Predation and its rate of return: the sugar industry, 1887–1914

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and

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We show that the price wars following two major entry episodes were predatory. Our proof is twofold: by direct comparison of price to marginal cost, and by construction of a lower bound to predicted competitive price-cost margins that we show to exceed observed margins. Predation occurred only when its relative cost to the dominant firm, the American Sugar Refining Company (ASRC), was small. Its most clear effect was to lower the acquisition price of entrants and small incumbents. It may also have deterred future capacity additions and raised ASRC's share of industry profits. Predation operated by strengthening ASRC's reputation as a willing predator.

1. Introduction

■ The continued exercise of market power depends upon deterring entry. Theory has clarified the range of rational strategies available to an incumbent. To assess whether such strategies are effectively used, we trace the evolution of the American sugar refining industry. We study entry following the formation of the Sugar Trust, later reorganized as the American Sugar Refining Company (ASRC), and focus on two sets of entrants, Spreckels and later Arbuckle Brothers and Doscher, who were met with sharp cuts in price. These price wars lasted about two years, with some interruptions, and included extended periods in which the price-cost margin fell to zero or below. We interpret these price wars as predation by ASRC.

Our evidence is based in part upon a direct comparison of price to marginal cost. As argued in Genesove and Mullin (1998), the simple technology of sugar refining and contemporary audits and testimony combine to provide a direct and credible measure of marginal cost. Because cost estimates can be controversial, we present a second test, based on competitive models, firms' capacities, and demand estimates. Using these, we construct predicted competitive price-cost margins and show that they exceed observed margins. This conclusion is robust to our measure of marginal cost, as it holds even when the non-raw-sugar component of marginal cost is assumed to be zero.

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These claims engage us in two debates, one particular to the industry and the other more general. Whereas Zerbe (1969) attributes the price wars to a *competitive* response to entry, and their end to mergers, Eichner (1969) views the price wars as a *predatory* response to entry. The arguments evoke the more general debate about whether predation can be rational, and whether it occurs.

We view predatory pricing as "a reduction of price in the short run so as to drive competing firms out of the market or to discourage entry of new firms in an effort to gain larger profits via higher prices in the long run than would have been earned if the price reduction had not occurred," as in Joskow and Klevorick (1979, pp. 219–220). The predatory strategy could operate either by restricting the rival's cash flow or by altering its perception of market conditions or the incumbent's likely future actions.

Because compelling evidence of predation is rare, we devote much of the article to establishing that ASRC engaged in it. There are three additional findings. First, ASRC's demand for predation was downward sloping. We conceive of ASRC as "purchasing" losses for its rival by paying a price in forgone current profits. We measure this price as the ratio of ASRC's losses in the predatory war to the entrant's losses. The measure's usefulness is demonstrated by respites in both price wars in the summer, when sugar demand is high. We demonstrate that predation was relatively more costly to ASRC then, and so its extent was sensitive to its cost. Second, predation reduced the costs of acquiring competitors, as inferred from comparisons with counterfactual nonpredatory buyout prices. Both predatory episodes ended with ASRC's acquisition of a new entrant and other small incumbents. Three, most entrants made money overall, after experiencing both predatory and nonpredatory periods.

The plan of the article is as follows. In Section 2 we review the industry's history. Section 3 outlines the competitive environment in which ASRC operated: the cost structure, entry conditions, and possible modes of pricing behavior. Sections 4 and 5 address the two entry episodes. In Section 6 we address dynamic nonpredatory alternatives. Section 7 documents the effects of predation, as well as ASRC's rationale for preying, by means of internal rates of return to ASRC calculated under various theories of predation. We examine entrants' profitability in Section 8 and in Section 9 discuss and dismiss other ways in which ASRC might have deterred entry. Section 10 concludes.

2. Historical overview

■ The Sugar Trust was formed in December 1887 as a consolidation of 18 firms controlling 80% of industry capacity. Refined prices rose 16%, and entry soon followed.[1]

The first entrant was Claus Spreckels Sr., who in December 1889 completed a plant in Philadelphia. That led to a two-year price war, and then to ASRC, the Trust's successor, acquiring the plant along with those of three Philadelphia firms that had not joined in 1887. These acquisitions were completed by April 1892. ASRC capacity rose to 15.2 million pounds per day and its share to 95%. Not all entrants were met by immediate price wars. Over the next several years, concentration slowly declined with the small-scale entry of five firms with an average capacity of 447,000 pounds per day, documented by Vogt (1908).

The next phase of competition began in 1898, with the entry of Arbuckle Brothers, the dominant U.S. coffee roaster. It owed that position to a patented packaging machine, which enabled it to sell coffee in small packages rather than in bulk. From 1892 to 1896, it applied the technology to sugar, buying it refined from ASRC and then reselling it packaged. In September 1896, Arbuckle Brothers announced its intention to enter sugar refining. ASRC 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, and production began in August 1898.

Another entrant, the Doscher refinery, began production in November of that year. When fully operational, each plant had a million-pound daily capacity, which together reduced ASRC's capacity share from 88% to 77%. This precipitated a severe price war, marked by pricing at

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[1] Eichner (1969) reports that the average refined price rose from $6.01 (per 100 pounds) in 1887 to $7.01 in 1888.

or below cost, shutdown by the independent refiners, and Doscher's partial shutdown. With the exception of one "respite," the price war continued until May 1900, when Doscher merged with two others to form the National Sugar Refining Company—a consolidation organized by the ASRC president, Henry Havemeyer, who received control of the new entity. Arbuckle Brothers remained in the industry.

The next several years witnessed both successful and unsuccessful entry attempts. Claus Spreckels Jr., the son, founded a refinery in 1901, achieving a toehold in the industry by 1902–1904. Adolph Segal, who in 1895 had constructed a refinery and then sold it to ASRC before it went into production, began construction of a second plant in 1901. Two years later, with the plant nearly complete, Segal's bankruptcy pushed the refinery into receivership. Production at the plant began only in 1912, after it had been sold and refurbished. In 1910 the federal government filed a monopolization suit against ASRC, seeking its dissolution. Although this case was not formally resolved until a 1922 consent decree, government victories in the American Tobacco and Standard Oil cases in 1911 led ASRC to relinquish control of the National.[2]

The industry's evolution is captured in Table A1 in the Appendix. The third through seventh columns report capacity and capacity shares for East Coast plants.[3] (The West Coast constituted a largely separate market from the East Coast, where sugar production was concentrated.[4] As the U.S. Department of Commerce (1976) indicates, the U.S. population was then heavily concentrated in the East, with 70% of the 1900 population east of the Mississippi and only 6% in the Pacific and Mountain regions. We therefore focus on the East Coast market.) These figures demonstrate ASRC's dominance. Its (adjusted) capacity share, which accounts for its control over the National from its 1901 founding until the 1911 antitrust-induced dissolution, generally exceeded 80%.

Table A1 shows two additional elements that will be central to our analysis. First, if we compare the capacity figures to the ninth column,"Eastern industry output," we see that ASRC capacity always sufficed to meet industry demand, while fringe capacity did not—before the Spreckels purchase and after the National sale it was generally half of industry output, and otherwise about a third. Second, if we compare the eleventh column, fringe's "estimated output"[5] to the fringe's "average annual capacity"[6] on the far right of the table, we see that in the non-price-war periods, the fringe generally produced close to capacity.[7] These observations, taken together, justify our use of the competitive models under capacity constraints that we present in Section 3.

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[2] *Weekly Statistical Sugar Trade Journal*, November 1 and December 6, 1906; November 29, 1911; March 18 and August 22, 1912. For a study of the sugar refiners' mechanism of collusion in the unconcentrated environment of the late 1920s and early 1930s, see Genesove and Mullin (2001).

[3] Capacities (in millions of pounds per day) and ASRC's Market Share are drawn from Willett and Gray, as supplemented by testimony before the Industrial Commission or the Hardwick Committee. Capacities are reported at the *start* of the year, or the quarter for 1898–1899, for all but the last column. ASRC's Market Share does not include National sales and covers the U.S. as a whole.

[4] This was due to the relative costs of water and land transport. Refineries located near the ocean to receive imported raw sugar directly into their warehouses. Once refined, sugar is subject to deterioration from prolonged exposure to moisture, ruling out ocean transport. Sugar was shipped into the nation's interior by rail and barge. Consequently, there was potential competition between East and West coast refiners near the Missouri and Mississippi rivers; otherwise the markets did not overlap.

[5] Fringe estimated output is the product of industry output and estimated (fringe) market share.

[6] This averages quarterly capacity over the year, and is more appropriate for comparison with annual fringe production than the measure reported in the fifth column.

[7] In some years, estimated fringe output exceeds fringe capacity. Aggregating quarterly capacities into an annual average and using a national rather than Eastern market share can explain the discrepancies. While some differences are large relative to the fringe size, they are not large relative to the market size. We view the capacity figures as more trustworthy than our estimates of fringe production. In any case, mismeasuring capacity on the order of the average "excess" production would little affect our results.

3. The competitive environment

■ **Technology.** Refined sugar was a homogeneous product, shipped to grocers in barrels, who then packaged it for consumers with no identifying mark.[8] Prices therefore tended to be uniform across firms within the East Coast market.

Raw sugar is transformed at a fixed coefficient into the refined product. Due to impurities and losses in the refining process, 100 pounds of raw sugar would yield only 92.5 to 93 pounds of refined sugar.[9] This technological coefficient remained unchanged over our sample period and beyond. (See U.S. Tariff Commission (1920).) The refiners utilized a common technology.[10] Marginal cost was constant up to plant capacity. Capacities were commonly known. The constant marginal cost can be summarized by

$$c = c_o + \frac{1}{.93} P_{RAW} = c_o + 1.075 P_{RAW},$$

where c represents the marginal cost of producing 100 pounds of refined sugar, and c_o represents all variable costs other than that of raw sugar itself, whose price is P_{RAW}. East Coast refiners faced the same P_{RAW} quoted in New York.

