# PREDATION AND ITS RATE OF RETURN: THE SUGAR INDUSTRY, 1887-1914

David Genesove
Hebrew University of Jerusalem and NBER[1]

Wallace P. Mullin
Michigan State University and NBER[2]

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[1]Department of Economics, Hebrew University of Jerusalem, Mount Scopus, Jerusalem 91905
[2]Department of Economics, MSU, East Lansing, MI 48824-1038, (517) 353-9934. Part of this research was undertaken while the first author was a Lady Davis Fellow at the Hebrew University of Jerusalem, and while the second author was John M. Olin Visiting Assistant Professor at the George J. Stigler Center for the Study of the Economy and the State, University of Chicago. We would like to thank Vrinda Kadiyali and participants at numerous workshops for helpful comments. The research assistance of David Burnstein, Sandra Chan and Young Ha is greatly appreciated.

**Abstract**

We study entry into the American sugar refining industry before World War I. 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. We argue that predation occurred only when the relative cost of it to the dominant firm was small. Its most likely rationale was to strengthen the dominant firm's reputation as a tough competitor. This had two complementary effects: it lowered the acquisition price of entrants and small incumbents, and may have deterred future capacity additions. Predation may have also raised the dominant firm's share of industry profits in a collusive equilibrium.

# 1 Introduction

The continued exercise of market power depends upon deterring entry. Recent theoretical work has clarified the range of strategies available to an incumbent firm, giving support to the potential rationality of predatory strategies. Because entry is a dynamic process, and an incumbent's actions to shape its competitive environment necessarily involve dynamic concerns, the issue is best explored by tracing the evolution of a single industry over a long duration.

This paper studies entry into the American sugar refining industry in the decades following the formation of the Sugar Trust. Initially organized in 1887, the Sugar Trust was reorganized as the American Sugar Refining Company (ASRC) in 1891, and by 1909 the company was the ninth largest corporation in the United States. In 1910, the federal government filed an antitrust suit against ASRC as part of the same political movement which brought prosecutions against Standard Oil, American Tobacco, and U.S. Steel. Surprisingly, the evolution of the sugar consolidation has received far less scrutiny from economists than that accorded these other consolidations.

Two sets of entrants, Claus Spreckels, and later Arbuckle Brothers & Doscher, were met with sharp decreases in price. These price wars lasted about two years, albeit 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 in part based upon a direct comparison of price to marginal cost. As we have argued in other work (Genesove and Mullin, 1998), the simple production technology of sugar refining and contemporary audits and testimony combine to provide a direct and highly credible measure of marginal cost.

Because estimates of marginal cost are always controversial, we present a second line of evidence, which relies upon the pattern of capacity constraints in the industry and models of competition. Using demand estimates and firm capacity figures, 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.

An allegation of predatory conduct is always controversial, whether levelled in the courtroom or the classroom. Our claims concerning ASRC's behavior therefore engage us in two debates, one particular to the sugar refining industry and the other, a more general debate

about the empirical relevance of predatory acts.

There is no dispute about the fact of the price wars. Both Zerbe (1969) and Eichner (1969) agree that entry triggered sharp reductions in refined prices. They differ in the interpretation. Their arguments evoke the more general debate about whether predation can be a rational strategy, and whether it occurs.

There are two explanations for each price war. First, the mere fact of entry may have led to increased competition and hence lower prices. Likewise, in this view, the end of the price war reflected no more than the increased concentration engendered by merger agreements. This is Zerbe's position, although only fully articulated with respect to the Arbuckle-Doscher war. Alternatively, the price wars were predatory. This interpretation is really an umbrella for several different explanations, each corresponding to a model of rational predation. (See Saloner (1987), Kreps and Wilson (1982), Bolton and Scharfstein (1990) and Cabral and Riordan (1994) for signalling, reputation, long purse and learning curve rationales for predation.) Eichner (p. 227) is in this vein in arguing that the price wars "demonstrated that any group invading the sugar refining industry would have to be prepared to face substantial losses. This in itself had a certain deterrent value and reinforced the barriers already in existence." Thus he ascribes a reputation motive to ASRC.

We consider each explanation in our analysis of the major entry episodes, bringing both strategic thinking and market data to bear.

A note about our definition of the term predation. Although this paper is not explicitly about antitrust, predation is a buzzword that automatically brings to mind a vast legal literature and caselaw. So there is a need to distinguish between a legal or normative standard and a scientific or positive one. Practical difficulties in implementing a legal standard may deter one from classifying as predatory in a legal sense what one is prepared to thus classify in a positive sense.

We could, and perhaps, will, argue about the appropriate positive standard. But at a minimum, under any positive standard, any evidence for predation must exclude competitive conduct as an explanation. By competitive conduct, we mean the static noncooperative equilibrium outcome in either prices or quantities, as we outline in section 3.3 on models of competition, and in the Appendix.

