be the same, and, as we saw, this yields estimates of the primitive parameters that are similar to those obtained from the other demand specifications.[52]

We note in passing that none of the demand specifications we use are consistent with the point estimates presented in column (2). On the one hand, one can reject equal slopes of the pricing rule in both demand states, a restriction which is assumed in all but the log-linear specification. On the other hand, at (significantly) less than 1.075, the estimate of the low season slope is inconsistent with a log-linear demand, which implies that increases in cost lead to a more than one for one increase in price.

The estimates in column (1), which omits all High Season effects, shows what conclusions we would reach were we to use the known value of k and ignore the seasonality of demand. This approach is similar to the estimation of market power in the cigarette industry, which uses excise taxes as a component of marginal cost, with $k = 1$ known. Since the theoretical slope in the pricing rule is $k\gamma/(\gamma + \theta)$, the estimated slope of 1.02 is consistent only with $\gamma > 0$. In fact, the implied θ is proportional to the assumed γ. For the linear demand curve, the implied θ is .054, which is close to our earlier estimates. For quadratic demand it is equal to .108, which is close to our direct value of .10. The quadratic demand curve with no season effects is:

$$\ln M = \underset{(.50)}{7.37} + 2\ln(\underset{(1.17)}{8.63} - P)$$

Not surprisingly, with the true k imposed, a demand specification that yields an estimate

[52]One can reconstruct this restricted "reduced form" pricing rule from the estimates presented in the N.L.I.V. table. It is $P = .793 + .997 \times P_{RAW}$, in the low season, and $P = .777 + .977 \times P_{RAW}$ in the high season.

Table 11: N.L.I.V. Estimates of Conjectural Variation Parameters

	quadratic		linear		log-linear		exponential		Direct Measure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\hat{\theta}$	.037	.035	.038	.037	.045	.040	.041	.037	.10
	(.024)	(.024)	(.024)	(.024)	(.028)	(.026)	(.026)	(.025)	
$\hat{c}_o$	.529	.393	.465	.39	.760	.381	.700	.389	.26
	(.272)	(.062)	(.285)	(.061)	(.262)	(.070)	(.279)	(.065)	
$\hat{k}$	1.033		1.052		.956		.978		1.075
	(.082)		(.085)		(.081)		(.083)		

Table 12: Pricing Equations for Refined Sugar (Linear Parameterization)

	(1)	(2)	(3)	(4)	(5)	(6)
	IV	IV	IV	OLS	OLS	OLS
Raw Price	1.02	.93	1.01	.99	.98	.99
	(.09)	(.09)	(.08)	(.05)	(.05)	(.05)
High Season × Raw Price		.31			.04	
		(.11)			(.07)	
High Season		-.97	.08		-.07	.08
		(.38)	(.03)		(.22)	(.03)
Constant	.67	.94	.66	.75	.77	.74
	(.28)	(.28)	(.26)	(.16)	(.16)	(.16)
χ^2_2 Test		21.67			6.66	

Dependent Variable is price of refined sugar. 97 observations. Instruments for columns (1) and (2) are High Season, the log of Cuban Imports, and interaction between the two. The reported χ^2_2 statistic is for the joint test that the coefficients on both High Season and High Season × Raw Price are zero.

near our direct measure of θ also obtains an excellent estimate of c_o: .23. Clearly the results from such an approach are fundamentally determined by the demand specification.[53]

[53] As Bulow and Pfleiderer (1983) point out, θ and c_o are not even separately identified with exponential demand.

Table 13: Industry Regimes

Jan 1890-Feb 92	Spreckels entry, price war
Mar 1892 -Sep 98	Acquisition of Spreckels, Small Scale Entry, Cartel Operation
Sep 1898-Apr 1900	Entry by Arbuckle Brothers and Doscher, price war
May 1900-10	End to Arbuckle war
Nov 1910-1913	Government antitrust suit

5 Conduct and Structure

Another way to explore the efficacy of the NEIO is to compare the various measures of conduct across different structural regimes. If we have characterized structure properly, then differences in structure should be reflected in differences in θ. Moreover, it is interesting to explore whether the NEIO can differentiate those conduct changes from changes in costs.

