Testing static oligopoly models: conduct and cost in the sugar industry, 1890–1914

David Genesove*

and

Wallace P. Mullin**

We explore the widespread methodology of using demand information to infer market conduct and unobserved cost components under the hypothesis of static oligopoly behavior. Direct measures of marginal cost and conduct, indicating small market power, serve as benchmarks. The more competitive models yield better cost estimates. The best cost estimates occur when conduct is estimated as a free parameter, which in turn only slightly underestimates our direct measure. It also tracks the decline in market power accompanying the industry's structural changes. The methodology is largely validated, although partial cost information can improve its predictive power. Conclusions are robust to the demand function.

1. Introduction

■ Measuring departures from marginal-cost pricing lies at the core of empirical Industrial Organization. Because marginal cost is often difficult to observe directly, the "new empirical industrial organization" (NEIO) infers market conduct and unknown cost parameters through the responsiveness of price to changes in demand elasticities and cost components. In this literature, the equilibrium oligopoly price, P, is characterized by the following generalization of the monopolist's first-order condition:

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

where Q is industry output, θ is the conduct or market power parameter, and c is marginal cost. This equation encompasses much of static oligopoly theory. For perfect

collusion or monopoly, θ equals one, for perfect competition it is zero, and for symmetric Cournot it is the inverse of the number of firms in the industry. One part of the literature estimates θ as a free parameter, using nonproportional shifts of the inverse demand curve to identify both it and cost parameters. Here, θ has the interpretation of "the average collusiveness of conduct" (Bresnahan, 1989). Alternatively, by prior choice of θ a specific game-theoretic model of conduct may be assumed and marginal cost directly inferred from (1).

These techniques have had widespread application. These include estimating conduct in specific industries (see Bresnahan's (1989) survey), testing a particular theory of oligopoly behavior (as in Porter's (1983) study of equilibrium price wars in a railroad cartel), and policy questions (such as Rubinovitz's (1993) study of monopoly power after the deregulation of cable television rates). A related literature, of which Berry, Levinsohn, and Pakes (1995) is a prime example, is concerned with estimating cost parameters under the assumption of a particular conduct (typically product differentiated Bertrand). In principle, these methods are applicable whenever cost data are at least partially absent and demand elasticity varies across either time or products within an industry. Although in some early studies the point was to supplement cost data (Appelbaum, 1979, 1982; Gollop and Roberts, 1979), in more recent practice NEIO cost estimates often supplant rather than supplement cost data.

Nonetheless, a number of objections have been raised against the methodology. Such 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 or marginal cost may be incorrect. More fundamentally, Corts (forthcoming) argues that since the estimated conduct parameter, $\hat{\theta}$, captures the *marginal* response of price, and hence the markup, to demand shocks, it will typically mismeasure the *level* of market power if industry behavior corresponds to a dynamic oligopoly game. More broadly than any specific objection, the NEIO approach has never been "tested," since that requires that one have at hand alternate measures of conduct and cost with which the NEIO estimates might be compared.

This article assesses the NEIO by doing just that. We utilize the U.S. East Coast cane sugar refining industry at the turn of the century for this assessment, both because the production technology is simple and because the industry underwent dramatic changes in the degree of competition, allowing us to evaluate the methodology under different structural conditions.

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 observe the prices of both raw and refined sugar, and since we have excellent estimates of labor and other costs, we can directly measure marginal cost and a true price-cost margin. We can therefore compare a direct measure of conduct computed from complete cost information with $\hat{\theta}$. We can also compare the indirect estimates of the cost parameters with our direct ones and assess the value of independent cost information whether θ is estimated or assumed.

With complete cost information, it is straightforward to measure θ directly. Rewrite (1) in terms of $\eta(P)$, the elasticity of demand:

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

so that θ equals the elasticity-adjusted Lerner index, L_η. We average L_η over time as an indication of the average level of market power. This average serves two functions.

First, it is a valid indicator of the overall divergence of price from marginal cost, normalized by the elasticity, whatever the structural interpretation one might attribute to it. Second, it has the behavioral interpretation of the "average collusiveness of conduct." To take an extreme example, suppose that behavior oscillated between perfect competition and perfect collusion in alternating periods. Then it would be appropriate to measure the average level of market power as .50, although of course the industry never behaves like a two-firm Cournot game and one would do a poor job of predicting prices in any given period with this measure.

To identify θ without complete cost information, we rely on nonproportional, seasonal shifts in inverse demand generated by the use of sugar in canning in the summer months. In practice, this entails nonlinear instrumental-variables estimation of a static oligopoly pricing rule derived from (1) that relates the refined-sugar price to the raw-sugar price and a seasonal dummy. Implicitly, this requires some restriction to be imposed on the stochastic behavior of θ. In many applications, it is assumed to be constant. That is an overly restrictive assumption; a weaker assumption would allow θ to vary, so long as it is uncorrelated with the instruments used to identify (1): the seasonal dummy and Cuban imports, which drive the raw-sugar price. In general, these instruments will be current cost or demand indicators.

The Corts critique can be recast as stating that in dynamic oligopoly, θ is correlated with these instruments, so that this methodology results in a biased estimate of the mean conduct parameter. For example, the Rotemberg and Saloner (1986) supergame model of oligopoly behavior in stochastic demand environments predicts that the equilibrium price will be closer to the monopoly price the smaller is current demand relative to future demand. Like all supergame models, it also predicts that price is nondecreasing, and in some states increasing, in the discount factor. This model may generate behavior in which the marginal response of price to demand shifters is independent of the discount factor, and hence the price level at some baseline state of demand; i.e., the marginal response of the markup differs from its level. The Corts critique is levelled squarely against the notion that an "average level of collusiveness" may be measured independently of an underlying behavioral model. Thus the estimation of (1) rests upon a static conception of firm conduct.

A note on firm differences. We possess output data at the industry level only (there are no recorded price differences) and so can make statements on behavior at that level only. There may have been differences in marginal cost across firms, but if so they were small. In any case, equation (1) remains valid; for example, it still captures the Cournot equilibrium, with θ equal to the reciprocal of the number of firms and c now interpreted as the (unweighted) average of marginal cost across firms.[1] The important asymmetry among firms was the large capacity of one dominant firm, which issue we return to in Section 6.

The article is structured as follows. After surveying the historical background in Section 2, we describe technology and present our direct cost measures in Section 3 and then estimate demand in Section 4. This allows us to construct L_η, which we find to be lower than structural features of the industry would suggest.

In Section 5 we estimate conduct and cost parameters under varying assumptions about the researcher's knowledge of demand and cost conditions. $\hat\theta$ underestimates L_η, although the difference is minimal. The difference across demand specifications is negligible. The cost parameters are more poorly estimated. Imposing information about the loss ratio of raw sugar did not materially affect $\hat\theta$, although it did improve the estimate of costs other than raw sugar. We also examine the bias in cost estimates when

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[1] This interpretation of c ensures that it and θ are invariant to changes in market share. When c is interpreted as a weighted average, with weights equal to shares, θ equals the Herfindahl index.

a particular value of θ is imposed by assuming a model of conduct. Given the relatively low value of L_η, the cost estimates are much worse if monopoly rather than perfect competition is assumed.

In Section 6 we consider the relationship between structure and conduct. The NEIO does track the decline in L_η over time. As a final test of these models, we examine how well they would have predicted the rise in refined prices consequent upon the Cuban Revolution of the late 1890s. Perfect competition and the first of our two Cournot models yielded the best predictions, and adding cost information improved the power of even apparently misspecified behavioral models such as monopoly. This illustrates the value of both the appropriate model of conduct as well as cost information in predicting market outcomes. Section 7 concludes.