Our broad definition of predation is any action an incumbent firm undertakes that sacrifices its own current profits in order to reduce its rival's profits and thereby either constrain entry or induce exit. This strategic effect could operate by altering the rival's cash flows, its perceptions of market conditions, or its beliefs about the incumbent's likely future actions.[1]

[1]This definition is in accordance with at least one suggested legal standard. "Predatory pricing behavior

We operationalize this concept by constructing as the price of predation to ASRC the ratio of its losses in the predatory war to the entrant's losses. We are thus conceiving of ASRC as "purchasing" losses for its rival by paying a price in foregone current profits. The usefulness of this measure is demonstrated in the two entry episodes, both of which are marked by respites in the price war in the summer, the high season of sugar demand. We demonstrate that predation was relatively more costly to ASRC in high than in low season, and so the respite reveals the limits to ASRC's willingness to pay for predation. Similar reasoning helps account for ASRC's pattern of responses to entrants. Predation occurred when fringe capacity had grown relatively large, and so the cost of preying had become relatively small.

The plan of this paper is as follows. The next section provides an overview of the industry's history. In section 3 we outline the competitive environment in which ASRC operated. This includes a discussion of the cost structure of sugar refining, the difficulty of entry, and an outline of possible modes of pricing behavior under these conditions. The next three sections address two entry episodes that sparked fierce price wars. Section 4 examines the entries of Arbuckle Brothers and Doscher, and the subsequent price war in detail, while section 5 examines the Spreckels Senior episode. Section 6 calculates internal rates of return to ASRC under various theories of predation. Two rationales advanced in the theoretical literature are shown to be unlikely explanations in this setting. The most likely rationale for the observed predation is that it enhanced ASRC's reputation as a tough competitor, which in turn lowered the buyout prices of both entrants and small incumbents. Reputation may have also served the complementary role of deterring future entry or expansion. Predation may have additionally raised ASRC's share of industry profits in a collusive equilibrium. Section 7 advances a preliminary explanation of how predation could have arisen in equilibrium. Section 8, which concludes, briefly discusses and dismisses other ways in which ASRC might have deterred entry.

# 2 Historical Overview

After several unsuccessful attempts at collusion, the Sugar Trust was formed in December 1887 as a consolidation of 18 firms controlling 80% of the industry's capacity. Notable among those choosing to remain outside the Trust were three Philadelphia refiners. The 20 plants

involves a reduction in 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." (Joskow and Klevorick, pp. 219-220.)

owned by the original Trust members were quickly reorganized and reduced to ten. Refined prices rose 16%, and entry soon followed.[2]

The first entrant was Claus Spreckels Senior who, in December 1889, completed a plant in Philadelphia.[3] That led first to a two-year price war, and then to ASRC, the successor to the Trust, acquiring the Spreckel's Philadelphia plant along with those of the three Philadelphia firms that had remained independent.[4] These acquisitions were completed by April 1892 and ASRC's capacity share rose to 95%.

This earliest episode exemplified one 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.

But not all entrants were met by immediate price wars. In the next several years, the degree of concentration slowly declined, as a series of firms entered, each at a relatively small-scale.[5] Five firms entered in all, each with a single plant, with an average capacity of 1340 barrels of refined sugar per day. This was in contrast to the 49,500 barrels capacity of ASRC and associated "friendly" companies.[6]

The next phase of the industry's competition began in 1898, with the entry of Arbuckle Brothers, a large wholesale grocer firm and the dominant roaster of coffee in the United States. It owed that position to a patented packaging machine, which enabled it to sell coffee in small packages, rather than in bulk. From 1892-1896, it applied the same technology to sugar, buying refined sugar from ASRC and then reselling packaged sugar. 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, finally producing in August 1898.

Another entrant, the Doscher refinery, began production in November of that year. When fully operational, each plant had a daily capacity of 3,000 barrels. This precipitated a severe price war, marked by pricing at or below cost, shutdown by the independent refiners, and the partial shutdown of Doscher. With the exception of one "respite," the price war continued until May 1900, when the Doscher refinery merged with two of the major independents

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

[3]Spreckels refined sugar on the West Coast, while the Sugar Trust was centered on the more populous East Coast. The Sugar Trust acquired a plant in California in spring 1888, touching off a price war on the West Coast. Spreckel's entry into Philadelphia can therefore be viewed as retaliation.

[4]The Sugar Trust was reorganized as a corporation in 1891.

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

[6]Vogt, p. 48.

to form the National Sugar Refining Company. This consolidation was organized by the ASRC President, who received the common stock, and therefore control, of this new entity. Arbuckle Brothers remained in the industry.