Inferring c_o is less straightforward. Nevertheless, a number of sources put c_o at 26¢ (per hundred pounds) in constant 1898 dollars. Since we have already detailed the evidence in Genesove and Mullin (1998), we review the issue only briefly here.

At the 1899 Industrial Commission (coincident with the second price war), Henry Havemeyer, ASRC president, testified that at a margin of less than 50¢, "the refineries are running at a loss."[11] By "margin" he meant the price difference between 100 pounds of refined and 100 pounds of raw sugar, so 50¢ translates into a c_o ranging between 16¢ and 26¢, given the range of raw sugar prices at the time. Another witness breaks c_o down: 5¢ for brokerage and government tax, 10¢ for packages, and 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 Hardwick Committee hearings, various people quoted costs implying a value of c_o ranging between 22¢ and 26¢ in constant 1898 dollars.[12] In addition, audits conducted by the U.S. Tariff Commission (1920) between 1914 and 1919 show c_o to be 25¢ in 1898 dollars.

Some part of these estimates may be fixed costs. However, of the inputs noted, only labor is likely to be fixed. The Tariff Commission is our only source to report labor costs separately, at 7.3¢. Were all labor treated as fixed, the commission's c_o estimate would be 18¢ (16¢ if we also subtract 1.7¢ for repairs and sundries). Were only salaried labor treated so, and assuming its cost to be 23% of total labor payments, as for cane sugar refining in the 1909 *Census of Manufactures* (U.S. Department of Commerce, 1913), c_o would be 24¢.[13]

We take 26¢ as our best estimate of c_o, as it is supported by the most and best evidence. At times, however, we also make use of 16¢ as a lower estimate. This range reflects our ignorance, not differences in refining costs among firms. There was general agreement at the Industrial Commission hearings that refiners shared the same technology. A commission merchant for one of the independents testified that "it is possible that the [larger houses] can refine at a smaller

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[8] Testimony of James Jarvie, a partner in Arbuckle Brothers, on June 15, 1899, before the U.S. Industrial Commission, Vol. I (hereafter IC), 1900, Part 2, pp. 146–147. Arbuckle Brothers was the first firm to sell sugar to grocers in labelled two-pound and five-pound packages. Yet even it sold mostly in barrels.

[9] Testimony of Stephen Buynitsky, (Customs Division of the Treasury Department), June 10, 1899, IC, Part 2, 1900, p. 44.

[10] June 1899 testimony, IC, Part 2, 1900, pp. 100, 112.

[11] Henry Havemeyer, June 14, 1899, testimony, IC, Part 2, 1900, p. 112.

[12] U.S. Congress (1912). Constant dollar prices are computed from the wholesale price index in Hanes (1993).

[13] Labor fixity may arise also from hoarding specialized, nonsalaried labor over the seasonal cycle. Indeed, as will be seen, the predatory periods occurred during the low season of winter and early spring. However, ASRC's production during these periods must have been unusually large—both because price was abnormally low and because the small fringe firms were shut down much of the time (see Section 6). Indeed, industry production during the first half of 1899 exceeded all but two of the previous half-years since 1890.

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."[14]

□ **Entry.** Although the near uniformity of costs suggests a common, known technology, entrants were drawn from a limited pool, being typically either owners who had sold out in the 1887 consolidation, or their brothers or sons, as noted by Eichner (1969). The exceptions are Arbuckle Brothers and Segal. However, Arbuckle Brothers had the patented packaging machine. Moreover, it had developed merchandizing expertise while selling repackaged ASRC-produced sugar, and then acquired production expertise by hiring the superintendent of ASRC's Boston plant. As for Segal, he never really proved he was capable of constructing a workable refinery.[15]

In 1900, the cost of a one-million-pound refinery ranged from $1.5 to $2.5 million, most of which was sunk, as the plant and machinery were almost entirely specific to the industry. As refiner Claus Doscher testified "If anything turns up that makes your plant useless for sugar refining, you have got nothing left that is worth anything for anything else."[16] The costly waterfront land was also developed in a specialized manner. Indeed, our research has uncovered only a single conversion of a sugar cane refinery to some other manufacturing purpose from 1887 through the 1930s.

An additional estimated $2.0 million in working capital was needed for the stock of raw sugar and for credit to brokers.[17] This, of course, was not sunk.

Entry was far from instant. Building a refinery—a several-story structure, with adjacent warehouses and docks—took from a year to eighteen months. Production started at a low level, as machinery was tested and fixed. It took a month or more for production to reach capacity, with substantial uncertainty over when production would start.[18]

□ **Models of competition.** Our second test for predation checks whether observed margins fell below those predicted by static models of competition. Here we review these models, specialized to the technological conditions of the sugar refining industry. The combination of identical constant marginal cost until capacity, a capacity that exceeds demand at marginal cost for one firm and small capacities for the rest (K) implies similar, if not identical, outcomes. We supplement these models with demand estimates based on Genesove and Mullin (1998). That article estimated static pricing models for 1890–1914, and found that industry pricing during non-price-war periods was more competitive than one might expect given the industry's structure. We use competitive and not collusive models because the former predicts lower margins and so provides a stronger test for predation. In Section 6 we consider (but reject) dynamic, competitive models as an alternative to our predation explanation.

A useful benchmark is the dominant firm and competitive fringe model, which assumes price taking by all firms other than one large firm, here ASRC. Because marginal cost is constant until capacity, there is no price responsiveness by the fringe for prices exceeding marginal costs; whatever price above c that ASRC sets, the fringe will always produce to capacity. (Of course, the fringe won't produce anything if price falls below c.)[19] In this model, the equilibrium price (p^d) is that which maximizes profits according to ASRC's residual demand, $D(p) - K$, which is the difference between market demand and fringe capacity. The fringe profits are $(p^d - c)K$.

Other models yield similar results. The Cournot equilibrium is identical to the dominant-firm equilibrium, so long as the fringe's capacity is sufficiently small (i.e., less than the per-firm Cournot output in the absence of capacity constraints). The Bertrand-Edgeworth equilibrium with

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[14] James Post, IC, Part 2, 1900, p. 151. Also see footnote 44.

[15] *Weekly Statistical Sugar Trade Journal*, January 21, 1897, and Fugate (1994). See Section 9 on Segal.

[16] Claus Doscher, IC, Part 2, 1900, p. 97. See also Wright (1924) and IC Part 2, (1900), pp. 97, 152. The only conversion was Segal's Camden plant, which ASRC purchased in 1896. Never operated as a refinery, its machinery was transferred to other ASRC plants and it was used as a storehouse until sold to a cereal foods manufacturer in 1905. *Weekly Statistical Sugar Trade Journal*, March 2, 1905.

[17] James Post, IC, Part 2, 1900, p. 152.

[18] *Weekly Statistical Sugar Trade Journal*, June 2, June 23, July 7, August 18, September 22, 1898.

[19] Section 6 discusses the fringe's actual behavior.

efficient rationing, while in mixed strategies, is also similar. The upper bound of the support of equilibrium prices is equal to p^d, the lower bound, $\underline{p}$,[20] exceeds marginal cost, and ASRC's expected profits equals its Cournot profits. The fringe's profits are now $(\underline{p} - c)K$.

These two prices are easily calculated for linear demand,[21] which we estimate to be

$$P(Q) = 6.33 \quad - .21Q$$
$$\quad (.44) \quad (.04)$$

As in Genesove and Mullin (1998), we use quarterly data over 1890–1914 and instrument output by U.S. imports of Cuban raw sugar, an inframarginal source of the input. The earlier article provides a lengthy justification of this empirical strategy.[22]

Unlike our estimation there, here we do not control for season. The earlier article found that "high season" (third quarter) demand was higher and less price sensitive, by economically and statistically significant amounts. Nonetheless, it also found that observed prices rose only negligibly in high season, compared to what one would expect from the demand estimates and the static pricing rules. Since here we will use estimated demand parameters to calculate nonpredatory prices, we chose to exclude seasonal effects. We omit a yearly time trend, and its inclusion would not materially change our results.[23]

For fringe capacity K, the dominant firm price is[24]

$$p^d(c_o) = \frac{1}{2}\{6.33 + [1.075 P_{RAW} + c_o] - .21K\}.$$

This is also the upper bound under Bertrand pricing. The lower bound is

$$\underline{p}(c_o) = p^M(c_o) - \sqrt{(p^M(c_o) - [1.075 P_{RAW} + c_o])^2 - (p^d(c_o) - [1.075 P_{RAW} + c_o])^2},$$

where $p^M(c_o) = \{6.33 + [1.075 P_{RAW} + c_o]\}/2$.[25] Our analysis uses a single reported price.

These results are robust to small cost differences between firms. Hold the dominant firm's costs at c, and denote the fringe's cost as c_f. So long as $c_f < \underline{p}$, the dominant firm $-$ Cournot price is unchanged, as is the support of Bertrand prices. The dominant firm's profits are unchanged in all static models, while the fringe's profits fall by $(c_f - c)K$.

If the condition on fringe capacity does not hold, so that fringe output is less than its capacity in Cournot equilibrium, then $p^d(c_o)$ will underestimate the Cournot price. This is in general true, since the slope of a (non-capacity constrained) Cournot best-response curve always exceeds -1. In our case, $p^d(c_o)$ underestimates the Cournot price by $.21/2$ times the fringe's excess capacity in Cournot equilibrium. Thus if the observed price lies below $p^d(c_o)$, it must also lie below the Cournot price.

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[20] At $\underline{p}$, $(\underline{p} - c)D(\underline{p}) = (p^d - c)(D(p^d) - K)$.

[21] Results are similar for exponential, quadratic, and log-linear demand.

[22] Here we estimate a linear *inverse* demand curve, and use quantity and price units different from those in our 1998 article. In the present article, price is in dollars per hundred pounds. Production is millions of pounds per day. Standard errors are in parentheses.

[23] Including a yearly time trend has negligible effects on demand estimates:

$$P(Q) = 6.27 \quad - .20Q \quad - .0045(Year - 1890)$$
$$\quad (.61) \quad (.08) \quad (.02)$$

The lower Bertrand margin constructed on the basis of demand with a yearly time trend differs from that used here by at most 1.7 cents per hundred pounds; the dominant firm prices differ by between 3 and 5 cents, but do not change our conclusions.