2. Historical background

■ After several unsuccessful attempts at collusion, the Sugar Trust, later incorporated as the American Sugar Refining Company (ASRC), was formed in December 1887 as a consolidation of 18 firms controlling 80% of the industry's capacity. The 20 plants owned by the original trust members were quickly reorganized and reduced to 10. Refined prices rose 16%. Entry soon followed with the construction in December 1889 of the Spreckels plant. This led first to a price war, and then to ASRC's acquiring the plant along with those of firms that had remained outside the original trust. This acquisition campaign was completed by April 1892 and raised ASRC's share of industry capacity to 95%.

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 ASRC.

In the next several years, the degree of concentration slowly declined as a series of firms entered, each at a relatively small scale. Then in fall 1898, two new firms, Arbuckle Brothers and Doscher, constructed large plants. This precipitated a severe price war, marked by pricing at or below cost and shutdown by some refiners. The war did not end until June 1900 with the merger of the Doscher refinery with two of the major independents in a transaction organized by Henry Havemeyer, the ASRC president. In 1910 the federal government filed suit, charging monopolization and restraint of trade, seeking the dissolution of ASRC. Although this case was not formally resolved until a 1922 consent decree, the government's victories in the American Tobacco and Standard Oil cases in 1911 led ASRC to initiate partial, "voluntary," dissolution.

Throughout this period, cane sugar refining was concentrated on the East Coast, which constituted a largely separate market from the West Coast.[2] The basis price for standard refined sugar was the price determined in New York City, which had the largest number of refiners.

Refined sugar can also be made from beets. The domestic and European beet sugar producers constituted two competitive fringes to the U.S. cane sugar refiners. Domestic beet sugar supplied less than 1% of U.S. consumption until 1894. This rose to 5% by 1901 and 15% by 1914, as documented by Palmer (1929). The center of the world's production of raw and refined beet sugar was in Europe. Although very little refined sugar was ever imported into the United States, in the early years of the Sugar Trust the threat of European imports affected U.S. prices. In 1888 and 1894, Havemeyer acknowledged setting the price of refined sugar so that none would be imported from

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[2] Refineries were located near the ocean in order to receive imported raw sugar directly into their warehouses. Refined sugar was shipped into the interior by rail or barge. Potential competition between East and West Coast refiners existed near the Missouri and Mississippi rivers, but otherwise their markets did not overlap.

Europe. In later years, refined sugar imports did not constitute a threat (imports were blockaded, to use Joe Bain's entry terminology). This was due to the Cuban Reciprocity Treaty of 1903, which granted Cuba preferential tariff rates on raw sugar, and to productivity gains in the Cuban sugar cane industry, which together lowered the New York price of raw sugar relative to the German price of raw beet sugar. Although we acknowledge the influence of these competitive fringes, they are not formally incorporated into our analysis.

For a more detailed discussion of the East Coast sugar industry over this period, see Eichner (1969), Zerbe (1969), or Genesove and Mullin (1997).

3. Technology of sugar production

■ Refined sugar was a homogeneous product. It was shipped in barrels to grocers, who in turn packaged the sugar for final consumers without any identification of the manufacturer.[3] Prices therefore tended toward uniformity.

Sugar cane was initially processed into raw sugar, a form that can be transported and stored for later refining. As Vogt (1908) indicates, the standard grade of raw sugar was "96 degree centrifugals," which is 96% pure sugar, or sucrose, and 4% water and impurities. The raw sugar was then "melted," purified, and crystallized by refiners into refined sugar, which is 100% sucrose.

The production technology of refined sugar was quite simple and the cane refiners utilized a common technology.[4] Raw sugar was transformed at a fixed, and known, coefficient into refined sugar. 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.

We have a precise estimate of k. Since raw sugar was only 96% sucrose, the lowest value of k that is physically feasible is $1/.96 = 1.041$. In fact, there was some loss of sugar in the refining process, so 100 pounds of raw sugar yielded only 92.5 to 93 pounds of refined sugar.[5] Put otherwise, the production of one pound of refined sugar requires 1.075 pounds of raw sugar, or $k = 1.075$. This coefficient remained unchanged over our sample period and beyond.

Inferring c_o is less straightforward. Nevertheless, we have a number of different sources of evidence that are consistent with each other. The earliest source is Havemeyer's 1899 testimony that he had never known any refining cost less than 50¢ per hundred pounds, and that at a 50¢ margin, "the refineries are running at a loss" and "dividends can hardly be paid out of profits."[6]

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[3] Testimony of James Jarvie, a partner in Arbuckle Brothers, on June 15, 1899, before the U.S. Industrial Commission (hereafter IC) (1900), Vol. I, Part 2, pp. 146–147. Arbuckle Brothers introduced the practice of selling refined sugar to grocers in labelled two-pound and five-pound packages. Yet even they sold most of their sugar in barrels.

[4] Claus Doscher of the New York Sugar Refining Co. and Henry Havemeyer of ASRC both testified that the general processes of sugar refining were common to all refiners. June 1899 testimony, IC, Vol. I, Part 2, 1900, p. 100 and p. 112, respectively.

[5] A Treasury official testified that "According to the data collected by . . . 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, IC, Vol. I, Part 2, 1900, p. 44.

[6] Henry Havemeyer, June 14, 1899, testimony, IC, Vol. I, Part 2, 1900, p. 112. The testimony on costs is summarized in Vol. I, Part 1, pp. 65–66.

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, one needs to know the raw price to infer the true net-of-raw-sugar-costs margin, $P - 1.075 \times P_{RAW}$. A partner in Arbuckle Brothers conveniently provides that price for us:[7] "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 4½ cents a pound, it will cost over 5 cents up to $5^{19}/_{100}$." Subtracting 4.5×1.075 from a total cost of 5 or 5.1, we obtain a value of c_o ranging between 16¢ and 26¢ (per hundred pounds).

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

At the 1911–1912 Hardwick Committee hearings, various refiners quoted a cost between 60¢ and 65¢ per 100 pounds, at a time when raw sugar was selling for $4.00 per 100 pounds (U.S. Congress, 1912). This implies a value of c_o ranging between 30¢ and 35¢ in nominal terms, or 22¢ and 26¢ in constant 1898 dollars. Constant dollar prices are computed from the wholesale price index in Hanes (1993).

Admittedly, as they originate in testimony, these estimates of c_o may be in doubt. However, government audits of the refiners' books for the U.S. Tariff Commission yield a value for c_o in 1914, the last year in our sample, of 35¢ in nominal terms, or 25¢ in 1898 dollars.[8]

One might object that some part of these estimates of c_o constitute fixed costs. Refinery inputs included, aside from raw sugar, containers, fuel, boneblack, and labor. Only labor is a serious candidate for a fixed cost. Among our sources, only the Tariff Commission reports labor costs separately. Were all labor fixed, this would reduce that source's estimate of c_o to 18¢. Of course, some part of labor must have been variable.[9]

We therefore take 26¢ as our best estimate of c_o, since that value is supported by the most and best evidence. At times we use 16¢ 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¢, non-raw-sugar inputs are 4.5% of all costs; at 26¢ they are 7.5%, using the mean raw price of $3.31. This range reflects our ignorance, not differences in firm costs. The witnesses at the Industrial Commission hearings agreed that refiners 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."[10]

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.[11] The plant and machinery were almost entirely specific to the sugar industry, with little value in any other use. In contrast, the land,

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[7] James N. Jarvie, June 15, 1899, testimony, IC, Vol. I, Part 2, 1900, pp. 138–139.

[8] U.S. Tariff Commission (1920), p. 33. We subtracted .013 for depreciation (which is *not* included in the previous estimates) 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 owing to the war. Also, the sugar industry was regulated in those later years.