The next several years witnessed both successful and unsuccessful attempts at entry. Claus Spreckels Jr., the son, founded the Federal Sugar Refinery in Yonkers, New York in 1901, achieving a toehold in the industry by 1902-1904. Adolph Segal, who in 1895 had constructed a refinery in Camden, New Jersey and then sold it to ASRC before it ever went into production, began construction of a second plant in Philadelphia 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 the refinery was sold to bondholders and refurbished.[7]

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, the government's victories in the American Tobacco and Standard Oil cases in 1911 led ASRC to initiate partial, "voluntary," dissolution.

The industry's evolution is captured by Table 1. ASRC's market share was always below its share of industry capacity. Accounting for its control over the National, ASRC's (Adjusted) Capacity Share was usually above 80 percent, until antitrust scrutiny intervened.

# 3 The Competitive Environment

## 3.1 Technology of Sugar Production

Refined sugar was a homogenous product. It was shipped to grocers in barrels, who in turn packaged the sugar for final consumers without any identification of the manufacturer.[8] Prices therefore tended toward uniformity.

The production technology of sugar is simple to describe. Raw sugar is transformed at a fixed coefficient into the final product, which is refined sugar. In this period, most refined sugar in the United States was derived from sugar cane. Sugar cane was initially processed into raw sugar, a form which can be transported and stored for later refining.

[7] Willett and Gray, November 1, 1906; December 6, 1906; November 29, 1911; March 18, 1912; August 22, 1912.

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

Table 1: Evolution of Industry Capacity

| Year | Events | Capacity: (millions of lbs per day) ASRC | National S.R. Co.† | Other | ASRC's Capacity Share Unadjusted | Adjusted† | ASRC's Market Share Unadjusted |
|---|---|---|---|---|---|---|---|
| 1887 | Sugar Trust formed | | | | | | 79.0 |
| 1888 | | | | | | | 75.0 |
| 1889 | Spreckels Sr. Entry | | | | | | 66.0 |
| 1890 | | 11.56 | 0 | 3.57 | 76.4 | 76.4 | 67.7 |
| 1891 | | 11.56 | 0 | 4.28 | 73.0 | 73.0 | 65.2 |
| 1892 | Spreckels sellout | 11.56 | 0 | 4.08 | 74.0 | 74.0 | 91.0 |
| 1893 | | 15.47 | 0 | 0.77 | 95.3 | 95.3 | 85.7 |
| 1894 | | 15.47 | 0 | 1.79 | 89.7 | 89.7 | 77.0 |
| 1895 | | 15.47 | 0 | 2.21 | 87.5 | 87.5 | 76.6 |
| 1896 | | 15.47 | 0 | 2.21 | 87.5 | 87.5 | 77.0 |
| 1897 | | 16.15 | 0 | 2.31 | 87.5 | 87.5 | 71.4 |
| 1898 | Arbuckle, Doscher entries | 16.15 | 0 | 2.31 | 87.5 | 87.5 | 69.7 |
| 1899 | | 16.15 | 0 | 3.57 | 81.9 | 81.9 | 70.3 |
| 1900 | Arbuckle-Doscher war ends | 16.15 | 0 | 4.79 | 77.1 | 77.1 | 70.1 |
| 1901 | | 16.15 | 3.26 | 2.55 | 73.5 | 88.4 | 62.0 |
| 1902 | | 16.15 | 3.26 | 2.55 | 73.5 | 88.4 | 60.9 |
| 1903 | | 16.15 | 3.40 | 3.26 | 70.8 | 85.7 | 61.5 |
| 1904 | | 16.15 | 3.40 | 3.26 | 70.8 | 85.7 | 62.3 |
| 1905 | | 16.15 | 3.40 | 3.64 | 69.6 | 84.3 | 58.1 |
| 1906 | | 16.15 | 3.40 | 4.32 | 67.7 | 81.9 | 57.3 |
| 1907 | | 16.15 | 3.40 | 4.49 | 67.2 | 81.3 | 56.8 |
| 1908 | | 16.15 | 3.40 | 4.49 | 67.2 | 81.3 | 54.3 |
| 1909 | | 16.15 | 3.40 | 4.83 | 66.2 | 80.2 | 50.4 |
| 1910 | Antitrust suit filed | 16.15 | 3.40 | 4.83 | 66.2 | 80.2 | 49.2 |
| 1911 | | 16.15 | 3.40 | 6.70 | 61.5 | 61.5 | 50.1 |
| 1912 | | 16.15 | 3.40 | 6.70 | 61.5 | 61.5 | 45.5 |
| 1913 | | 16.15 | 3.40 | 7.04 | 60.7 | 60.7 | 44.0 |
| 1914 | | 16.15 | 3.40 | 7.55 | 59.6 | 59.6 | 43.0 |

†The National Sugar Refining Company of New Jersey was formed at the end of the Arbuckle-Doscher War in 1900. Because a controlling interest of its stock was owned by ASRC and ASRC's President, the National was run in harmony with ASRC from its inception until this control was relinquished in 1911-1914. ASRC's Adjusted Capacity Share counts the National's capacity as part of ASRC for 1901-1910 inclusive. ASRC's Market Share does not include sales by the National.