[24] We assume efficient rationing. The Bertrand price would be higher under proportional rationing.

[25] Let $\Delta \equiv p^M - \underline{p}$. Simple algebra shows that $\pi(\underline{p}) = (1/.21)(p^M - c - \Delta)(p^M - c + \Delta)$, and $\pi^d = (1/.21)(p^d - c)(p^d - c)$. Then, since $\pi(\underline{p}) \equiv \pi^d$, $(p^M - c)^2 - \Delta^2 = (p^d - c)^2$.

We will be interested in what we term the "proper margin," $P - 1.075 \times P_{RAW}$, and its theoretical counterparts,

$$PM^d(c_o) \equiv p^d(c_o) - 1.075 P_{RAW} = \frac{1}{2}\{6.33 - .21K\} + \frac{1}{2}c_o - \frac{1.075}{2}P_{RAW} \qquad (1)$$

and $\underline{PM}(c_o) \equiv \underline{p}(c_o) - 1.075 P_{RAW}$.

## 4. Arbuckle Brothers and Doscher

■   We examine this episode first because we know the most about it. It coincided with congressional hearings, and it received extensive coverage in Willett and Gray's *Weekly Statistical Sugar Trade Journal*. Its origins lie in Arbuckle Brothers' use of its patented packaging machine in the mid-1890s to package and resell ASRC sugar. Accounts differ on the order of the three crucial events that followed, but not on their occurrence. One, ASRC offered to buy the packaging machine, but Arbuckle Brothers refused. Two, Arbuckle Brothers (which was paying the same rate as other customers) asked for a discount on the refined sugar, but ASRC refused. Three, Arbuckle Brothers announced its intention to manufacture sugar.

☐   **Pricing below marginal cost.** Figure 1 graphs the proper margin, i.e., the net of raw sugar costs margin ($P - 1.075 \times P_{RAW}$), from 1898 through 1900. Horizontal lines at 26¢ and 16¢ designate our best and lower estimates for c_o, the non-raw sugar cost of refining. In the aftermath of entry in August (Arbuckle Brothers) and November (Doscher) 1898, denoted by vertical lines, the proper margin fell into and even below this range, indicating pricing below marginal cost.[26]

This did not escape comment by contemporary industry experts. In the early weeks of the war, the *Weekly Statistical Sugar Trade Journal* stated, "The present difference between raw and refined sugar is reduced this week to 47 cents. . . . Anyone familiar with the amount of raw sugar . . . required to produce 100 lbs. [refined] . . . does not require to be told that there is an actual loss to refiners at 47 cents difference."[27] This difference was subsequently reduced further.

FIGURE 1

ARBUCKLE BROTHERS–DOSCHER WAR

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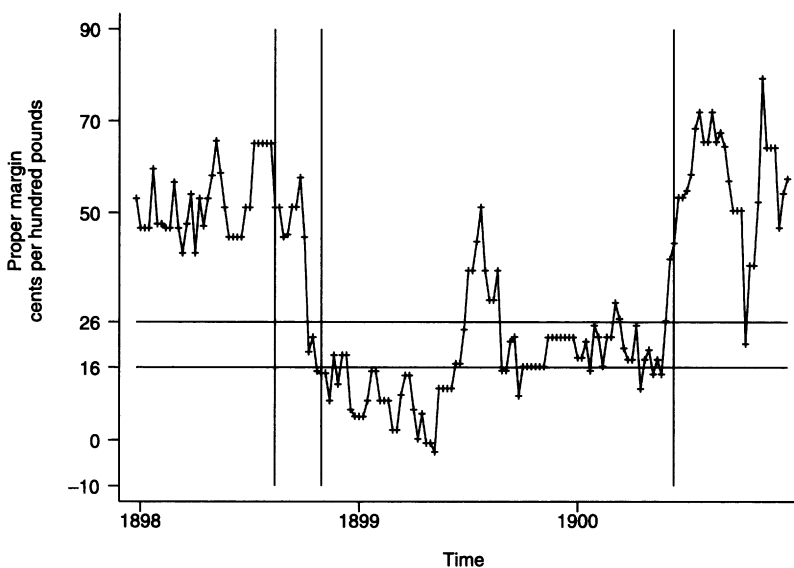
[26] The third vertical line marks the June 1900 end of the price war.

[27] *Weekly Statistical Sugar Trade Journal*, October 20, 1898, p. 5.

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How, then, did Zerbe (1969) argue that ASRC did not suffer out-of-pocket losses? His cost figures are similar to ours, but he examined the margin at an annual frequency only, for 1898–1900. In 1899 it reached a new low of 50¢, consistent with zero (variable) profits. But as we have shown, for several months during that year ASRC priced below marginal cost. Our higher frequency data are the more appropriate, since prices were set weekly.

□ **A lower bound on competitive prices.** Zerbe (1969) rejects the predatory interpretation, attributing the sharp price drop upon entry to the breakdown of a cartel and a return to competition, which he associates, in turn, with marginal cost pricing. That logic, however, casts ASRC as a price taker, an absurd role for a firm with nearly 80% of industry capacity. A more reasonable definition of competitive conduct is the noncooperative static equilibrium. We showed in Section 3 that, with rivals capacity constrained, the noncooperative equilibrium price exceeds marginal cost. As a test for predation, then, a price below marginal cost is sufficient but not necessary.

Here we offer a second test, one that substitutes knowledge about demand and capacity for cost. Employing the demand estimates from Section 3, we calculate the dominant firm price, p^d, both before and after entry. We find that observed prices fell too low to be the product of dominant firm or Bertrand pricing in the face of enlarged fringe capacity. To remove uncertainty over costs as a source of skepticism of our results, we calculate p^d for three values of c_o: zero, 16¢, and 26¢. Assuming $c_o = 0$ corresponds to ignoring the testimony and auditing information of Section 3. By undervaluing marginal cost, the calculated p^d at 0¢ will underestimate the true dominant firm price and thus bias our results against the conclusion that prices were too low to be rationalized by competition. Assuming $c_o = 16$¢ adopts our lower bound estimate from Section 3; assuming $c_o = 26$¢ adopts our upper bound. In all cases, we focus on the predicted p^d for the period after *both* Arbuckle Brothers and Doscher had entered.

Figure 2 plots the observed proper margin (denoted by a plus), PM^d (which, recall, is the dominant firm and Cournot price, and upper bound for Bertrand), and $\underline{PM}$ (the lower Bertrand bound), by assumed value of c_o. Confidence intervals for the predicted margins, derived from the demand estimates and the delta rule, are also reported. The interval associated with the Bertrand lower bound is shaded in grey; the much wider interval for the dominant firm proper margin is unshaded.

It is clear from the top portion of Figure 2 that even assuming $c_o = 0$, the observed proper margin during the price-war period lay well below the predicted competitive proper margins. The summer 1899 respite is again the exception, and we discuss it below. The margin falls below the confidence interval nearly one in every five weeks overall, and one in four in the nonrespite periods.

The middle and bottom portions of Figure 2 confirm the pattern: observed margins fall below competitive margins during the price war. However, at the bottom, where we assume $c_o = 26$¢, the observed proper margin falls below the predicted competitive proper margin for several weeks in 1898, ahead of the price war. The middle case ($c_o = 16$¢) looks better: observed margins are usually within the competitive range in the non-price-war periods, and below this range in the price-war periods. Nonetheless, having more confidence in the documentary evidence than the imprecisely measured demand estimates, we consider $c_o = 26$¢ the better estimate.[28]

□ **Price war respite.** The proper margin rose about 30¢ and then fell the same amount between May 25 and September 7, 1899. This was much larger than the usual seasonal rise. Summer was the period of peak sugar demand, due to complementarity between sugar and fruit in fruit canning, as noted in Genesove and Mullin (1998). In normal, nonpredatory times, the average proper margin was 5.9¢ higher and production 19% higher in high season (third quarter), although only the latter was statistically significant.

Why did ASRC temporarily halt the price war? The answer lies in the old claim that predation

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[28] In October 1900, the proper margin also falls below predicted competitive margins in the lower two portions of Figure 2. This seems to have been a mini-price war, aimed at inducing Arbuckle Brothers to reduce its production as market demand declined seasonally. See *Weekly Statistical Sugar Trade Journal*, October 4, 1900, and Eichner (1969).