[9] The *Census of Manufactures, 1909* (U.S. Department of Commerce, 1913) reports that payments to salaried workers constituted 23% of total labor payments. Taking that as the proportion of labor costs that was fixed, the estimate of c_o would be 24¢.

[10] James Post, IC, Vol. I, Part 2, 1900, p. 151.

[11] IC, Vol. I, Part 1, 1900, p. 67.

a significant element of the refinery's cost, had considerable salvage value.[12] Refineries were constructed on the waterfront so that the imported raw sugar could be unloaded directly into the plant or nearby warehouses. Entry costs were therefore considerably but not completely sunk.

Industry production was always well below industry capacity. ASRC in particular retained substantial excess capacity even in the depths of the Arbuckle-Doscher price war. The strategic role of excess capacity, if any, is discussed in Genesove and Mullin (1997).

Our specification and measurement of marginal cost does not incorporate capital costs. The *Census of Manufactures* (U.S. Department of Commerce, 1913) indicates that sugar refining was the second most capital-intensive industry in the United States in 1909–1910. Nevertheless, every indication is that marginal cost was constant up to plant capacity. Moreover, the minimum efficient scale of a plant was small relative to market demand.[13] As the testimony indicates, any reduction in marginal cost that ASRC experienced in its larger plants was minimal.

4. Demand

■ Three issues arise in estimating demand: the frequency of data, the choice of instruments, and functional form.

We have the luxury of weekly data. The advantage of 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 than the long-run elasticity. Use of 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. The alternative of explicitly modelling firms' dynamic problem is inappropriate for a validation study of static oligopoly models. We compromise by using quarterly data. The estimates are similar when we use monthly data.

Our prices come from Willett and Gray's *Weekly Statistical Sugar Trade Journal.* Unfortunately, consumption figures are not available. Instead, we have estimates of *Meltings* (production) from Willett and Gray. Because of final-good inventorying and production-to-order policies (with a one-month lag), the two do not correspond exactly. *Meltings* should serve as a reasonable proxy, however. Extensive inventorying of refined sugar was avoided, according to Lynsky (1938, p. 84), because of the risk of "deterioration of the refined sugar which might become lumpy or undergo slight chemical changes," requiring reprocessing or discount sales.

A second issue is the choice of instruments. We do not use P_{RAW} as an instrument because, at 25% of the total world consumption, U.S. consumption was too large a fraction of the total market to regard the raw price as uncorrelated with U.S. demand shocks. Instead, we use imports of Cuban raw sugar. As column (1) of Table 1 indicates, the vast majority of Cuban exports (and production) went to the United States. This fraction never fell below 85%, and it exceeded 98% in every year between 1900 and 1909. Column (2) shows total Cuban sugar production, while column (3) expresses Cuban imports as a share of total U.S. imports. This fraction is much smaller and more

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[12] 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. IC, Vol. I, Part 1, 1900, p. 152.

[13] Testimony and the size of new entrants suggest that the minimum efficient scale was a plant of about a million pounds per day. That could supply 9% of market demand at its low point seasonally, in the fourth quarter.

TABLE 1   Cuban Sugar Production and Exports, U.S. Sugar Imports

	Cuban Sugar		Percent of U.S. Receipts from		
	(1)	(2)	(3)	(4)	(5)
	Percent				
	Exported	Total		U.S.	Full-Duty
Year	to United States	Production	Cuba	Territories	Countries
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	17.6	13.8	68.7
1901	99.99	612,775	22.9	17.3	59.8
1902	99.99	863,792	25.0	23.3	51.7
1903	98.32	1,003,873	45.9	19.6	34.5
1904	99.59	1,052,273	60.0	22.5	17.5
1905	+99.99	1,183,347	43.0	24.7	32.3
1906	99.64	1,229,736	54.2	23.9	22.0
1907	99.57	1,444,310	57.7	22.3	20.1
1908	+99.99	969,275	46.9	32.2	20.8
1909	99.99	1,521,818	49.5	27.6	23.0
1910	94.26	1,804,349	60.8	32.1	7.1
1911	99.88	1,469,250	59.8	33.7	6.4
1912	92.64	1,895,984	52.7	39.3	8.0
1913	90.01	2,428,537	65.4	31.2	3.4
1914	86.74	2,597,732	72.2	27.5	.3

Notes: The figures prior to 1899 are calendar years and are from the *Weekly Statistical Sugar Trade Journal*, as is total Cuban production in 1912–1914. The remaining statistics for 1900–1914 are reported by fiscal year and are taken from U.S. Tariff Commission (1929).

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 the latter is not available quarterly.[14]

Cuban Imports were an inframarginal source of raw sugar for the United States, at least in the short run, and so exogenous to U.S. demand. Cuba was a low-cost source of raw sugar for the United States both because it was the closest source to the East Coast refiners and because after 1903 it enjoyed a preferential tariff of 80% of the full duty. The next-best alternative destination for Cuban sugar was London, for which shipping costs were considerably higher than to New York. Also, because all facets of

[14] Moreover, U.S. imports may be more accurately measured than Cuban production.

the Cuban industry, including shipping schedules, were directed toward the U.S. market, there were substantial switching costs to selling elsewhere.[15] So even very low realizations of U.S. demand for Cuban raw sugar would be unlikely to divert Cuban sugar from the United States.

The extent of the endogeneity of *Cuban Imports* over the long run depends upon the sources of the variation in Cuban production: the seasonality of the annual harvest cycle, yearly climatic variations, the Cuban Revolution, the subsequent Spanish-American War (which impeded both the production of raw sugar and its transport to the United States), and a secular increase in the planting of sugar cane. The sources of the first four types of variations are clearly exogenous to demand.[16] The last, however, may have been a response to growing U.S. demand. More generally, any planting in the (correct) anticipation of demand will introduce a correlation between *Cuban Imports* and demand shocks. We do not think that the resulting bias will be significant. First, much of the secular increase in sugar cane planting was in response to the Reciprocity Treaty of 1903, which is properly regarded as exogenous to demand.[17] (See Dye (1994) on technological and organizational improvements in Cuban sugar cane production.) Second, Cuban sugar cane yields a harvest for five years and requires almost no tending, so that the "capital stock" is relatively fixed.

The possibility of storage suggests another source of an endogeneity bias. Might not a negative demand shock that lowers P_{RAW} induce Cuban suppliers to shift some exports into the next quarter, when P_{RAW} might be higher? That scenario is highly unlikely. The key issue is whether a shock to U.S. demand would induce speculative raw sugar storage *in Cuba*. If the induced storage activity took place in the United States, after importation, then *Cuban Imports* remain exogenous to shocks to U.S. demand. In fact, harvesting the raw sugar at the time dictated by weather conditions and then exporting it to New York as soon as possible was always the most profitable policy. Below we explain why.

The willingness of suppliers to engage in speculative storage depends upon the available storage technology. For the Cuban raw sugar factories, that meant warehousing the raw sugar in Cuba. But except for temporary storage at docks awaiting transportation to the United States, raw sugars were never warehoused in Cuba during this period, since the continual hot weather posed deterioration risks that were absent in New York.[18] Moreover, since New York 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.

For the Cuban planter, storage meant delaying the cane harvest, thereby storing the sucrose in the cane. Sugar cane harvested other than when most ripe loses some

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[15] There are contemporary comments that sending Cuban sugars elsewhere "would always involve inconvenience and costs, and these considerations would lead to acceptance by Cuban exporters of what might otherwise be considered unacceptable bids for their sugar." U.S. Tariff Commission, (1929), p. 72.