As an initial attempt to quantify industry structure, we have divided our entire sample into 5 subperiods, which crudely correspond to different structural regimes. Table 13 gives the dates and brief descriptions of the 5 regimes.

The purpose of this exercise is simply to compare the conduct estimates across clearly different structural regimes. In particular, we will compare the post-entry "price war" regime (the Spreckels war and the Arbuckle War) with the "no-price war" regime (all other periods). We know *a priori* that structural conditions differed across these regimes. For our benchmark, we use the elasticity adjusted Lerner Index from the log-linear demand specification, although our comparisons are not sensitive to this choice. Recall from Table 9 that conduct during the two price wars was different from the other periods.

In order to evaluate the NEIO methodology, we estimate θ and any unknown cost parameters while relaxing the constraint that θ is constant over the entire sample. In particular, we let θ take on the value of θ_o during the normal, non-price war periods, and the value of θ_1 during the price war regime. Table 14 reports the results, which is organized in much the same way as Table 11.[54]

[54]The choice of instruments proceeds in analogous fashion. When k is unknown, the instruments are constant, log of Cuban imports, High Season, and WAR, where WAR is a dummy variable equal to 1 for the

In all four cases, θ is estimated to decrease during the price war regime by an amount that is of a similar magnitude as the difference in the adjusted Lerner Index, and this effect is statistically significant at conventional levels of significance. Moreover, we can now reject the hypothesis of perfect competition for the normal, non-price war regime ($\theta_o = 0$) at or near the 5% level for all 8 specifications. Note also that the estimates of c_o, while well-removed from our direct measure, are close to the corresponding values reported in Table 11, when θ was assumed to be constant.

Although it is heartening to see that the model captures the decrease in θ, this is a rather weak test. Price war periods are defined by dramatic decreases in the margin and because θ is the only parameter which we allow to vary by structural regimes, it is inevitable that we estimate a decrease in θ. A stronger test permits c_o to change across structural regimes as well. This addresses the following question: if the researcher observes a fall in refined prices, can he, by means of the CV approach, distinguish between a change in cost and a change in market conduct? We therefore let c_o and c_1 designate non raw-sugar variable costs in the non-price war, and price war periods, respectively. The results, reported in Table 15, suggests that the NEIO cannot distinguish between cost and conduct changes, since costs are estimated to drop considerably, while the estimated reductions in θ are minimal. Since we know from direct evidence that costs were, in fact, constant, this exercise points up the value of *a priori* information. Absent the knowledge, and the restriction, that costs are constant across structural regimes, the CV approach cannot distinguish between changes in conduct and changes in cost.

A final method to assess the sensitivity of estimated conduct to changes in structural conditions is to allow θ to be a function of market structure. For parsimony, we allow θ to be a linear function of the market share of ASRC, the dominant cane sugar refiner. This final exercise should be viewed more as a summary of the data than as a structural regression. As Table 16 reveals, estimated conduct does indeed become less competitive with increases

Arbuckle or Spreckels post entry price wars, and zero otherwise. For the specification in which k is known, the instruments are constant, High Season, and WAR.

Table 14: N.L.I.V. Estimates of Conjectural Variation Parameters, Regime Comparison

	quadratic		linear		log-linear		exponential		Direct Measure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\hat{\theta}_o$	.043	.043	.046	.046	.047	.044	.044	.043	.11
	(.022)	(.022)	(.023)	(.023)	(.025)	(.023)	(.023)	(.022)	
$\hat{\theta}_1 - \hat{\theta}_o$	-.095	-.100	-.112	-.108	-.065	-.092	-.076	-.100	-.09
	(.052)	(.042)	(.069)	(.051)	(.036)	(.033)	(.044)	(.040)	
$\hat{c}_o$	.446	.410	.374	.402	.681	.411	.621	.414	.26
	(.260)	(.054)	(.280)	(.056)	(.258)	(.056)	(.277)	(.055)	
$\hat{k}$	1.063		1.084		.988		1.009		1.075
	(.078)		(.083)		(.080)		(.083)		