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FIGURE 2

ACTUAL AND COMPETITIVE PROPER MARGINS
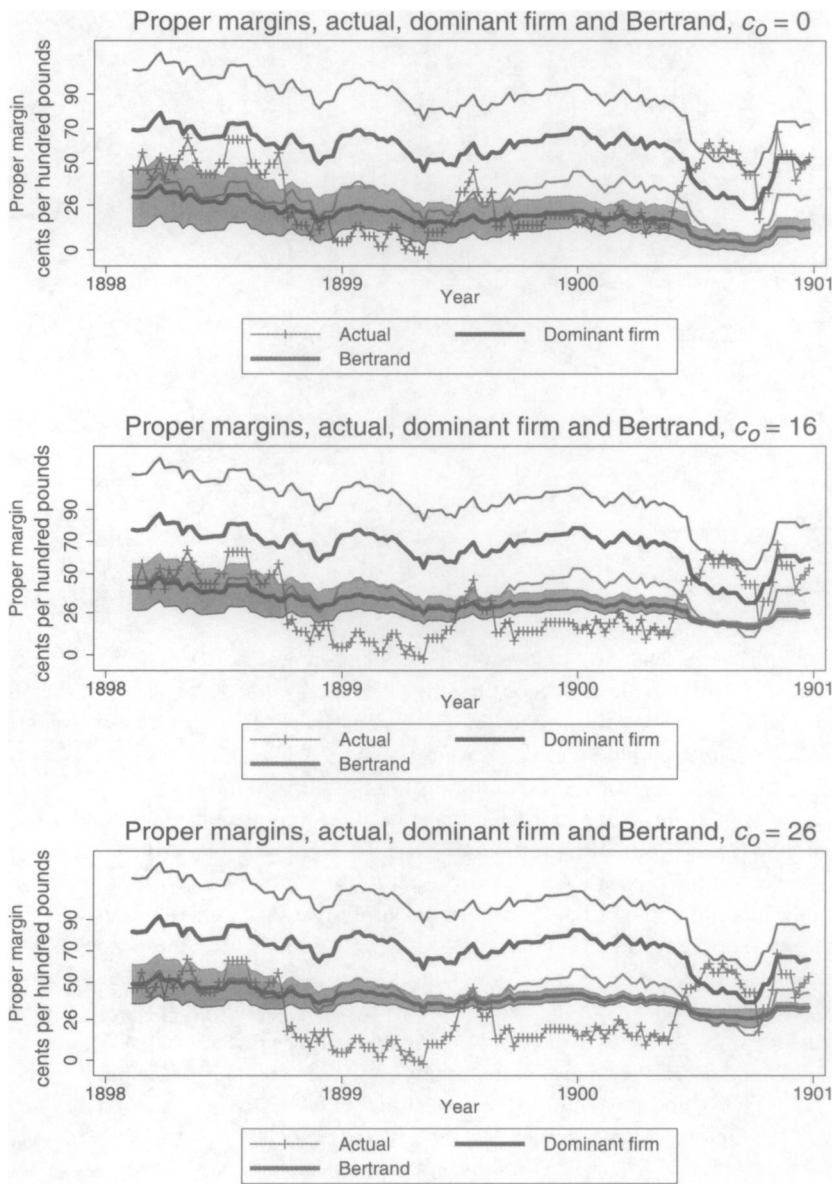
is irrational since the predator, being larger, must suffer more than the prey. Since ASRC was not capacity constrained, even in high season, its effective size changed seasonally, and therefore so did its cost of preying.[29] Because of both the higher margin and the higher output, ASRC sacrificed more flow profits in high season than in low season by preying.

Of course, the fringe's profits were normally higher in the high season as well. If a price war is meant to deny entrant profit flows, its greatest gross return is when the entrant's competitive profits are greatest. But ASRC would gain more from a high season respite than would entrants: with

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[29] Havemeyer testified in the midst of the Arbuckle Brothers–Doscher war that ASRC's capacity was 20% greater than the current market "demand" (IC, Part 2, 1900, p. 107).

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FIGURE 3

COST OF PREDATION, ARBUCKLE BROTHERS–DOSCHER WAR
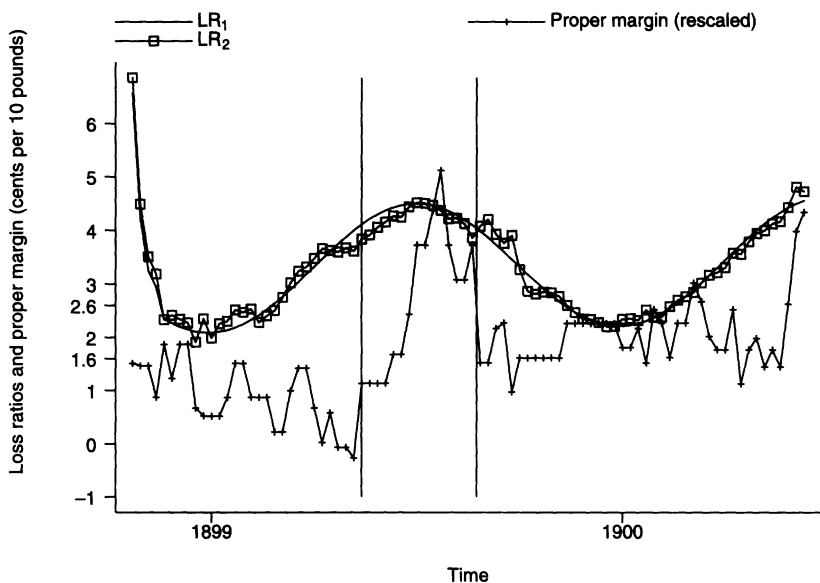
ASRC producing more than Arbuckle Brothers and Doscher, a higher margin, with no change in production levels, would benefit it more than the latter in absolute terms, though the proportional effect would be the same. With production higher, and its rivals' capacity constrained, ASRC's benefit from the respite would be greater proportionately as well.

We operationalize the price of predation by computing a loss ratio: the ratio of ASRC's loss from the price war to the rivals' loss. The cost of the price war at any point in time was the excess of *nonpredatory* profits over *predatory* profits. Nonpredatory profits we take to be fully accommodative — in the sense of ASRC restricting its output one for one with the capacity of the entrant, thus maintaining the price.[30] As an initial simplification, we assume that predation called for marginal cost pricing, so that predatory profits for all firms were zero. Since all firms face the same price-cost margin, the loss ratio then simplifies to ASRC's (counterfactual) nonpredatory output, divided by the capacity of the entrant (K_e). We predict nonpredatory total output $(\widehat{Q})$ from a regression ($R^2 = .50$) of weekly meltings on seasonal variables (the sine and cosine defined over the week with an annual frequency) and a time trend, over 1890–1914 (excluding the predation periods). With K as fringe capacity, we then construct ASRC output as $\widehat{Q} - K$. Our initial measure of the ratio of incumbent to rival losses is therefore $LR_1 = (\widehat{Q} - K)/K_e$. K_e, and so K, increase abruptly with the entry of Arbuckle Brothers and then Doscher, and rise gradually over a month or two after entry as equipment was tested and adjusted. Admittedly, the loss-ratio measure captures only relative costs and misses any variations in the gains from predation associated with the entrant's cash flow needs.

Figure 3 displays LR_1 and the proper margin, rescaled for comparability, over the Arbuckle Brothers–Doscher war. At the beginning, with the proper margin near or below 1.6¢ per ten pounds, our lower measure of marginal cost, LR_1, is very high and then falls sharply. The high value of LR_1 is due to the low initial capacity of the Arbuckle Brothers plant. So predation at this early stage was very costly. The benefit must have been high as well, perhaps because predation at that point could persuade the entrant to abandon its efforts, or convince wholesalers not to

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[30] A dominant firm strategy under linear demand would have ASRC restricting its output by only half a pound for every pound of the entrant's capacity, thus lowering price. Results for this alternative are qualitatively the same.

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switch refiners.[31] The loss ratio also helps explain why predation did not start immediately with Arbuckle Brothers' initial production; the price of predation at that stage was too high.

LR_1 reaches its maximum during the respite. Interestingly, the price war pauses and then resumes when LR_1 is near 4. Thus, at that stage of the war, ASRC was willing to pay $4 to reduce the entrants' profits by $1, but was not willing to pay more than that. The demand for predation is downward sloping!

These initial calculations falsely assume that predatory prices were set at marginal cost. To correct for that, we subtract from the usual profits the actual profits of ASRC and the entrants, under the assumption that all fringe firms produced at capacity. We therefore calculate a second loss ratio, which we also display in Figure 3:

$$LR_2 = \frac{\$.43(\widehat{Q} - K) - (p - c)(Q - K)}{\$.43K_e - (p - c)K_e},$$

where Q and $p - c$ are the observed industry output and price-cost margin. We multiply the counterfactual output levels by 43¢, the average real price-cost margin ($c_o = 26$¢) from 1893 to 1897, the years between our major entry episodes. The pattern is nearly identical to that of LR_1.

This logic explains not only the seasonal pattern, but ASRC's response to other entrants as well. ASRC tolerated small entrants and a limited share of industry capacity in independent hands. These small entrants were practicing judo economics, to use Gelman and Salop's (1983) phrase. But entry by a large firm (and the concomitant sizable addition to independent capacity) triggered a predatory response.

5. Spreckels

■   President Havemeyer of ASRC offered precisely this explanation in his Industrial Commission testimony: "Harrison [an incumbent Philadelphia refiner] was there [in 1889]; we did not fight him; we could make our dividend without fighting him, but when [in 1890] Spreckels came in with his enormous capacity we either had to fight or make no dividend; we concluded to fight and that is what we are doing now."[32]

In entering, Spreckels sought not only profits but also retaliation for the Sugar Trust's incursion into his California territory.[33] In early 1888, the Trust, composed of East Coast and Louisiana plants, acquired a plant on the West Coast (a largely separate market, as noted), in apparent violation of an understanding with Spreckels. Shortly thereafter, Spreckels announced his intention to enter the Eastern market and in May began construction of a plant in Philadelphia. The initial capacity was a million pounds per day, but even before initial production, he made plans to double its capacity by duplicating the plant.[34]

The aftermath is apparent from Figure 4, which shows the nominal proper margin for 1889–1892. We graph the nominal values to avoid discontinuous changes that an annual, general price index would introduce. The horizontal lines are the 1890 dollars equivalent of our estimates of c_o: a best estimate of 31¢ (26¢ in 1898 dollars), with 19¢ (16¢) as a lower bound. The two vertical lines designate Spreckels' first, minimal production on December 9, 1889, and the acquisition of the Philadelphia refiners on March 4, 1892.

□   **Pricing below marginal cost.** As Figure 4 indicates, the proper margin was below our estimate of c_o weeks at a time. The proper margin fell sharply at the end of 1889, and hovered at or below c_o for most of 1890, rising well above it only for a respite in high season. Price war

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[31] See Section 6.

[32] Henry Havemeyer testimony, IC, Part 2, 1900, p. 108.

[33] We must rely on Eichner's (1969) account here. The oldest copies of the *Weekly Statistical Sugar Trade Journal* that we could obtain are from 1891, the middle of the Spreckels war. Eichner was able to examine earlier issues in the offices of Willett and Gray, the publishers, which has since gone out of business.

[34] *The New York Times*, August 4, 1889, p. 4.