[16] Prinsen Geerligs (1912, p. 173) discusses the dramatic and persistent effects of the Cuban Revolution and Spanish-American War. Although these sources of variation in Cuban production could have served as alternative instruments, we could construct only weakly correlated instruments from the available climatic data. Bound, Jaeger, and Baker (1995) discuss the relevant problems.

[17] In an unreported demand regression, we include a linear time trend. Endogeneity bias can arise only from anticipated deviations from that trend. The coefficient on trend is small and statistically insignificant, and since the variable's inclusion has little effect on other coefficients, we exclude it from our reported specification.

[18] Suitable Cuban storage facilities were constructed in the early 1920s. Before then, 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." Reynolds (1924, p. 52).

sucrose.[19] Also, the harvest season was dictated by the onset of the rainy season.[20] Postponing the harvest in hopes of securing a better price ran the significant risk that the rainy season would begin before all the cane could be harvested. That would not be a total loss, as a portion of the cane would be available for harvest the following season, in December, but delaying harvest was a very crude tool for trying to arbitrage month-to-month, let alone quarter-to-quarter, price differences.[21] Likewise, a *positive* shock to U.S. demand 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, premature cutting would substantially reduce the sugar content of the crop.

Demand estimation typically involves a functional-form assumption. The typical NEIO study 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 50¢. We are therefore interested in comparing the implied cost and conduct estimates from a variety of commonly employed functional forms.

A general form of the demand curve is

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

where P is the price of refined sugar. This specification includes, as special cases, the quadratic demand curve ($\gamma = 2$), the linear ($\gamma = 1$), and the log-linear ($\alpha = 0$, $\gamma < 0$), as well as, in the limit, the exponential demand curve (α, $\gamma \to \infty$, and α/γ 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 is

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

and so is affine in the marginal cost.

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.[22] We allow both β and either α or γ to depend on *High Season*. This specification allows high demand to both increase demand proportionately and change the monopoly price.

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[19] Reynolds (1924, pp. 27–30). 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.

[20] Prinsen Geerligs (1912) notes that "comparatively light showers" of two inches could make transportation of cut cane impossible. "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" (p. 178).

[21] 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. (*Weekly Statistical Sugar Trade Journal*, June 21, 1906, p. 2.) Yet even these centrals would lose sucrose by delaying the harvest beyond the point of peak sucrose content.

[22] This excludes the early strawberry crop from *High Season*, but demand estimation on monthly data, with June through September classified as *High Season*, yields similar results.

We estimate demand for four common functional forms: the quadratic, the linear, the log-linear, and the exponential. The corresponding equations, excluding seasonal effects, are as follows:

$$\text{Quadratic} \qquad \ln Q = \ln(\beta) + 2 \ln(\alpha - P) + \epsilon \qquad (6)$$

$$\text{Linear} \qquad Q = \beta(\alpha - P) + \epsilon \qquad (7)$$

$$\text{Log-Linear} \qquad \ln Q = \ln(-\beta) + \gamma \ln(P) + \epsilon \qquad (8)$$

$$\text{Exponential} \qquad \ln Q = \ln(\beta) + \frac{\gamma}{\alpha} P + \epsilon. \qquad (9)$$

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 (NLIV), as defined in Amemiya (1985).

Table 2 reports summary statistics. Prices are in constant 1898 dollars per hundred pounds, using the wholesale price index in Hanes (1993). *Meltings* and *Cuban Imports* are measured in hundreds of thousands of long tons. The sample covers 1890:I–1914: II but omits one quarter during the Cuban Revolution in which *Cuban Imports* were zero. The effect of excluding this quarter is small.

Table 3 presents the demand estimates, separately by season. The right-hand side of each column reports the coefficients and their standard errors, while the left-hand side lists the corresponding demand parameters for that specification. The reported standard errors are heteroskedasticity-robust, and they are corrected for serial correlation for four lags by the method of Newey and West (1987).[23]

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 χ^2 test for equality of the two sets of coefficients across the seasons is significant at the 5% level or better.[24]

The monopoly pricing rules for both seasons are shown in the first two rows of Table 4. From comparison to Table 2 it is evident that the hypothetical monopoly prices are much higher than the observed prices. To illustrate, consider the linear specification. Recalling that $c = .26 + 1.075*P_{RAW}$, the mean monopoly prices for the low and high season would be $4.80 and $5.90, respectively, well above the observed refined prices of $3.99 and $4.14.

These results foreshadow some of our final conclusions. Observed prices are well below monopoly levels; any market power is minimal. A comparison of Tables 2 and 3 helps cast light on the ability of the NEIO approach to estimate that market power correctly. During the *High Season,* demand is less elastic, and refined prices do rise. But since the price increase is minimal, we will infer a small, though positive, value of θ. Conversely, theoretical models that assume low market power will perform best in recovering cost parameters.

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[23] The autocorrelation structure of the errors is best described by an AR(1) with a correlation coefficient of about .4, depending on the demand specification.

[24] In an unreported regression, we added a linear time trend to account for both an increasing population and the encroachment of beet sugar. The estimated trend was small, negative, and highly insignificant. We chose this indirect approach because neither variable was available at a quarterly frequency. The effective growth of beet sugar is particularly difficult to assess given that it was concentrated in the Midwest.

TABLE 2 Sample Statistics

	Full Sample		Low Season		High Season	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Refined Price (P)	4.03	.62	3.99	.63	4.14	.58
Raw Price (P_{RAW})	3.30	.59	3.28	.61	3.36	.53
$P - 1.075*P_{RAW}$	.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 observations	97		73		24	

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

5. Conduct and costs

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

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

The third and fourth rows of Table 4 present the generalized pricing rules for both seasons, as functions of θ and c. Clearly the pricing rule is sensitive to the assumed demand specification, unless θ is small. This is especially noteworthy in the present context given that the demand functions estimated in Table 3 are indistinguishable, in the sense that paired comparisons using the instrumental-variables version of the P_E test of MacKinnon, White, and Davidson (1983) yield absolute t-statistics less than .5,

TABLE 3 Demand for Refined Sugar, Separately 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]								
Refined Price	α_L	7.72 (.86)	β_L	−2.30 (.48)	γ_L	−2.03 (.48)	$\left(\frac{\gamma}{\alpha}\right)_L$	−.53 (.12)
Intercept		−1.20 (.47)	$\beta\alpha_L$	13.37 (1.90)		4.19 (.65)		3.52 (.48)
High season [N = 24]								
Refined Price	α_H	11.88 (2.03)	β_H	−1.36 (.36)	γ_H	−1.10 (.28)	$\left(\frac{\gamma}{\alpha}\right)_H$	−.26 (.07)
Intercept		−2.48 (.54)	$\beta\alpha_H$	10.74 (1.57)		3.17 (.40)		2.70 (.29)
$\chi^2_{(2)}$ test		6.90		28.18		29.17		25.96

Notes: Standard errors are in parentheses. They are heteroskedasticity-robust and corrected for serial correlation with four lags, by the method of Newey and West (1987). *Refined Price* is instrumented by the log of *Cuban Imports*. The reported $\chi^2_{(2)}$ statistic is for the joint test of equality of the coefficients on price and the intercept across seasons.