The market share figures are from Willett and Gray. The capacity figures are from Willett and Gray, as supplemented by testimony before the Industrial Commission or the Hardwick Committee, and are reported for the first quarter of each year.

The standard grade of raw sugar, whose homogeneity was ensured by polariscope testing, was 96% pure sugar, or sucrose, and 4% water and impurities. In fact, there was some loss of sugar in the refining process, so 100 pounds of raw sugar would yield only 92.5 to 93 pounds of refined sugar.[9] This technological coefficient remained unchanged over our sample period and beyond.[10] Most of the raw sugar refined in the U.S. was produced in the tropics, especially Cuba, although Louisiana was an important domestic source. The raw sugar was then "melted," purified, and crystallized by refiners into refined sugar, which is 100% sucrose.

The cane refiners utilized a common technology.[11] Marginal cost was constant up to plant capacity, and infinite beyond that. These plant capacities were known both to industry participants and observers. In addition to the 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:

$$c = c_o + 1.075 * P_{RAW}$$

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 1.075 is the coefficient of the fixed-coefficient production technology between raw sugar and refined sugar.

Inferring the value of $c_o$ is less straightforward. Nevertheless, we have a number of different sources of evidence that are consistent with each other. Our best estimate of $c_o$ is 26 cents (per hundred pounds) in constant 1898 dollars, but we admit a range of estimates from 16¢ to 26¢.

The earliest evidence on $c_o$ comes from testimony before the Industrial Commission in 1899, which was coincident with the Arbuckle-Doscher price war.[12] Henry Havemeyer, President of ASRC, testified that at a margin of less than 50¢ a hundred pounds "the refineries are running at a loss".[13] By "the margin", Havemeyer meant the difference between the price of 100 pounds of refined sugar and 100 pounds of raw sugar. Because raw sugar was transformed into refined sugar at less than a one-for-one basis, this "margin" does not represent a true net-of-raw-sugar-costs margin. One needs to know the price of raw to infer that

[9]Testimony of Stephen Buynitsky, an official from the Customs division of the Treasury Department, June 10, 1899, *IC,* Volume I, Part 2, 1900, p. 44.

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

[11]Henry Havemeyer of ASRC and Claus Doscher both testified that the general processes of sugar refining were common to all refiners. June, 1899 testimony, *IC,* Volume I, Part 2, 1900, p. 100, p. 112.

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

[13]Henry Havemeyer, June 14, 1899 testimony, *IC,* Volume I, Part 2, 1900, p. 112.

value, which is $P - 1.075 \times P_{RAW}$ and which we denote the "proper margin." A partner in Arbuckle Brothers conveniently provides that price for us:[14] " [the cost of refining is] from 50 to 60 points, or one-half to six-tenths of a cent per pound. In other words, if raw sugar costs $4\frac{1}{2}$ cents a pound, it will cost over 5 cents up to $5\frac{10}{100}$." Subtracting $4\frac{1}{2} \times 1.075$ from a total cost of 5 or $5\frac{10}{100}$, we obtain a value of $c_o$ ranging between 16¢ and 26¢.

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¢.[15]

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

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

One might object that some part of these estimates constitute fixed cost. Refinery inputs included, aside from raw sugar, containers, fuel, boneblack and labor. Only the last of these is a serious candidate for a fixed cost. Among our sources, only the U.S. Tariff Commission reports labor costs separately, ascribing a cost of 7.24¢ to labor. So, even were all labor fixed, this would reduce that source's estimate of $c_o$ to 18¢, still within our range. If we then subtract the Commission's figure of 1.7¢ for repairs and sundries, we reach our lower estimate of 16¢. Of course, some part of labor must have been variable. The 1909 Census of Manufactures, the first to report cane sugar refining separately from other parts of the sugar cane industry, reports payments to salaried workers as 23% of total labor payments.[19]

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[14] James N. Jarvie, June 15, 1899 testimony, *IC,* Volume I, Part 2, 1900, pp. 138-139.

[15] The 10¢ for packages is confirmed by a Bureau of Labor Statistics audit in 1913, that showed it to vary between 9.4¢ and 10.8¢, with an average of 10.2¢, ( in 1898 dollars), at selected months in 1905, 1910 and 1911. Bureau of Labor Statistics, 1913.