FIGURE 4

SPRECKELS SR. WAR
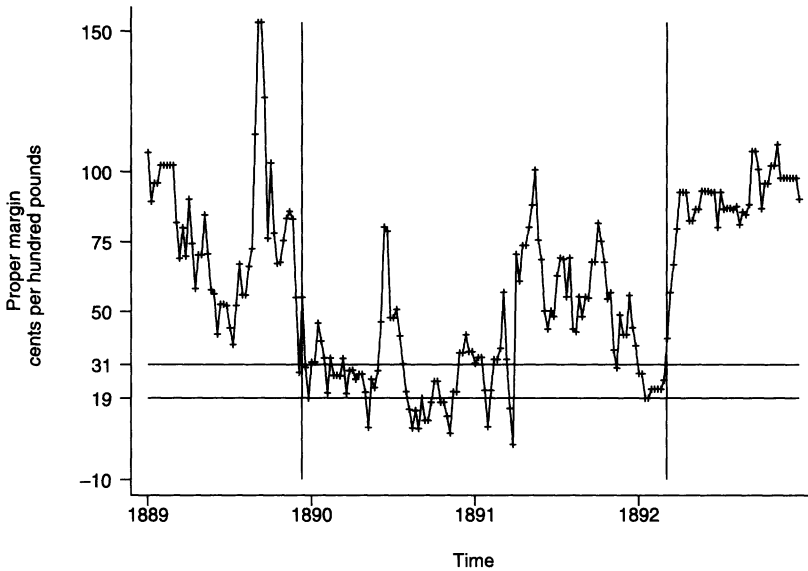
conditions carried into 1891, excepting the high season respite. The Spreckels Philadelphia plant and the remaining independent Philadelphia refiners were acquired by ASRC in February and March, 1892. Within a month, the proper margin increased from 25¢ to 92¢.

The *Weekly Statistical Sugar Trade Journal* noted that price was below marginal cost. In January 1892 it reported "a considerable loss of refining, owing to renewed competition between" ASRC and the Philadelphia refiners. It even quantified the loss as 10¢ per hundred pounds, which given prevailing prices implies a nominal value for c_o of 28¢, close to our 1890 value of 31¢, and well within our range of estimates.[35]

◻ **Price war respites.** In 1890, the proper margin rose from 23¢ on May 21 to 80¢ on June 11. The respite was brief, however, with the proper margin falling to 21¢ at the end of July. The reason for this respite is the same as before: predation was costlier for ASRC in high season.

The proper margin rose in the spring and summer of 1891 as well. The usual high season respite argument applies here also, but there are two confounding forces. One was the abolition of duties on raw sugar by the McKinley Tariff on April 1, 1891, which reduced the raw sugar price from $5.68 to $3.53 per hundred pounds. As equation (1) indicates, decreases in the raw sugar price led to increases in the competitive proper margin, under linear demand, thus increasing the cost of predation. The runup in the proper margin is also coincident with an initial rapprochement between ASRC and Spreckels. This is evidenced by recorded monthly payments by the ASRC West Coast plant to a shipping concern operated by Spreckels' sons, which began at $70,000 in January 1891 and increased to $200,000.[36]

◻ **ASRC-Spreckels peace process.** Early in 1891, ASRC offered to sell Spreckels its West Coast plant in return for "a half interest in Spreckels' Philadelphia concern." Spreckels rejected this offer, but subsequent negotiations produced Western Sugar Refining, a holding company equally owned by Spreckels and ASRC, which leased the two companies' West Coast plants.

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[35] *Weekly Statistical Sugar Trade Journal*, January 14, 1892, p. 3. Our price index yields 29¢.

[36] Spreckels Financial Records, BANC MSS C-G 190, The Bancroft Library, University of California, Berkeley.

In return, Spreckels sold a 45% equity stake in his Philadelphia plant to Havemeyer for $2.25 million.[37]

Although the creation of the Western was publicly known by spring or summer 1891, the other arrangements remained secret. Rumors of a deal were afoot, largely because of the summer 1891 respite, but Spreckels denied them.[38] We discuss the final disposition of the peace process in Section 7.

6. Dynamic nonpredatory alternatives

■ We find the foregoing to be evidence of predation. But the analysis has omitted shut-down and switching costs, factors in models of price wars without predation. Even after accounting for these costs, ASRC's actions were predatory.

□ **Shut-down and start-up costs.** If ASRC was pricing below marginal cost, why did the prey continue to produce? Several times in the Arbuckle Brothers–Doscher war, the incumbent independents did shut down or run at "minimum capacity."[39] Nevertheless, there were periods with price below marginal cost in which they continued to produce, for a couple of reasons. Month-long contractual obligations and the value of a reputation for assured supply may lead firms to produce at a current loss. Also, as explained in Dixit and Pindyck (1994), shut-down costs will drive a wedge between the margins at which it is optimal for a price-taking firm to shut down and start up production. The reports of fringe firms running at "minimum capacity" indicate that such costs existed. Changing expectations of the future paths of prices will have made the shut-down and start-up margins variable, and so prevent us from identifying a single value of the proper margin at which shut-down occurred or production resumed. Nevertheless, it is telling that the minimum proper margin above which the incumbent independent refiners always produced was 26¢.

Arbuckle Brothers never shut down. Even the technologically identical Doscher refinery significantly curtailed its production in the late stages of the war. Arbuckle Brothers' advantage lay ultimately in its packaging machine. Its packaged sugar earned a premium of 6¢ at the retail level, thus giving the firm substantial, but incomplete, protection from ASRC's below-cost pricing—incomplete, because, as Figure 1 shows, cost exceeded price by more than 6¢ at times, and because most of its sugar in this period was still sold unpackaged, in barrels. But the factors that led other fringe firms to produce during the price war would have been especially relevant to Arbuckle Brothers, an entrant whose packaging machine promised it a bright future.[40]

Our explanation for why the fringe did not fully shut down introduces additional benefits and costs not covered by price and our estimate of c_o: shut-down and start-up costs, reputation, and the value of packaging. However, so long as these considerations enter the fringe's costs only, they invalidate neither the cost-based test of predation, for which only ASRC's costs are relevant, nor the second test; as Section 3 noted, a lower fringe cost will leave the dominant firm and lower Bertrand prices unchanged, while a higher fringe cost will render our calculation a lower bound for the true counterfactual proper margin.

We argue that this is indeed the case. The premium for packaged sugar can be seen as a negative cost for Arbuckle Brothers only. Shut-down and start-up costs, or the value of a reputation

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[37] Eichner (1969, p. 165). In rejecting the initial, but accepting the final, offer, Spreckels sacrificed half of the West Coast monopoly for 5% more, and so control, of his Philadelphia plant. Retaining an East Coast presence ensured multimarket contact in case ASRC should decide to reenter the West Coast.

[38] *The New York Times*, August 27, 1891, p. 1. The first mention of the Western in the ledger books of ASRC's West Coast plant appears on April 15. The *Weekly Statistical Sugar Trade Journal*, August 27, 1891, p. 3, reports that although there is no factual basis for the rumors that Spreckels has been acquired by ASRC, they reached some sort of arrangement, as evidenced by the advance in refined prices.

[39] *Weekly Statistical Sugar Trade Journal*, November 17, 1898, p. 2; February 2, 1899; October 5, 1899; January 25, 1900; and February 23, 1900.

[40] *Weekly Statistical Sugar Trade Journal*, May 17, 1900; August 25, 1898; December 1, 1898; and February 16, 1899.

for assured supply, would have been relevant only for the fringe: such costs might lead a firm to *tolerate* a price below manufacturing costs for a time (i.e., continue to produce when a rival sets such a price), but not to *choose* it (i.e., set such a price as a best response to a rival's above-cost price). ASRC could have lowered its output during the price war, raised its current profits, and yet still have maintained its option of remaining in the industry.[41]

□ **Switching costs.** In Klemperer (1989, 1995) and Elzinga and Mills (1999), price wars occur upon entry as the new firm temporarily absorbs buyers' switching costs. Although most sugar was sold unbranded at the retail level, making switching costs for households unlikely, shifting to a new firm may plausibly have been costly to wholesalers and retailers, as in Elzinga and Mills (1999)—e.g., due to uncertainty over assured supply from the new firm.

The basic argument, first made by Klemperer (1989), is that entrants must initially price below the incumbent's prevailing price to induce buyers to switch, causing the incumbent to lower its price part-way in response, lest entrants steal too many of its customers. The price cuts in the formal models are large, even when switching costs are small: because there is a continuum of entrants, each earns zero profits; because buyers are subsequently locked in, postentry margins are positive; thus entrants' margins are negative in the entry period.

We would not expect such large effects in the sugar industry, however. Entering firms need not earn zero profits, since the set of potential entrants was small. Moreover, the entrant would not price so low, and the incumbent would not respond as much, since the entrant's capacity limits the number of customers it can steal. The extent of the price cuts would only be on the order of the switching cost, then. Without knowing the actual switching costs distribution, however, we cannot say much about the extent of their likely effect on prices—and so how well a switching cost model might fit the average margins in the two entry episodes we have discussed.

Nonetheless, a number of observations favor the predation model over the switching-cost model. Industry consensus held that the price wars were of ASRC's making, not the entrants'. As the *Weekly Statistical Sugar Trade Journal* reported, "That the war is one sided is shown by the fact that all the independents simply follow the moves of [ASRC] either up or down and attempt no leading aggressive move."[42] Furthermore, were switching costs important, then all firms would have had to set their price below the rest of the industry at their time of entry (although ASRC might not always have found it profitable to respond). We see no evidence of this in any of the other seven entry episodes noted in Section 2. Likewise, Spreckels and Arbuckle Brothers and Doscher would still have had to price low in the high season to gain or maintain their customers; again, ASRC might have found it unprofitable to respond, but then we would have expected reports on the price difference. Indeed, although the switching-cost model requires a price differential between the incumbent and entrants, we never observe that. Nor does the aftermath of the price wars fit well with the model. The model provides no obvious explanation for the post-price-war acquisitions of incumbent, fringe firms, which we discuss in the next section. Also, Table A1 in the Appendix shows the fringe producing to capacity in the years immediately after the two price wars, indicating that ASRC's price cut did not stop buyers from switching to the surviving entrants.