TABLE 4   Demand for Refined Sugar, Derived Estimates

	(1) Quadratic	(2) Linear	(3) Log-Linear	(4) Exponential	(5) Lerner Index
$P^M(c)$: _High Season_ = 0	$2.57 + .67c$	$2.91 + .5c$	$1.97c$	$1.89 + c$	
$P^M(c)$: _High Season_ = 1	$3.96 + .67c$	$3.96 + .5c$	$10.1c$	$3.85 + c$	
$P(c; \theta)$: _High Season_ = 0	$\dfrac{7.72\theta}{2+\theta} + \dfrac{2}{2+\theta}c$	$\dfrac{5.82\theta}{1+\theta} + \dfrac{1}{1+\theta}c$	$\dfrac{2.03}{2.03-\theta}c$	$1.89\theta + c$	
$P(c; \theta)$: _High Season_ = 1	$\dfrac{11.88\theta}{2+\theta} + \dfrac{2}{2+\theta}c$	$\dfrac{7.91\theta}{1+\theta} + \dfrac{1}{1+\theta}c$	$\dfrac{1.10}{1.10-\theta}c$	$3.85\theta + c$	
η at Full sample mean					
High Season = 0	2.18	2.24	2.03	2.13	
High Season = 1	1.03	1.04	1.10	1.05	
Adjusted Lerner index, L_η					(Unadjusted)
Mean	.099	.107	.095	.097	.054
Standard Deviation	.097	.118	.083	.089	.045
Standard Error	.024	.028	.021	.022	.0046

so that no one specification can be rejected in favor of another.[25] Thus a researcher would find it difficult to choose among them.

We organize our comparison of alternate estimates of θ by varying the econometrician's information set 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, as outlined in Sections 3 and 4.

□   **The elasticity-adjusted Lerner index, L_η.** 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. The bottom of Table 4 presents summary statistics of L_η, with η taken from Table 3 and assuming $c_o = .26$. The last row shows the standard error, correcting for the estimation of η.[26]

For all four demand curves, the mean L_η is close to .10. We use this value as our direct estimate of θ, the deviations in the actual values presented in Table 4 being negligible both economically and statistically. An estimate of .10 corresponds to the conduct of a static, ten-firm symmetric Cournot oligopoly. We can reject both perfectly competitive conduct and monopoly pricing. Overall, the relatively low values of L_η suggest a more competitive environment than one would expect from an industry that averaged six firms and whose largest firm had an average market share of 63%. The likely explanation is that industry pricing was constrained by threats of (domestic) entry or of foreign imports.

The variation in L_η is easily accounted for. Table 5 shows L_η's secular decline, in line with the decline in ASRC's market share and the two postentry price wars.[27] We return to both issues in Section 6. Table 6 shows seasonality in L_η. Competition is least

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[25] In conducting these tests, the square of the log of _Cuban Imports_ is used as an additional instrument.

[26] The standard errors adopt the general method of moments, in which we add to the moments implicit in the instrumental-variables estimates of Table 3 the additional moment condition $\Sigma_i L_{\eta i} - \overline{L}_\eta = 0$, where $\overline{L}_\eta$ is our estimate of the mean adjusted Lerner index.

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

TABLE 5   **Lerner Indices by Year**

	Lerner Index				American Sugar Refining Co.'s Market Share
	Unadjusted		Elasticity Adjusted (linear)		
Year	Mean	Standard Deviation	Mean	Standard Deviation	
1890	.00	.01	.00	.08	67.7
1891	.05	.04	.06	.08	65.2
1892	.11	.07	.20	.15	91.0
1893	.12	.03	.29	.10	85.7
1894	.10	.05	.17	.09	77.0
1895	.09	.03	.19	.07	76.6
1896	.09	.05	.26	.13	77.0
1897	.10	.01	.26	.12	71.4
1898	.03	.04	.16	.19	69.7
1899	−.02	.02	−.09	.08	70.3
1900	.02	.04	.05	.10	70.1
1901	.08	.01	.20	.06	62.0
1902	.08	.03	.11	.05	60.9
1903	.07	.04	.11	.07	61.5
1904	.04	.04	.06	.06	62.3
1905	.06	.03	.16	.13	58.1
1906	.05	.03	.07	.05	57.3
1907	.06	.03	.08	.06	56.8
1908	.05	.01	.07	.03	54.3
1909	.02	.02	.03	.04	50.4
1910	.02	.01	.03	.02	49.2
1911	.04	.03	.06	.04	50.1
1912	.04	.02	.06	.04	45.5
1913	.03	.02	.03	.01	44.0
1914	.02	.02	.02	.02	43.0
Average	.05	.05	.11	.12	63.1

Notes: The market share figures are from the *Weekly Statistical Sugar Trade Journal.*

TABLE 6   **Lerner Index Seasonality**

	Quarter I		Quarter II		Quarter III		Quarter IV	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Unadjusted	.048	.042	.065	.042	.064	.047	.038	.047
Linear	.102	.106	.162	.138	.075	.063	.086	.134

in the second quarter and greatest in the third (*High Season*). This result suggests dynamic oligopoly models, such as Rotemberg and Saloner (1986) and Haltiwanger and Harrington (1991), in which the anticipation of future improvements in demand conditions abets collusion and the opposite hinders it, 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 *High Season* only and always with the third quarter.

This seasonality in L_η is troubling, since *High Season* will be used as an instrument in estimating the pricing rule. If we think of the errors in the pricing rule as arising in part from deviations in the degree of competition at any one time, then it is clear that they will be correlated with *High Season*. This is Corts's (forthcoming) argument. 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 while acknowledging the failure of an assumption to hold, we examine how well the methodology does in reproducing the full-information estimates of conduct and cost.

□ **The NEIO conduct estimate, $\hat\theta$.** Substituting (3) into (10) yields the following pricing rule:[28]

$$P = \frac{\alpha\theta + c_o\gamma}{\gamma + \theta} + \frac{\gamma}{\gamma + \theta}kP_{RAW}. \tag{11}$$

Given the dependence of the pricing rule on the demand specification, we estimated this equation using each of the demand specifications. The estimated cost and conduct parameters were quite similar, as might have been expected given the elasticities reported in Table 4. For brevity and later convenience, in the remainder of the article we report the results for the linear specification only.

Substituting $\gamma = 1$ and multiplying by $1 + \theta$, we respecify (11) as

$$E[\{(1 + \theta)P - \alpha\theta - c_o - kP_{RAW}\}\mathbf{Z}] = 0. \tag{12}$$

Keep in mind that α takes different values in the different seasons. $\mathbf{Z}$ is the vector of instruments: a constant, *High Season,* and the log of *Cuban Imports*. We instrument with the last because of the potential endogeneity of P_{RAW}. Whether the source of the error in equation (11) is cost or market power, that error will be negatively correlated with P_{RAW}—increases in it will lead to increases in the refined price and so decreases in the demand for, and the price of, raw sugar. The first-stage regression is

$P_{RAW} = 3.34 + .07$ *High Season* $- .19$ log *Cuban Imports* $R^2 = .18,$ $N = 97.$
      (.06)   (.13)   (.04)

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.[29] In each case, the researcher substitutes any known cost parameters into (12) and recovers estimates of the unknown cost parameters and θ. Third, both k and c_o may be known. In this case, L_η is directly observed.

Table 7 reports the NLIV estimates of (12). Column (1) corresponds to unknown c_o and k; column (2) assumes that k is known to be 1.075 (in which case we drop the log of *Cuban Imports* from the instrument list). Demand parameter estimates are from

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[28] The limit of this equation for exponential demand is $P = (\alpha/\gamma)\theta + c_o + kP_{RAW}$.

[29] This corresponds to the cigarette industry studies by Sumner (1981), Sullivan (1985), and Ashenfelter and Sullivan (1987), which use taxes as a component of cost, so that $k = 1$.