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

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

[18] To make the figures compatible to the quoted estimates, we subtracted the reported values of 1.3¢ for depreciation and 5.6¢ for receipts for by-products from the reported total refinery cost of 42.0¢, to arrive at an estimate of 35.1¢. The 1915 and 1916 figures are similar. From 1917 on, the figures increase, presumably reflecting changing relative prices consequent of the war, as well as the regulation of the sugar industry in those later years.

[19] The figure is for all of the United States. However, the 1929 Census, shows that this proportion does

If we take that proportion as the part of labor costs that was fixed, though, of course, not sunk, then the estimate of $c_o$ would be 24¢.[20]

We therefore take 26¢ as our best estimate of $c_o$, since that value is supported by the most and best evidence. At times, however, we will 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 among the witnesses at the Industrial Commission hearings 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."[21]

## 3.2 The difficulty of entry

Although the near uniformity of production costs suggests a common, known technology, entrants were drawn from a limited pool. As Eichner points out, they were typically either owners of refineries who had sold out in the 1887 consolidation, or their brothers or sons. Paradoxically, the very consolidation of the industry, and its consequent rationalization of physical assets, created a pool of potential entrants. The exceptions to the rule are Arbuckle Brothers and Segal. Arbuckle Brothers had the patented packaging machine to compensate for its unfamiliarity with the sugar industry. Moreover, it was able to develop or acquire the requisite expertise. It developed expertise in sugar merchandizing in the mid-1890s, while buying refined sugar from ASRC, repackaging it with its machine, and selling small packages of sugar. It acquired production expertise in sugar production by hiring the superintendent of ASRC's Boston plant.[22] As for Segal, he never really proved he was capable of constructing a workable sugar refinery.[23]

In 1900, the estimated cost of a refinery with a capacity of 3,000 barrels per day ranged from $\$1,500,000$ to $\$2,500,000$.[24] Much of this cost was sunk. The plant and machinery

not difffer very much across the regions.

[20] Labor fixity may arise also from hoarding specialized, non-salaried labor over the seasonal cycle. Indeed, as will be seen, the predatory periods occured 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 4.1). Indeed, industry production during the first half of 1899 exceeded all but two of the previous half-years since 1890.

[21] James Post, *IC*, Volume I, Part 2, 1900, p. 151. Also, see footnote 53.

[22] Willett and Gray, January 21, 1897, and Fugate, p. 60.

[23] See Section 7.

[24] *IC,* Volume I, Part 1, 1900, p. 67.

were almost entirely specific to the industry.[25] The land, which, in order to unload imported raw sugar directly into the plant or nearby warehouses, was on the waterfront and so costly, was also developed in a specialized manner.[26] Indeed, our research has uncovered only a single conversion of a sugar cane refinery into some other manufacturing purpose from 1887 through the 1930s.[27] This is especially noteworthy given that ASRC retained reserve capacity throughout these years, including the price war periods.

To these entry costs one must add the estimated $\$2,000,000$ in working capital, which would have been needed for the stock of raw sugar and for credit to brokers.[28] None of this, of course, was sunk.

Entry was far from instant. Building a refinery took from a year to a year and a half, as a several-story refinery was constructed, along with adjacent warehouses and docks.[29] Production would start at a low level, as machinery was tested and fixed. It might take a month or more for production to reach capacity. There was also substantial uncertainty over when production would start.[30]

## 3.3 Models of Competition and Collusion

Here we review a number of basic models of competition and collusion, specialized to the technological conditions that prevailed in the sugar refining industry. The combination of identical constant marginal cost ($c$) until capacity, a capacity that exceeds demand at marginal cost for one firm and small capacities for the rest ($K$), turns out to be convenient, for it implies similar, if not identical, outcomes for the standard theoretical models. A more detailed discussion of collusive equilibria is presented in the Appendix.

[25] Philip G. Wright, *Sugar in Relation to the Tariff*, 1924, p. 29. Refiner Claus Doscher testified that "If anything turns up that makes your plant useless for sugar refining, you have got nothing left that is worth anything for anything else." *IC,* Volume I, Part 2, 1900, p. 97.

[26] One witness estimated the replacement cost of two particular refineries at $ 1,700,000 each. The land was valued at $600,000 for a waterfront location in Brooklyn, and $250,000 for a location in Yonkers. *IC,* Volume I, Part 2, 1900, p. 152.

[27] This was Segal's Camden, New Jersey plant, which ASRC purchased in 1896. Never operated as a refinery, its machinery was transferred to other ASRC plants, then used as a storehouse until sold to a cereal foods manufacturer in 1905. Willett and Gray, March 2, 1905.