7. Was predation profitable?

■ There are three possible sources of predatory gains: lower buyout prices, future entry deterrence, and greater market share in a postentry collusive equilibrium. Note that driving the newly added capacity itself out of the industry was impossible, as the salvage value of a sugar refinery plant was very small.[43]

ASRC did succeed in altering control of industry capacity, however. Each predatory episode

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[41] ASRC would have faced the costs of adjusting its output, but the large fluctuations in industry output to accommodate the high season suggests that adjustment costs were small.

[42] *Weekly Statistical Sugar Trade Journal*, November 17, 1898, p. 2.

[43] See Section 3. Likewise, turn-of-the-century British shipping cartels were able to drive out new entrants (Scott

ended with its purchase of not only an entrant, but also a number of the small, incumbent independents, and at much lower prices than a nonpredation valuation of the fringe firms. This parallels Burns' (1986) finding that American Tobacco lowered the buyout prices of both victims and other incumbents through predation. But we pose a tougher test than Burns, by systematically considering not only the benefits of predation, but the costs as well. To do so we calculate an internal rate of return (*IRR*) for predation. Later we argue that the reduction in acquisition costs was most likely due to ASRC's strengthened reputation as a willing predator, possibly reinforced by ASRC's exploitation of rivals' liquidity constraints.

First we document that predation did, indeed, lower acquisition costs. We focus on the Arbuckle Brothers–Doscher war. We need an estimate of ASRC's gross price war losses, the difference between its nonpredatory and actual profits. We calculate the former, as in LR_2, as the profits ASRC could have obtained by maintaining the average interwar real margin of 43¢. This yields gross losses of $21.13 million.

□ **Acquisition costs.** *Arbuckle Brothers–Doscher war*. The Arbuckle Brothers–Doscher war was brought to an end with Havemeyer's acquisition of the Doscher, Mollenhauer, and National refineries and their consolidation into the new National. Havemeyer received control of the new firm. The three exiting refiners received preferred stock, with dividend payments of $423,984 per year guaranteed by ASRC.[44] Predation was successful if, absent it, the buyout price would have been higher. That buyout price would have to be at least as great as the net present value of $(p - c)K_I$, where K_I is the target fringe's capacity and equilibrium output.[45] The three firms had a combined capacity of 2.87 million pounds per day. The nonpredatory buyout price would then depend on the targets' expectations of future prices, given no predation. At best, they might have expected the mid-1890s margin of 43¢ to continue, and so anticipated profits of $(365 \times 2.87 \times 10^6 \text{ lbs.}) \times \$.0043/\text{lbs.} = \$4.5$ million per year. At worst, they might have anticipated Bertrand competition. The lower Bertrand proper margin averaged 39¢ over 1900–1914, corresponding to a price-cost margin of 13¢, and so anticipated target profits of $1.36 million per annum. Even the latter is over three times the observed buyout payments.

Thus predation reduced acquisition costs. But was it profitable? Under the optimistic expectations, predation produced an annual gain to ASRC of $4,500,000 − $423,894 = $4.1 million. The resulting *IRR* was $4.1/$21.13, or a healthy 19.3%.[46] With the pessimistic expectations, the *IRR* to ASRC was 4.4%. Taken alone, this is insufficient to justify ASRC's investment. But reducing acquisition costs was only one, albeit important, effect of predation. Later we consider complementary effects of predation, and one should *add* the internal rates of return from these sources in computing an overall return.

Explanations for reduced acquisition costs. There are two possible mechanisms. First, predation could have changed rivals' beliefs about future profits, thereby reducing the perceived "fundamental" value of a fringe refinery. Second, it could have exploited fringe liquidity constraints to induce a "fire sale" of the refinery below its fundamental value.

One avenue for changing rivals' beliefs we can dismiss is cost *signalling*. In Saloner's (1987) formalization, since the rival's profits are decreasing in the incumbent's costs, proof

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Morton, 1997), while the J.E.C. railroad cartel had to allocate them market share (Porter, 1983), since entry costs on the specific route were wholly sunk in the latter case, but not at all in the former. In the latter, prevailing bankruptcy law allowed the court to effectively dismiss a bankrupt railroad's debt, permitting the incumbent management to continue, so that predation could not alter the control of capacity either. Finally, in early telephony, some but not all costs were sunk, and Southern Bell's acquisitions were preceded by wars of attrition (Weiman and Levin, 1994).

[44] As holders of *preferred* stock, the exiting refiners would receive only these payments and no share of residual profits. All values are in 1898 dollars. The transaction details are given in Eichner (1969).

[45] Table A1 implies that fringe-capacity utilization averaged 80% in 1903–1908. Using that figure reduces the *IRR* estimates by approximately 20% (since the counterfactuals are either linear in K_I or nearly so), and so makes little qualitative difference.

[46] Our *IRR* calculations assume all losses are incurred in the first, predatory, period, followed by a perpetual stream of identical benefits per period.

that an incumbent has low costs will lower the minimum buyout price that the rival would accept. Assuming the fringe produces at capacity, that price would be the net present value of $(p - c_f)K_I$, where c_f is the fringe's cost. Thus, the gross per-period return to ASRC of predation was $K_I \Delta c(dp/dc)$, where Δc is the difference between high and low cost, and dp/dc is the responsiveness of price to increases in the incumbent's cost in nonpredatory periods.

Signalling cost by a sudden price cut might seem unconvincing for an incumbent that has been setting prices weekly for several years before entry, although one might argue that price is more revealing about cost the more competitive the circumstances. Whatever the case, the plausible range of a rival's beliefs about ASRC's costs is too small to justify a signalling explanation. Although we do not know what the precise beliefs were, we do know that the actual cost differences across firms were small. Section 3 quoted Industrial Commission testimony that assessed the possible cost advantage as 3 to 5¢ per hundred.[47] Using the higher real 5¢ figure for Δc, a value of .93 for dp/dc (from Genesove and Mullin's (1998) estimate of the response of the refined price to the raw price, adjusted for the loss in sugar refining), and Doscher, Mollenhauer, and the National's combined capacity of 2.87 million pounds, we obtain a yearly gross return of $(365 \times 2.87$ million pounds$) \times .05$¢/pound $\times .93 = \$486,000$. This is too small to account for buyout savings ranging from \$936,000 to \$4.07 million, annually. Alternatively, the signalling rationale implies a predation *IRR* of \$.486/\$21.13, or a meager 2.3%.

Buyout prices were simply too low to be consistent with competitive conditions. Payments of \$423,000 per year are consistent with a future average real price-cost margin of 4¢, far below the 13¢ that the lower Bertrand price-cost margin (recall, the lower bound for competitive margins) averaged during the Arbuckle Brothers–Doscher war. One explanation is that the fringe firms anticipated continued predation if they did not sell out. During much of the predatory period, these refiners experienced out-of-pocket losses, with the actual price-cost margin averaging *minus* 7¢. ASRC had proved itself willing to price below competitive levels and/or cost for 18 of the preceding 22 months, and there was no reason not to suspect that it would continue to do so. In other words, it had established a *reputation* for itself as a willing predator. We will return to this.

Alternatively, binding *liquidity constraints* might have forced the fringe firms to sell out for less than the expected present discounted value of profits, as in Bolton and Scharfstein's (1990) model of Telser's (1966) "long purse" hypothesis. The model does not include buyouts, but its logic would predict them in the presence of industry-specific sunk assets. Arbuckle Brothers (and Spreckels) possessed internal funds, and so were not as vulnerable to this effect. But the acquired fringe refineries did not have such an advantage.

The long purse rationale is more convincing here than in many other industries. The usual critique—that it fails to explain why entry does not reoccur, once the incumbent has raised prices after inducing exit—is less convincing where entry is difficult and the pool of people capable of entering is small. If ASRC succeeded in absorbing some fringe capacity, it would be years before new entry occurred. Nor can one object that a financially constrained firm could have sold to outside bidders at fundamental prices. Those most capable of running a sugar refinery were already in the industry, and would have been themselves financially constrained. In terms of Shleifer and Vishny (1992), a sugar refinery was an industry-specific asset, and ASRC's predation was an industry-specific shock to liquidity.

Although the long purse story is a possible mechanism for reducing acquisition costs, we do not emphasize it, as we lack evidence of it, such as creditor pressure on the fringe firms, or nonpayment of accounts. In contrast, we do have such evidence for reputation, as seen in the manipulation of rivals' beliefs about competitive conditions, which we turn to now.

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[47] James Post, IC, Part 2, 1900, p. 151. Testimony before the Hardwick Committee in 1911 (U.S. Congress, 1912) implies a cost range of 5¢ (3.75¢ in 1898 dollars). The cost range in the U.S. Tariff Commission (1920) survey is much larger. The gap in the average nonsugar costs of the most and least costly plant in 1917 was 35¢ (17¢ in 1898 dollars). There are a few reasons for this: the survey included all U.S., not only East Coast, plants; inflation was high, so plant differences in production timing would have led to different measured costs; and wartime regulation may have generated cost differences.

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Spreckels war: "bogus independent." That the predatory actions had not only the *effect* but also the *purpose* of affecting buyout terms is illustrated by the fate of the incumbent Philadelphia refiners in the Spreckels war. By mid-1891, ASRC's Havemeyer had secretly obtained a 45% stake in Spreckels' Philadelphia plant; peace was at hand. In fall 1891, ASRC began discussions with Spreckels on buying out his remaining share. ASRC kept both these negotiations and Havemeyer's minority stake secret, for it also wished to purchase the three remaining independent Philadelphia refiners. Knowledge of Spreckels' acquisition would have increased the buyout price of these plants.

The final acquisition of Spreckels and the other Philadelphia refiners was worked out from late 1891 to early 1892, but became public only in March 1892. As Figure 4 shows, the proper margin fell in October 1891 and reached at or below marginal cost in early 1892. If ASRC's 45% stake would of itself have assured continued peace with Spreckels, then ASRC's forgone profits during the resumption of the price war represent a predatory investment that lowered the acquisition price of the remaining Philadelphia refiners. These refiners were led to believe that active competition with Spreckels, and hence low profits, were likely to continue for some time. That was certainly the *Weekly Statistical Sugar Trade Journal's* conclusion.[48]

ASRC's actions are reminiscent of American Tobacco's "bogus independents" discussed by Burns (1986). American Tobacco channeled much of its price cuts through these secretly controlled subsidiaries so that target firms would erroneously infer that competition was, and would remain, vigorous and thus sell out at a lower price. After the secret detente, Spreckels served as a "bogus independent."