TABLE 7	NLIV Estimates of Pricing Rule Parameters		
	Linear		Direct Measure
	(1)	(2)	(3)
$\hat{\theta}$	.038 (.024)	.037 (.024)	.10
$\hat{c}_o$	.466 (.285)	.39 (.061)	.26
$\hat{k}$	1.052 (.085)		1.075

Table 3, which includes a seasonal variation. The standard errors are heteroskedasticity-robust and serial correlation–robust. They are constructed according to the Newey and West (1987) procedure, with four lags, and take into account that the demand parameters are themselves estimated. The variance-covariance matrix of (θ, c_o, k) is $\mathbf{W}_2 + \mathbf{V}$, where $\mathbf{W}_2$ is the Newey and West estimate and $\mathbf{V} = \mathbf{D}^{-1\prime}(\mathbf{C}'\mathbf{W}_1\mathbf{C})\mathbf{D}^{-1}$, in which $\mathbf{W}_1$ is the Newey and West estimate of the variance-covariance matrix of the demand parameters, $\mathbf{D}$ is the matrix of derivatives of the moment conditions from equation (12) with respect to (θ, c_o, k), and $\mathbf{C}$ 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. The final column (3) reports the direct measure of cost parameters we used in our Lerner index analysis, along with the associated measure of θ.

We draw three main conclusions. First, the methodology performs reasonably well in estimating θ. $\hat{\theta}$ is always close to L_η. Monopoly ($\theta = 1$) would be rejected under both specifications, as would, more generally, Cournot with nine or fewer firms. On the other hand, the point estimates are quite close to perfect competition ($\theta = 0$), which cannot be rejected. (In Section 6, however, where the price-war periods will be controlled for, perfect competition will be rejected.) θ is underestimated due to the correlation between L_η and *High Season*; refined price rises in *High Season*, but proportionately less than the elasticity falls.

Second, the cost parameters are estimated less well: k is underestimated, although one cannot reject $k = 1.075$. In contrast, c_o is overestimated.

Third, partial cost information does not improve $\hat{\theta}$. Imposing information about k, when c_o is unknown, does not move $\hat{\theta}$ toward our direct measure. It does, however, improve the estimate of c_o and substantially raise its precision.

Our benchmark conduct estimate, L_η, is constructed under the assumption that $c_o = .26$. When c_o is set equal to .16, the lower bound in our range of estimates, L_η increases to .15. Since the NEIO underestimates the conduct parameter, using a higher benchmark level of market power makes the procedure look worse. But this degradation is not substantial, as both values of L_η would lead to the rejection of both perfect competition and monopoly, and we would retain our main conclusion: the NEIO performs reasonably well in estimating θ. Moreover, our other conclusions remain undisturbed. One caveat is that even an $L_\eta = .15$ reflects relatively low market power, and Corts (forthcoming) has argued that the NEIO will perform poorly only when θ is large.

To understand why we obtain these estimates, recall from Table 4 that the pricing rule is linear in P_{RAW} and shifts in a parallel fashion across seasons. Thus a reparameterization of (11) that is linear in its parameters corresponds to the regression of the

Refined Price on a constant, *High Season,* and the *Raw Price,* as in column (2) of Table 8.

As that column shows, price increases by only 8¢ in the high season. That price responds to *High Season* at all will be taken as evidence against perfect competition. But the coefficient is small relative to the predicted increases in the monopoly price from Table 4, and thus it results in the low NLIV estimate of θ. For example, the linear demand estimates imply an increase of $\theta/[1 + \theta]$ times $2.09 = 7.91 - 5.82 = \alpha_H - \alpha_L$ in the oligopoly price, and thus a θ of $.04 = .08/(2.09 - .08)$. The estimate of k is then obtained from the coefficient on the raw price: $\hat{k} = 1.01 \times (1 + .04) = 1.05$. Given that we underestimate both θ and k, the remaining element must be overestimated to rationalize the difference between the refined and raw price. Our estimates of the conduct and cost parameters assuming quadratic or exponential demand can also be calculated from column (2). The interested reader will see that the values are quite close to those assuming linear demand. With log-linear demand, the slope of the pricing rule differs by season, as permitted in column (3) of Table 8. The NLIV estimation constrains the ratios of the slopes and intercepts of the pricing rule to be the same; this yields estimates similar to those of the other demand specifications.

Column (1), which omits all *High Season* effects, shows the conclusions we would reach were we to use the known value of k and ignore the demand seasonality. This approach is similar to the early estimation of market power in the cigarette industry, which attempted to identify θ through the responsiveness of price to cost (excise taxes) alone. 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. Clearly, the results from such an approach are fundamentally determined by the demand specification.

□ **Estimating cost under assumed conduct.** An alternative is to estimate unknown cost parameters under the assumption of a particular model of firm behavior, that is, by restricting θ to equal a specific value. Here, we evaluate two simple models, perfect competition ($\theta = 0$) and monopoly ($\theta = 1$). We defer estimation of the Cournot model to the next section.

Table 9 reports the results for linear demand.[30] As is to be expected, costs are overestimated when perfect competition is assumed and underestimated when monopoly is. Nor is it surprising that the discrepancy is greater under the monopoly assumption (which runs into the constraint that $c_o \geq 0$), given the low value of L_η. That the perfect-competition assumption leads to a substantial overestimate of c_o, rather than of k, under linear demand ($\gamma = 1$) is evident from the Taylor series expansion of the pricing rule around $\theta = 0$,

$$P \approx c_o + \theta[\alpha - c_o]/\gamma + k[1 - \gamma^{-1}\theta]P_{RAW}.$$

Recall that α, the maximum willingness to pay, is on the order of six to eight dollars. Thus the intercept in the pricing rule is more sensitive to the true value of θ than the slope.

Finally, the cost estimates from assuming perfect competition (or monopoly) are inferior to those obtained when conduct is also estimated, as the comparisons with columns (1) and (2) of Table 7 indicate.

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[30] The results for the other demand curves are similar. When k is unknown, we instrument with the log of *Cuban Imports* and a constant. When $k = 1.075$ is known, we instrument with a constant.

TABLE 8   Pricing Equations for Refined Sugar (Linear Parameterization)

	(1)	(2)	(3)
Raw Price	1.02	1.01	.93
	(.09)	(.08)	(.09)
High Season × Raw Price			.31
			(.11)
High Season		.08	−.97
		(.03)	(.38)
Constant	.67	.66	.94
	(.28)	(.26)	(.28)
$\chi^2_{(2)}$ test			21.67

Notes: Dependent variable is price of refined sugar. 97 observations. Columns (1) and (2) use the log of *Cuban Imports* as an instrument, and column (3) adds the interaction between that and *High Season* as an additional instrument. The reported $\chi^2_{(2)}$ statistic is for the joint test that the coefficients on both *High Season* and *High Season × Raw Price* are zero.

6. Conduct and structure

■ Figure 1 presents annual values of L_η from Table 5, along with several structural measures of competition: ASRC's market share, fringe capacity, and the reciprocal of the number of firms.[31] The evolution of L_η has two components, the postentry price wars in 1890–1892 and 1898–1900, and a gradual decline as entry and expansion by the fringe eroded ASRC's market share. In this section, we see whether the NEIO approach and the static oligopoly models can explain this evolution.

To see whether the NEIO can capture the structural change of the postentry price wars, we reestimate equation (12) by letting θ take on the value of θ_0 during the normal, non-price-war periods and θ_1 during the price-war regime of 1890:I–1892:II and 1898: IV–1900:II. L_η averaged .02 during the wars, .11 otherwise. We report the results for linear demand in Table 10. The estimated change in θ during the price war regime is indeed negative, of similar magnitude as the difference in L_η, and statistically significant. Moreover, we can now reject perfect competition for the normal, non-price-war regime ($\theta_0 = 0$). The estimates of c_o, while well removed from our direct measure, are little changed from Table 7.