[28] James Post, *IC,* Volume I, Part 2, 1900, p. 152.

[29] Willett and Gray's description of the Doscher refinery in 1898 highlights the chief features: "The buildings are completed, including the boiler house, filter house, main refinery and packing department, side by side in the order named, or practically one immense building, eleven stories in heighth and about 300 feet in length. On the opposite side of the street is another large building in which are the offices and machine shops. It has abundunt wharf room and sheds covering 150 × 400 feet for storing raw sugars." Willett and Gray, September 22, 1898, p. 5.

[30] Willett and Gray, June 2, June 23, July 7, August 18 1898.

The *dominant firm and competitive fringe* model 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. 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 static models of competition 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 equilibrium output in the absence of capacity constraints). The outcome of the *Bertrand-Edgeworth* model, which has an equilibrium only in mixed strategies, is somewhat different, but it, too, shares many features common to the dominant firm model. The upper bound of the support of the Bertrand equilibrium prices is equal to $p^d$, the lower bound, $\underline{p}$,[31] marginal cost, and ASRC's expected profits are the same as its deterministic Cournot profits. The fringe's profits are $(\underline{p} - c)K$, and so lower than in the dominant firm model, but the property that they are proportional to the fringe's capacity and linear in its costs is maintained.

Collusion can be modelled by means of repeated games. Asymmetric capacity brings to the fore an often ignored indeterminacy in the equilibrium solution for repeated games: there is a range of market shares that are sustainable, even for a given total industry output.[32] Only by appending a bargaining model can a unique outcome be obtained.

Nonetheless, there is a simple test to determine whether conduct is collusive. A collusive equilibrium is sustainable only if the fringe produces at less than its capacity. Otherwise, ASRC's collusive profits would be, at most, its dominant firm profits (by definition of the same) - which is what ASRC would earn in a competitive reversion. Thus it could not be punished for deviating. That logic fails, however, when firms collude not just on price or output, but on the level of capacity itself. In that scenario, price would exceed the competitive level, ASRC would accept profits lower than dominant firm profits, and a fringe firm that expanded its capacity would be credibly punished by ASRC lowering the price to the competitive level.

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 $c_f$. Then so long as $c_f < \underline{p}$, the dominant

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

[32] For example, in the repeated Bertrand game with no capacity constraints, any configuration in which the market share of the larger firm is less than the discount factor is sustainable.

firm-Cournot equilibrium is unchanged, as is the support of Bertrand equilibrium prices. The dominant firm's profits are unchanged in all static models, while the fringe's profits fall by $(c_f - c)K$. The properties of equilibria of repeated games noted above continue to hold.

# 4 Arbuckle Brothers and Doscher

We examine this entry episode first because we know the most about it. It coincided with Congressional hearings, and received extensive coverage in Willett and Gray's *Weekly Statistical Sugar Trade Journal*, the authoritative trade publication.

The sequence of events which led Arbuckle Brothers to construct its own sugar refining plant is unclear. Arbuckle Brothers owned a patented packaging machine which it used in the mid 1890s to package and resell sugar they purchased from ASRC. There is conflicting testimony on the *sequence* of the following three events, but no dispute about their occurrence. One, ASRC offered to buy the packaging machine, but Arbuckle Brothers refused to sell it. Two, Arbuckle Brothers (which was paying the same rate as any other customer) asked for a discount on refined sugar from ASRC, but was refused. Three, Arbuckle Brothers announced its intention to begin manufacturing sugar.

Figure 1 shows the path of weekly refined and raw prices from the start of 1897 through the close of 1900. There is a sharp reduction in refined prices between the Arbuckle Brothers and Doscher entries in August and November, 1898, which are denoted by the two vertical lines. The third vertical line marks the end of the price war in June, 1900.

## 4.1 Pricing below marginal cost

Figure 2 graphs the proper margin, i.e., the net of raw sugar costs margin ($P - 1.075 \times P_{RAW}$), from the start of 1898 until the end of 1900. It adds horizontal lines at 26¢ and 16¢ to designate our best and lower estimate for $c_o$, the non-raw sugar cost of refining. In the aftermath of entry, the proper margin fell into and even below this range, indicating pricing below marginal cost.

This did not escape comment by contemporary industry experts. In the early weeks of the war, Willett and Gray state "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."[33] This difference was subsequently reduced further.

[33] Willett and Gray, October 20, 1898, p. 5.

How, then, did Zerbe argue that ASRC did not suffer out of pocket losses from this price war? His cost figures are similar to ours, but he examines the margin between raw and refined sugars only at an annual frequency, for the years 1898-1900. In 1899 this was a new low of 50¢, which was consistent with zero (variable) profits. But as our evidence demonstrates, for several months ASRC priced below marginal cost. Our higher frequency data are the more appropriate, since ASRC set prices on a weekly, if not daily, basis.