The profitability of this strategy was substantial. We conservatively ignore its inducing Spreckels to exit from the East, and instead focus on the reduced buyout prices of the independents. The three Philadelphia refiners sold out for ASRC stock worth $10.81 million.[49] Had they known of the Spreckels' deal, they could have reasonably expected a return to the 43.4¢ average price-cost margin under the Trust before Speckels' entry, and so profits of $4.45 million per year, given their capacity of 2.83 million pounds per day. ASRC's losses over the whole price war were $12.16 million.[50] The resulting *IRR*, 19.5%, indicates the attractiveness of predation in reducing the acquisition cost of competitors.

This also suggests the importance of reputation, or manipulating rivals' beliefs. Obviously, secrecy about the impending acquisition of Spreckels was important in reducing the buyout prices, although that effect need not operate through reputation. (For example, under the long purse scenario, financing of the independents could become easier were it common knowledge that more-profitable conditions were imminent.) But in extending the war, ASRC pretended to be tougher than it was, preying longer than necessary to induce Spreckels' exit. That helped build a reputation as a willing predator, and that reputation was preserved by keeping the ploy secret. Strikingly, Eichner (1969) notes that many of the independent Philadelphia refiners learned of Havemeyer's 1891 acquisition of a minority stake in Spreckels' Philadelphia plant only in the 1912 testimony in ASRC's monopolization suit!

☐ **Entry deterrence.** Predation may also have deterred future entry. Certainly, the rate at which additional fringe capacity entered slowed down after the Arbuckle Brothers–Doscher price

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[48] Its January 21, 1892, report noted a belief that a minority interest in Spreckels had passed into hands friendly to ASRC in early 1891. It concluded, however, that any such interest had been insufficient to soften competition, so that the profit outlook for 1892 was grim.

[49] We use average monthly stock values from April 1892 (IC, Part 1, 1900, p. 67), shortly after the Philadelphia acquisitions were made public. This is a conservative choice, since this news and the price war's end raised the value of ASRC common stock by 15% from February to April. The value of a preferred share rose 4%.

[50] For the "second stage" of the war, from October 1891 to March 1892, we compute both ASRC's actual and counterfactual output as observed Industry Output less non-Spreckels fringe capacity. So we assume that ASRC treats the Spreckels' capacity as its own. For the first stage of the war, we compute ASRC's actual and counterfactual output as observed industry output less total fringe capacity.

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war, from a yearly rate of 613,000 pounds per day to 347,000 after the war.[51] Were this decline all ascribed to ASRC's predation after the Arbuckle Brothers–Doscher entries, could it, of itself, rationalize the predatory losses? The predatory gain under that hypothesis is the difference between the net present value of ASRC's dominant firm profits given the two entry flows. This calculation requires an assumed price of raw sugar (with the predatory gain declining in the price of raw sugar), and an "initial" fringe capacity level.[52]

The results depend crucially on the fringe capacity level. If the new National's capacity is included in the fringe capacity, then the maximum IRR is 3.2%. However, if the National's capacity is excluded (as it was under the control of the ASRC president), the internal rates of return increase substantially. At a raw sugar price of $3 (the postentry average), the IRR is 14.8%. It falls to 10.0% for raw sugar selling at $3.35 (the "interwar average," and our preferred value), and 6.6% for $3.50 (the 1890–1897 average).

Thus the predatory investment can be rationalized by its effect of deterring additional entry only when combined with the anticipated acquisition of the fringe firms.

☐ **Bargaining.** Finally, although Arbuckle Brothers was not bought out, predation could still have shifted its profits to ASRC. Under this scenario, ASRC's goal was a larger share of output, and so profits, in a post-price-war collusive equilibrium. As shown in our working paper, Genesove and Mullin (1997), a range of fringe output is sustainable in a collusive equilibrium. Furthermore, in such an equilibrium the fringe must produce less than capacity, for otherwise ASRC could at most earn its dominant firm profits — and so could not be punished for deviating. Yet the last two columns of Table A1 show that only in six of the ten years after the Arbuckle Brothers–Doscher price war did the fringe produce less than capacity.

Even were those six years, with an average 80% utilization rate, representative of all the years, the implied gain is too small to rationalize predation by itself. Under this "bargaining" rationale, ASRC's gain would be the difference between the fringe's part of collusive profits when producing at capacity and its actual production. The collusive price-cost margin could not have been expected to be greater after entry than before, so as an upper bound we set that at 43¢, the average real margin from 1893 to 1897.

The capacity of Arbuckle Brothers and the other independents was 2.5 million pounds per day in 1901. Even if predation reduced their subsequent capacity utilization from 100% to the 80% average, ASRC's maximum yearly gross gain would be only $(100\% - 80\%) \times (2,500,000 \text{ pounds} \times 365) \times .43¢ = \$785,000$, an IRR of 3.7%. Since the actual margin from 1901 to 1914 was only 18.5¢, ASRC's realized gain would have been $338,000, an IRR of 1.6%. Since both calculations assume that ASRC would have received none of the collusive gains without predation and all of them with predation, and since actual average utilization was higher, they are likely to be well above the actual value. Thus bargaining over a collusive share alone cannot rationalize predation.

☐ **Reputation.** Reputation models require potential entrants to ascribe a positive probability to the predator preying for reasons other than to establish a reputation. Reputation is built by mimicking the actions of those who would act that way in any case. There is no shortage of reasons to prey: to signal a low cost, and so acquire a firm at lower price; to achieve a larger share of a postentry collusive agreement; to force a financially constrained firm to sell out. We have rejected the first two as likely sole explanations for ASRC's behavior because the IRR was too low, and the third because of the lack of confirmatory evidence. But that is not to say that ASRC's rivals would have assessed no chance of it requiring a lower rate of return than what we calculated for the first two, nor imagined that ASRC thought that they thought ASRC's costs might be much

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[51] This is the period from the post-Spreckels consolidation up to, and including, the Arbuckle Brothers and Doscher entries.

[52] We assume entry stops when the dominant-firm price has decreased to the sum of marginal production cost and the annualized per-unit cost of capacity. We take the unit cost of capacity as 2¢ per pound, corresponding to the cost of physical capital discussed in Section 3. The results were invariant to using zero or 4¢ per pound a day (to include working capital) instead.

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lower than they were, nor believed that ASRC might erroneously believe that fringe firms might be in danger of bankruptcy.

We do not argue that any positive probability that ASRC was "tough" would have sufficed for reputation to have been effective, as in Milgrom and Roberts (1982) or Kreps and Wilson (1982). As Fudenberg and Levine (1989, 1992) suggest, the greater the entrants' subjective probability that the dominant firm would want to prey other than for reputational reasons, the shorter the number of periods necessary to establish a reputation, during which time the predator must suffer entry and the consequent price wars. Thus, reputation will be most effective the more profitable is predation in and of itself. Admittedly, demonstrating that the conditions were in place for the reputation mechanism to operate places us in a rhetorical bind, for in arguing for it we must attach some plausibility to mechanisms that we have already rejected. However, the calculated rates of return turn out to be just right for our argument—too low to justify the predation by themselves, but not so low that an entrant could reasonably dismiss the possibility that ASRC would decide to prey on that basis.

Empirically, reputation is distinguishable from other mechanisms of predation in its increasing effectiveness over time, as potential entrants become more convinced that the dominant firm is a willing predator. Unfortunately for us, ASRC's predatory behavior was cut short by antitrust authorities, preventing us from examining whether buyout prices decreased with the number of predatory incidents, as Burns (1986) did. However, the timing of the major entry episodes and associated predations are consistent with a growing reputation. It took only two years for Spreckels to enter and be preyed upon after the formation of the Sugar Trust in 1887. But it then took seven years after the Spreckels war for ASRC's adjusted capacity share to fall below 80%. And after the Arbuckle Brothers–Doscher war, ASRC retained at least that capacity share for about 11 years, until it relinquished control of the new National for antitrust reasons. Furthermore, the manner in which the Philadelphia refiners were acquired points very strongly to a manipulation of rivals' beliefs.

8. Was entry profitable?

■   A complete account of predatory pricing must explain the behavior of entrants. There are four essential points.

The pool of potential entrants was limited, as it required rare human capital that was usually employed by an incumbent. Entry required an industry-specific sunk investment in a refinery. The return on the investment was uncertain, since future price-cost margins depended on future entry and ASRC's response to it. Entrants could not know whether or not predation would occur and, if it did, for how long.[53]

Finally, entrants differed. Some had an additional, strategic value to entry. Arbuckle Brothers had its packaging technology, while Spreckels wished to protect his West Coast monopoly. And these firms, controlling other profitable businesses and therefore having access to internal funds, could be less vulnerable to long purse predation, and so more willing to enter, than stand-alone entrants. From the viewpoint of earlier entrants, subsequent entrants were random events that adversely affected their profitability.

The rationality of entry is determined *ex ante*, when the investment was sunk. *Ex post* profitability is, nonetheless, revealing, as it suggests that the actions were *ex ante* rational.

Spreckels' entry into Philadelphia was profitable *ex post*. His capital costs were $5 million.[54] He sold a 45% equity stake to Havemeyer in 1891 for $2.25 million, and then the remaining 55%

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[53] Indeed, the Spreckels war nearly ended prematurely when a nervous director quietly bought control of the Sugar Trust, then concluded a tentative agreement with Spreckels. Only a threat by Havemeyer to resign his presidency and build competing refineries—which he years later admitted was noncredible, given the time needed to build a refinery—scuttled the deal. See Eichner (1969).