In order to capture the secular decline in market power, we first allow θ to be a linear function of ASRC's *Capacity Share*. This should be viewed primarily as a summary of the data rather than as a structural regression. As Table 11 reveals, estimated conduct does indeed become less competitive with increases in ASRC's share of industry capacity. ASRC's decline in capacity share from 90% to 60% is predicted to lead to a decline in θ of .18. For comparison, column (3) reports the regression of L_η on ASRC's *Capacity Share*. Its coefficient is positive and of the same magnitude. But the comparison on the cost side is less encouraging: the estimates in columns (1) and (2) are far removed from the direct measures.

Finally, we consider how well two simple static oligopoly models can capture the gradual increase in competition over time. The first model, Cournot I, assumes constant, identical marginal cost across firms, and no capacity constraints. This model implies that $\theta = 1/N_t$, where there are N_t firms in the market in quarter t.

Cournot I ignores the key asymmetry in this industry, the difference in capacity between ASRC and the fringe. Our emphasis upon capacity rather than marginal cost

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[31] The latter two series are evaluated at the start of the year, although we constructed them quarterly.

TABLE 9   Cost and Price Estimates for Different Behavioral Models

	Perfect Competition		Cournot I		Cournot II		Monopoly		Direct Measure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\hat{c}_o$	.674	.476	.00	.069	.00	.00	.00	.00	.26
	(.281)	(.034)	(.239)	(.071)	(.922)	(.400)	(1.65)	(.563)	
$\hat{k}$	1.015		1.096		.883		.529		1.075
	(.087)		(.071)		(.253)		(.471)		
Predicted price changes, Cuban Revolution									
$\widehat{\Delta P}$	.689	.729	.620	.608	.300	.365	.179	.365	.702
	(.059)		(.040)		(.086)		(.086)		

Notes: Demand parameters are taken from the linear form in Table 4, estimated separately by season. Cost parameters are constrained to be nonnegative. Predicted increase in refined prices is based upon the increase in the price of raw sugar by 68 cents per hundred pounds from the third quarter of 1896 to the third quarter of 1897.

is supported by simple calculations from a Cournot model without capacity constraints but with differential costs. In Section 3 we cited testimony that the larger plants might have a "three or five cents" cost advantage over smaller plants. A Cournot game in which ASRC had $c_o = .21$ (over *all* its plants) and faced three rivals, each with $c_o = .26$, predicts an ASRC market share of 30% at the mean raw price, far lower than its observed average share of 63%.[32] Nor can product differentiation account for ASRC's market share, as most sugar was sold to consumers without any manufacturer identification, and the homogeneity of the product was attested to by all participants in the industry.[33]

Cournot II incorporates the asymmetry in capacities. Firms are assumed to have identical marginal costs up to their individual capacities, which differ. They simultaneously make output decisions each period. Since ASRC had enough capacity to serve the entire market at all times, the equilibrium outcome is the same as the classic case of a dominant firm facing a competitive fringe: for any market price above marginal cost, the fringe will produce up to their capacity, and the dominant firm will act as a monopolist on its residual demand curve.[34] This model departs from our previous formulations, as our pricing rule equation is that of a monopolist facing a residual demand curve of the market demand less total fringe capacity.

Cost parameters from the pricing rule were estimated under the nonnegativity constraint. The results in Table 9 confirm the earlier claim that the less-competitive models of conduct yielded the worse estimates of cost. This becomes clearer when Cournot I and II are compared both to each other and to monopoly. Because predicted prices exceed observed prices, the cost parameters are underestimated, and the bias is greater the less competitive the model.

In closing, we consider the market experiment provided by the Cuban Revolution in the third quarter of 1897, in which *Cuban Imports* to the United States fell to zero. We excluded this quarter from our estimation of demand, conduct, and cost. This

[32] In only one year did ASRC face fewer than three rivals. ASRC is the only firm whose market share we observe annually, although we can construct all firms' capacities quarterly.

[33] Differentiation due to refiner location was limited in the East Coast industry during this period. Capacity was concentrated around New York City, with additional plants in Boston, Philadelphia, and Baltimore. A plant's transportation cost advantage was largely limited to serving its local market.

[34] This assumes that the fringe's output in a Cournot game absent capacity constraints exceeds the fringe capacity.

FIGURE 1

EVOLUTION OF CONDUCT AND STRUCTURE
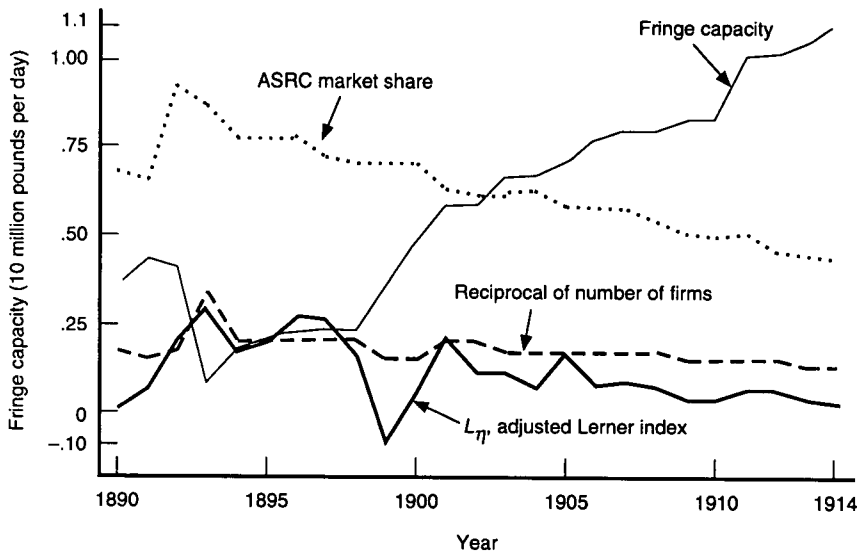
exogenous supply disturbance generated a large runup in the price of raw sugar. P_{RAW} rose 68¢ from 1896:III to 1897:III, reaching \$3.98. We treat this 68¢ increase as exogenous and use the models to predict the change in the refined price, which rose 70.2¢ over the same period. By focusing on the change in prices, we place primary importance on the estimates of k and on the model of firm conduct, since from the pricing rule, $\widehat{\Delta P} = [\hat{k}/(1 + \theta)]\Delta P_{RAW}$.

The general pricing rule of equation (10) shows that for large values of θ, the extent of pass-through can be quite sensitive to the assumed demand specification. Yet in this example, with an observed pass-through of 1.03, and so an implied θ near zero, the relative performance of the different behavioral models was not substantively affected by the demand specification.

So we report the predicted price changes for linear demand only, in the final row of Table 9. Perfect competition yields estimates very close to the actual 70.2¢ price increase. Cournot I underestimates the price increase, although the difference is insignificant. The much more severe underestimation by Cournot II and monopoly arises

TABLE 10   NLIV Estimates of Pricing Rule Parameters, Price War Regimes

	Linear		Direct Measure
	(1)	(2)	(3)
$\hat{\theta}_0$	.046	.046	.129
	(.023)	(.023)	
$\hat{\theta}_1 - \hat{\theta}_0$	−.112	−.108	−.127
	(.069)	(.051)	
$\hat{c}_o$	.375	.402	.26
	(.280)	(.056)	
$\hat{k}$	1.084		1.075
	(.083)		

TABLE 11   NLIV Estimates of Pricing Rule Parameters, ASRC
            Capacity Shares

	Linear		Direct Measure
	(1)	(2)	(3)
$\hat{a}_\theta$	−.340	−.222	−.336
	(.179)	(.087)	(.073)
$\hat{b}_\theta$	.601	.400	.594
	(.246)	(.120)	(.097)
$\hat{c}_o$	1.262	.417	.26
	(.480)	(.098)	
$\hat{k}$	.816		1.075
	(.128)		

Notes: Here, θ is a linear function of American Sugar Refining Company's share of industry capacity: $\theta = a_\theta + b_\theta \ ASRC \ Capacity \ Share$.

both from their underestimation of k and from the less-competitive conduct they imply; a higher fraction of the increase in marginal cost is predicted to be absorbed rather than passed on to consumers.[35] The example illustrates the value of both the appropriate model of conduct as well as cost information in predicting market outcomes.