We speak of ASRC *setting the price*, since, logically, the price war was entirely of its making. Because ASRC had enough capacity to satisfy the entire market, a rival who set a price above the ASRC price would make no sales - as twice happened to the Howell refineries. A rival could gain by setting a price below ASRC's price only if it were not already capacity constrained. Even then, it could certainly not force ASRC to lower its price below the dominant firm price level. The sequencing of price cuts is consistent with this logic. Only once did Arbuckle Brothers lead ASRC in cutting price. As Willett and Gray report: "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 moves."[34]

If ASRC was pricing below marginal cost, why did the prey continue to produce? Several times the incumbent independent refineries, principally the Mollenhauer, did shut down or ran at "minimum capacity".[35] 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.[36] Also, shut-down costs will drive a wedge between the margins at which it is optimal to shut down and start up production. The reports of 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 shutdown occurred or production resumed. Nevertheless, it is telling that the minimum proper margin above which the incumbent independent refiners always produced was 26¢.

The one non-ASRC firm that never shut down was Arbuckle Brothers. Even the Doscher refinery, which was constructed contemporaneously, with the same capacity, and, presumably, the same technology as the Arbuckle Brothers' plant, significantly curtailed its production

[34]Willett and Gray, November 17, 1898.

[35]Willett and Gray, November 17, 1898, February 2, 1899, October 5, 1899, January 25, 1900, February 23, 1900.

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

in the late stages of the war.[37] Arbuckle Brothers' advantage lay ultimately in its packaging machine. Its packaged sugar earned a premium of 6¢ at the retail level,[38] thus giving the firm substantial, but incomplete, protection from ASRC's below-cost pricing - incomplete, because, as Figure 2 shows, price fell below cost at times an amount greater than the premium, and because most of its sugar in this period was sold unpackaged, in barrels. But the factors that led the other fringe firms to produce during the price war would have been especially relevant as well to Arbuckle Brothers - a new entrant whose packaging machine promised it a bright future in the industry.

In explaining why the fringe firms did not fully shut down during the price war, we have introduced additional benefits and costs not covered by price and our estimate of $c_o$ - shutdown and start-up costs, reputation, the value of packaged goods, and so forth. These considerations do not invalidate the comparison of the proper margin to $c_o$ as a sufficient condition for predation. The essential element of predation is that the incumbent firm price below the competitive level, of which a price below its *own* cost is sufficient evidence. The premium for packaged sugar was, of course, relevant to Arbuckle Brothers' profit calculus only, not ASRC's. Furthermore, the value of reputation and shutdown and start-up costs might lead a firm to *tolerate* a price below manufacturing cost for a time, not to choose it.

## 4.2 A Lower Bound on Competitive Prices

Zerbe rejects the predatory interpretation of this episode, instead attributing the sharp drop in prices with Arbuckle Brothers' entry to the breakdown of a previously existing cartel (p. 360). He attributes the price war with a return to competition, which he associates, in turn, with a price that equals marginal cost. That logic, however, casts ASRC as a price taker, an absurd role for a firm with nearly eighty percent of industry capacity.

A more reasonable definition of competitive conduct is the noncooperative static equilibrium. We showed in Section 3.3 that, with rival firms 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.

In this section we offer a second, independent line of reasoning, that substitutes knowledge about industry demand and capacity for cost information. Employing estimates of industry demand parameters from Genesove and Mullin (1998), 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

[37] Willett and Gray, May 17, 1900.

[38] Willett and Gray, August 25, 1898, December 1, 1898 and February 16, 1899.

of dominant firm pricing in the face of enlarged fringe capacity.

The dominant firm price $p^d$ is of course a function of not only demand and fringe capacity but cost as well. To eliminate uncertainty over $c_o$ as a source of skepticism over our results, we calculate $p^d$ at both $c_o = 26¢$ and zero. By undervaluing marginal cost, the calculated $p^d$ at $0¢$ will underestimate the true dominant firm price, and so bias our results against the conclusion that prices were too low to be rationalized by competition. Furthermore, we focus on the predicted dominant firm price for the period after *both* Arbuckle Brothers and Doscher had entered, which represents a local maximum of fringe capacity.