Table 15: N.L.I.V. Estimates of Conjectural Variation Parameters, Cost Sensitive Price Wars

	quadratic		linear		log-linear		exponential		Direct Measure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\hat{\theta}_o$	.032	.031	.032	.033	.041	.034	.037	.032	.11
	(.022)	(.022)	(.022)	(.024)	(.027)	(.024)	(.024)	(.023)	
$\hat{\theta}_1 - \hat{\theta}_o$	-.016	-.016	-.017	-.017	-.024	-.017	-.020	-.015	-.09
	(.035)	(.036)	(.036)	(.036)	(.034)	(.040)	(.043)	(.038)	
$\hat{c}_o$	.470	.439	.417	.435	.684	.434	.632	.439	.26
	(.252)	(.055)	(.261)	(.058)	(.259)	(.058)	(.274)	(.055)	
$\hat{k}$	1.065		1.081		.991		1.010		1.075
	(.079)		(.080)		(.083)		(.084)		
$\hat{c}_1 - \hat{c}_o$	-.162	-.171	-.168	-.163	-.101	-.178	-.118	-.177	0
	(.128)	(.110)	(.124)	(.104)	(.134)	(.130)	(.147)	(.119)	

in ASRC's market share. There is variation in the estimated slope of θ across specifications, but if we use .004 as a compromise, then ASRC's decline in market share from 90 % to 60% is predicted to lead to a decline in θ of .12. Once again relying on the log-linear demand as a benchmark, the results from the comparison regression of L_η on ASRC's market share are reported in column (9). There is a positive coefficient on ASRC's share, which is less than but of the same magnitude as the CV estimates. One should note that the CV estimates of the cost parameters are much worse in this specification than in any of the preceding specifications.

Table 16: N.L.I.V. Estimates of Conjectural Variation Parameters, ASRC Shares

	quadratic		linear		log-linear		exponential		Direct Measure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
a_θ	-.278	-.172	-.279	-.179	-.313	-.156	-.316	-.166	-.068
	(.093)	(.060)	(.092)	(.057)	(.131)	(.085)	(.130)	(.076)	(.041)
b_θ	.005	.003	.005	.003	.006	.003	.006	.003	.0026
	(.001)	(.001)	(.001)	(.001)	(.002)	(.001)	(.002)	(.001)	(.0006)
$\hat{c}_o$	1.174	.407	1.131	.413	1.367	.389	1.336	.397	.26
	(.306)	(.058)	(.324)	(.057)	(.309)	(.068)	(.327)	(.061)	
$\hat{k}$	.839		.854		.771		.784		1.075
	(.092)		(.096)		(.094)		(.097)		

In these specifications, θ is a linear function of ASRC's market share: $\theta = a_\theta + b_\theta ASRCSHARE$.

6 Conclusion

This paper's main objective was methodological. We wanted to assess the performance of the NEIO approach in correctly characterizing the salient features of the sugar refining industry.

In the main our results should be reassuring to NEIO adherents.

The Conjectural Variations approach yielded estimates of the industry conduct parameter that were close to the direct measure we derived from full cost information. This result was robust to our choices of the functional form of demand. The NEIO did underestimate the conduct parameter, but this deviation was minimal in our context. The CV approach did a better job in detecting *differences* in conduct arising from different structural regimes, but that was true only in the situation in which the researcher imposed important cost information, the stability of cost across structural regimes. This therefore highlights the importance of *a priori* information in this framework.

Critics of the NEIO might take solace in the fact that the sugar industry is extraordinarily well suited for the application of NEIO techniques. Given the production technology and the observability of a cost component that varies tremendously, a failure of NEIO techniques in this industry would have been reason for serious doubt. Perhaps other industries with a similar production technology and information structure, such as gasoline refining, could be used to evaluate this methodology further.

In this paper we have asked the tightly focused question of whether the CV methodology can reproduce the measure of conduct that we obtain using full cost information. An auxiliary objective of this paper was to make an overall assessment of the extent of market power in the sugar refining industry, as a first step in a larger project. We find that the (average) conduct of the sugar industry at the turn of the century was only mildly collusive. That leads to a second set of questions. What structural features account for that conduct? What were the sources of market power and the constraints on market power? We look forward to addressing these questions in upcoming work.

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