7. Conclusion

■   The objective of this article was to evaluate the success of static oligopoly models in characterizing conduct and costs in the sugar refining industry. Although in the main our results should be reassuring to NEIO adherents, they also suggest that direct cost measures can improve conduct and other cost estimates.

We found that NEIO estimates of the industry conduct parameter were close to the direct measure we derived from full cost information, and insensitive to the assumed demand form. The NEIO approach did underestimate the conduct parameter, but this deviation was minimal in our context. It was successful in capturing the secular decline in the degree of market power.

Additional conclusions were reached when we assumed a specific form of conduct and estimated cost. The resulting cost estimates were sensitive to the assumed model of behavior, as one would hope and expect. Nevertheless, the predictive power of even an apparently misspecified model could be improved when direct cost measures replaced one or both estimated cost parameters.

There is currently a debate in empirical Industrial Organization circles between those who would estimate the conduct parameter as a free parameter and those who would restrict it to those specific values consistent with game-theoretic models. Certainly, the "structuralists" are correct in pointing out that a freely estimated θ provides no guide in predicting the effects of entry of exit and, in differentiated-goods markets, the location of new goods. This article does show, however, that by freeing θ, both cost parameters and the response of price to observable changes in cost are better estimated.

Critics of the estimation of static oligopoly pricing rules might note 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 these techniques in this industry would have been reason for

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[35] Underestimation is replaced by severe overestimation for these two models under log-linear demand.

serious doubt. Other industries with a similar production technology and information structure, such as gasoline refining, could be used to evaluate this methodology further.

References

AMEMIYA, T. *Advanced Econometrics.* Cambridge, Mass.: Harvard University Press, 1985.

APPELBAUM, E. "Testing Price Taking Behavior." *Journal of Econometrics,* Vol. 9 (1979), pp. 283–294.

———. "The Estimation of the Degree of Oligopoly Power." *Journal of Econometrics,* Vol. 19 (1982), pp. 287–299.

ASHENFELTER, O. AND SULLIVAN, D. "Nonparametric Tests of Market Structure: An Application to the Cigarette Industry." *Journal of Industrial Economics,* Vol. 35 (1987), pp. 483–498.

BERRY, S., LEVINSOHN, J., AND PAKES, A. "Automobile Prices in Market Equilibrium." *Econometrica,* Vol. 63 (1995), pp. 841–890.

BOUND, J., JAEGER, D.A., AND BAKER, R.M. "Problems with Instrumental Variables Estimation When the Correlation Between the Instruments and the Endogenous Explanatory Variable Is Weak." *Journal of the American Statistical Association,* Vol. 90 (1995), pp. 443–450.

BRESNAHAN, T.F. "Empirical Studies of Industries with Market Power." In R. Schmalensee and R.D. Willig, eds., *The Handbook of Industrial Organization.* New York: North-Holland, 1989.

CORTS, K.S. "Conduct Parameters and the Measurement of Market Power." *Journal of Econometrics,* forthcoming.

DYE, A. "Cane Contracting and Renegotiation: A Fixed Effects Analysis of the Adoption of New Technologies in the Cuban Sugar Industry, 1899–1929." *Explorations in Economic History,* Vol. 31 (1994), pp. 141–175.

EICHNER, A.S. *The Emergence of Oligopoly: Sugar Refining as a Case Study.* Baltimore: Johns Hopkins Press, 1969.

PRINSEN GEERLIGS, H.C. *The World's Cane Sugar Industry.* Altrincham, England: Rodger, 1912.

GENESOVE, D. AND MULLIN, W.P. "Predation and Its Rate of Return: The Sugar Industry, 1887–1914." Working Paper no. 6032, National Bureau of Economic Research, 1997.

GOLLOP, F.M. AND ROBERTS, M.J. "Firm Interdependence in Oligopolistic Markets." *Journal of Econometrics,* Vol. 1 (1979), pp. 313–331.

HALTIWANGER, J. AND HARRINGTON, J.E., JR. "The Impact of Cyclical Demand Movements on Collusive Behavior." *RAND Journal of Economics,* Vol. 22 (1991), pp. 89–106.

HANES, C. "The Development of Nominal Wage Rigidity in the Late 19th Century." *American Economic Review,* Vol. 83 (1993), pp. 732–756.

LYNSKY, M. *Sugar Economics, Statistics, and Documents.* New York: United States Cane Refiners' Association, 1938.

MACKINNON, J.G., WHITE, H., AND DAVIDSON, R. "Tests for Model Specification in the Presence of Alternative Hypotheses: Some Further Results." *Journal of Econometrics,* Vol. 21 (1983), pp. 53–70.

NEWEY, W.K. AND WEST, K.D. "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica,* Vol. 55 (1987), pp. 703–708.

PALMER, T.G. *Concerning Sugar.* Washington, D.C.: U.S. Sugar Manufacturing Association, 1929.

PORTER, R.H. "A Study of Cartel Stability: The Joint Executive Committee, 1880–1886." *Bell Journal of Economics,* Vol. 14 (1983), pp. 301–314.

REYNOLDS, P.K. *The Story of Cuban Sugar.* Boston: United Fruit Co., 1924.

ROTEMBERG, J.J. AND SALONER, G. "A Supergame-Theoretic Model of Business Cycles and Price Wars During Booms." *American Economic Review,* Vol. 76 (1986), pp. 390–407.

RUBINOVITZ, R.N. "Market Power and Price Increases for Basic Cable Service Since Deregulation." *RAND Journal of Economics,* Vol. 24 (1993), pp. 1–18.

SULLIVAN, D. "Testing Hypotheses About Firm Behavior in the Cigarette Industry." *Journal of Political Economy,* Vol. 93 (1985), pp. 586–598.

SUMNER, D.A. "Measurement of Monopoly Behavior: An Application to the Cigarette Industry." *Journal of Political Economy,* Vol. 89 (1981), pp. 1010–1019.

U.S. CONGRESS, HOUSE OF REPRESENTATIVES. Special Committee on the Investigation of the American Sugar Refining Company and Others. *Hearings.* 62nd Congress, 2d Session. 1911–1912. Washington, D.C.: U.S. Government Printing Office, 1912.

U.S. DEPARTMENT OF COMMERCE, BUREAU OF THE CENSUS. *Thirteenth Census of the United States taken in the Year 1910. Volumes VIII–X: Manufactures, 1909.* Washington, D.C.: U.S. Government Printing Office, 1913.

U.S. INDUSTRIAL COMMISSION. *Reports,* Volumes 1, 13, 14. Washington, D.C.: U.S. Government Printing Office, 1900.

U.S. TARIFF COMMISSION. *Refined Sugar: Costs, Prices and Profits.* Washington, D.C.: U.S. Government Printing Office, 1920.

————. *Effects of the Cuban Reciprocity Treaty of 1902.* Washington, D.C.: U.S. Government Printing Office, 1929.

VOGT, P.L. *The Sugar Refining Industry in the United States.* Philadelphia: University of Pennsylvania Press, 1908.

WEEKLY STATISTICAL SUGAR TRADE JOURNAL. Various issues, 1891–1915. New York: Willett and Gray.

ZERBE, R.O. "The American Sugar Refinery Company 1887–1914: The Story of a Monopoly." *Journal of Law and Economics,* Vol. 12 (1969), pp. 339–375.