[54] Claus Spreckels Jr.'s testimony before the Hardwick Committee in the U.S. Congress, 1912. This includes working capital. Although the capacity of the Spreckels plant was 1 million pounds, expansion plans had been undertaken. The Spreckels calculations are in 1890 dollars. The remaining calculations in this section are in 1898 dollars.

in early 1892 for $5.26 million.[55] When we include Spreckels' Philadelphia operating profits and losses,[56] the resulting *IRR* to his *entry* was 18.4%. This calculation is conservative, since it ignores the gains from inducing ASRC to retreat from the West Coast.

The mid-1890s entrants, who were acquired by ASRC after the Arbuckle Brothers–Doscher war, also made money overall. The (original) National, which began production in 1894, received nonpredatory profits for nearly its first five years before the 1898–1900 price war and acquisition. These loom large in calculating the entrant's *IRR*. We take its capital costs as $3.2 million for a 767,000-pound plant.[57] With a price-cost margin of 43¢ in the mid-1890s, its nonpredatory profits were $1.20 million annually. We take its annual operating losses during the almost two-year Arbuckle Brothers–Doscher war as $203,500.[58] The cash value of its buyout price was $2.25 million. All told, *ex post* the *IRR* for entry was over 28%. The earlier post-Spreckels entrants, such as Mollenhauer, did even better, since they received additional years of nonpredatory profits.

The entry of such firms is entirely consistent with our explanation. Small firms could enter without inducing predation, because predation would be too costly for ASRC. So a reasonable *ex ante* belief would have been that predation might occur eventually, but not immediately, a belief validated *ex post*.

The only entrant who lost money was Doscher, who suffered immediate predation and exited. His million-pound plant cost $4.0 million to build.[59] He sold it for $2.24 million, and made losses during the short period of production. Evidently, he did not expect ASRC to prey, or prey so soon. Perhaps he doubted a coffee roaster's ability to build and operate a working sugar refinery, and thought ASRC would not react to a single plant's entry.

In contrast, Arbuckle Brothers' entry was profitable *ex post*. Its capital costs and initial operating losses were nearly identical to Doscher's. But Arbuckle Brothers remained in the industry after the price war. The average price-cost margin from 1901–1914 was 18.5¢, and so its annual operating profits after 1900 were $675,000, with an *IRR* of 14.7%.[60]

The contrast between these two outcomes is instructive. Technologically, the two plants were nearly identical. Built within four months of each other, each took 20 months to produce its first sugars, and each had a million-pound capacity. But strategically, the entrants were quite distinct. Doscher was motivated solely by profits from refining sugar. The product differentiation inherent in prepackaged goods gave Arbuckle Brothers some degree of market power; so in entering and then refusing a buyout, it had the additional strategic goal of securing refined sugar at marginal cost to avoid the double-marginalization problem.

9. Other responses to entry

■   Although ASRC's predation was evidently profitable, it nevertheless involved substantial costs and was not completely successful, as some entry occurred. Could ASRC have done better? A review of the most obvious alternatives suggests not.

We see no strategic activity by ASRC before an entrant's plant is completed, when the prospective savings from halting construction would have given the entrant a greater incentive to abandon the attempt. The multiple stages of entry—the announcement of intent, the purchase of land, and the construction over a year or two—gave ASRC ample opportunity to identify the

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[55] In the latter case Spreckels received ASRC stock, which has been valued using its April 1892 market value, as we did in calculating the buyout prices of the other Philadelphia refiners.

[56] Our best guess is that Havemeyer purchased the 45% in April 1891, and so after that Spreckels receives only 55% of operating profits from the Philadelphia plant. Our conclusions are robust to adjusting this date.

[57] This is the sum of $1.7 million in plant construction costs and $1.5 million in working capital (including raw sugar inventories). The latter was not sunk but is included because ASRC acquired it in the 1900 buyout.

[58] This uses the real average margin of −7.3¢. It ignores possible shutdowns, but the effects of incorporating that are small.

[59] This is the sum of $2 million in plant construction costs and $2 million in working capital. Even excluding working capital costs, Doscher lost money.

[60] This conservatively ignores the small price premium it commanded on its packaged sugars.

imminency of entry and so focus its deterrent activities on an identified entrant at a particular point in time.

There was, however, little that ASRC could have done to thwart entry at this stage. Adding capacity would not have been a credible threat, since in 1887 ASRC already had enough capacity to accommodate the entire market at marginal cost. Foreclosure through long-term contracts with either retailers or brokers would have proven difficult, given the large numbers of the first and the ease of entry for the second. Arbuckle Brothers' leapfrog over wholesalers in New England to deal directly with retailers during the price war, as described in Eichner (1969), shows that intermediate distribution stages did not constitute insurmountable bottlenecks. Nor would a strategy of long-term contracts with large buyers, such as fruit canners, have been successful. That demand was concentrated in the summer months, when overall demand was high, so locking those buyers in would not have locked entrants out.

Indeed, waiting for an entrant to actually produce refined sugar before taking costly predatory actions, or making acquisition overtures, is a sensible way to screen an entrant's capabilities. Not every constructed plant was a workable one, as ASRC learned the hard way. Adolph Segal's Camden plant, which ASRC bought from him ahead of production for about \$50,000 to \$100,000 above his construction costs, reportedly had an inadequate water supply and was therefore inoperative, as noted by Zerbe (1969). ASRC might also have doubted the ability of Arbuckle Brothers to construct a workable plant, and for that reason ignored its threat to build one after rejecting its request for a price discount.[61]

10. Conclusion

■   The general feeling in the profession seems to be that predation is rare. Indeed, the U.S. Supreme Court's 1986 *Matsushita* decision rested on the "consensus among commentators that predatory pricing schemes are rarely tried, and even more rarely successful."[62] It is therefore crucial to document when predation definitely did occur, whether it was profitable, and the manner in which it was effective. We have shown that ASRC engaged in predation, by comparing price with both marginal cost and predicted competitive prices. We thus agree with Eichner (1969) that ASRC's actions were predatory, although our evidence on predation and its effects is more systematic. We reject Zerbe's (1969) claim that the price wars were merely reversions to competitive, marginal-cost pricing. Predation's main effect was to lower the acquisition price of entrants and small incumbents. It operated, at least in part, by influencing rivals' beliefs, as ASRC developed a reputation as a willing predator.

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[61] Neither could a long-term contract to supply Arbuckle Brothers with refined sugar at marginal cost, in return for sale of its refinery to ASRC, have substituted for predation, as such an arrangement would have been susceptible to *ex post* opportunism by both sides. See Genesove and Mullin (1997).

[62] *Matsushita Electric Industrial Co.* v. *Zenith Radio*, 475 U.S. 574 (1986) at 589.

Appendix

■   A table outlining the evolution of industry capacity follows.

TABLE A1   Evolution of Industry Capacity

		Capacity			ASRC			Eastern Industry Output	Fringe (excluding the National)		
					Capacity Share		Market Share		Estimated Market Share		Average
Year	Events	ASRC	The National	Other	Unadjusted	Adjusted	Unadjusted			Estimated Output†	Annual Capacity
1887	Sugar Trust formed						79.0				
1888							75.0				
1889	Spreckels Sr. entry						66.0				
1890		11.33	0	3.50	76.4	76.4	67.7	7.26	32.3	2.34	3.87
1891		11.33	0	4.20	73.0	73.0	65.2	9.31	34.8	3.24	4.23
1892	Spreckels sellout	11.33	0	4.00	74.0	74.0	91.0	8.79	9.0	.79	1.27
1893		15.17	0	.75	95.3	95.3	85.7	8.60	14.3	1.23	1.08
1894		15.17	0	1.75	89.7	89.7	77.0	9.31	23.0	2.14	1.92
1895		15.17	0	2.17	87.5	87.5	76.6	9.04	23.4	2.12	2.17
1896		15.17	0	2.17	87.5	87.5	77.0	9.17	23.0	2.11	2.17
1897		15.83	0	2.27	87.5	87.5	75.4	9.72	24.6	2.39	2.27
1898:(I)		15.83	0	2.27	87.5	87.5	69.7	9.22	30.3	2.79	2.51
1898:II		15.83	0	2.27	87.5	87.5					
1898:III	Arbuckle entry	15.83	0	2.50	86.4	86.4					
1898:IV	Doscher entry	15.83	0	3.00	84.1	84.1					
1899:(I)		15.83	0	3.50	81.9	81.9	70.3	10.34	29.7	3.07	3.82
1899:II		15.83	0	3.60	81.5	81.5					
1899:III		15.83	0	3.93	80.1	80.1					
1899:IV		15.83	0	4.27	78.8	78.8					
1900	Doscher sellout	15.83	0	4.70	77.1	77.1	70.1	10.46	29.9	3.13	3.60
1901		15.83	3.20	2.50	73.5	88.4	62.0	10.49	25.1	2.63	2.50
1902		15.83	3.20	2.50	73.5	88.4	60.9	10.85	24.4	2.64	2.53
1903		15.83	3.33	3.20	70.8	85.7	61.5	10.42	24.8	2.59	3.20
1904		15.83	3.33	3.20	70.8	85.7	62.3	11.77	25.1	2.95	3.38
1905		15.83	3.33	3.57	69.6	84.3	58.1	11.04	29.0	3.20	4.07
1906		15.83	3.33	4.23	67.7	81.9	57.3	12.22	29.4	3.60	4.33
1907		15.83	3.33	4.40	67.2	81.3	56.8	11.96	30.8	3.68	4.40
1908		15.83	3.33	4.40	67.2	81.3	54.3	12.11	33.2	4.02	4.65
1909		15.83	3.33	4.73	66.2	80.2	50.4	12.65	37.2	4.71	4.73
1910	Antitrust suit filed	15.83	3.33	4.73	66.2	80.2	49.2	13.40	37.9	5.07	4.73
1911		15.83	3.33	6.57	61.5	61.5	50.1	12.93			
1912		15.83	3.33	6.57	61.5	61.5	45.5	13.66			
1913		15.83	3.33	6.90	60.7	60.7	44.0	13.85			
1914		15.83	3.33	7.40	59.6	59.6	43.0				

Note: See discussion in the text for more information.

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