The easiest case to consider is linear demand. (The results are quite similar for exponential, quadratic and log-linear demand) With a fringe capacity of $K_f$ and market demand curve

$$\begin{array}{ccc} D(P) = 12.36 & -1.97 & P \\ & (1.46) \quad (0.36) & \end{array}$$

(and so ASRC residual demand curve $D^d(P) = 12.36 - K_f - 1.97P$),[39] the dominant firm price is

$$p^d(c_o) = \{\frac{12.36 - K_f}{1.97} + 1.075P_{RAW} + c_o\}/2$$

and so the predicted proper margin under dominant firm, or Cournot, pricing is

$$PM^d(c_o) \equiv p^d(c_o) - 1.075P_{RAW} = \frac{12.36 - K_f}{1.97} + \frac{1}{2}c_o - \frac{1.075}{2}P_{RAW} \tag{1}$$

Under Bertrand competition, price will fluctuate randomly between $p^d$ and $\underline{p}$, defined in Section 3.3. For the linear demand curve,

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

where $p^M(c_o) = \{\frac{12.36}{1.97} + [1.075P_{RAW} + c_o]\}/2$.[40] Let $\underline{PM}(c_o) \equiv \underline{p}(c_o) - 1.075P_{RAW}$.

[39] Price is in cents per hundred pounds, while production is in hundred of thousands of long tons per quarter. Standard errors are in parentheses. The demand curve is estimated quarterly over 1890-1914 by instrumental variables, with Cuban imports as the instrument, as in Genesove and Mullin, except there is no control for season here. The logic for using Cuban imports, which was an inframarginal supply of raw sugar at the time, is laid out in Genesove and Mullin (1998).

In constructing the residual demand curve, we assume, as throughout, that the rationing rule is efficient. The competitive price would be higher under a proportional rationing rule.

[40] Let $\Delta \equiv p^M - \underline{p}$. Simple algebra shows that $\pi(\underline{p}) = 1.97(p^M - c - \Delta)(p^M - c + \Delta)$, and $\pi^d =$

Figure 3 plots the observed proper margin, $PM^d$, and $\underline{PM}$, by assumed value of $c_o$ It is clear that during the period of the price war the observed proper margin lay well below the predicted competitive proper margins, even under the assumption of $c_o = 0$. The exception is the summer of 1899, in which the actual and the predicted dominant firm proper margins are very close. This is the same period in which the proper margin is seen to exceed 26¢ in Figure 2. We return to this issue in the next subsection.

The behavior of the proper margin outside of the price war period is also interesting. It suggests competitive (Bertrand) pricing before Arbuckle Brothers' entry, and either competitive or supracompetitive prices after the agreement. This behavior is consistent with the reports that the fringe firms were producing at capacity before, and that Arbuckle Brothers was restricting its output after, the price war. It is inconsistent with Zerbe's claim of collusive prices before the price war.

## 4.3 Price War Respite

The margin varied over the price war, and did not always hover at the point of zero profits. Figure 2 shows that the price war was interrupted in 1899 by the summer months. Indeed, Figure 3b shows that the proper margin just exceeds $\underline{PM}(26¢)$ at its peak. This was the period of peak sugar demand, due to the complementarity between sugar and fruit in fruit canning (Genesove and Mullin (1998)). Why did ASRC temporarily halt the price war? The answer is related to the traditional critique of the rationality of predation that the predator, because it is larger, must suffer more than the prey. Because ASRC was not capacity constrained, even in high season, its effective size changed seasonally, and therefore so did its cost from preying. From our previous work we know that on average the proper margin was higher in high season than in low (53¢ versus 46¢), and that production was 20% higher in high season than in low (511,000 long tons in the third quarter versus an average 420,000 in all other quarters). Both because of the higher margin and the higher output, ASRC sacrificed more flow profits in high season than in low season by failing to price above marginal cost.

Of course, the fringe's profits were normally higher in the high season than the low season. If a price war is meant to drain the entrant of its cash reserves or deny it profit flows, its greatest gross return is when the entrant's competitive profits are greatest. But it is easy to see that ASRC would gain more from a high season respite than the entrants did. With ASRC producing more than Arbuckle Brothers and Doscher, a higher margin would benefit

$1.97(p^d - c)(p^d - c)$. Then, since $\pi(\underline{p}) \equiv \pi^d$, $(p^M - c)^2 - \Delta^2 = (p^d - c)^2$

it more than the latter in absolute terms, though the proportional effect would be the same. And with the entrants capacity constrained, all the increase in demand would go to ASRC.

We operationalize the revealed willingness to pay for predation by computing a loss ratio - the ratio of ASRC's loss from the price war to the loss suffered by its rivals. The cost to continuing the price war at any point in time was the excess of *non-predatory* profits over *predatory* profits. Non-predatory profits we take to be fully accommodative - in the sense of ASRC restrict its output one for one with the capacity of the entrant, thus maintaining the price.[41] As an initial simplification, we assume that the predatory strategy 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 non-predatory output, divided by the capacity of the entrant. Non-predatory output, which we label $\widehat{Q}$, is, of course, a counterfactual; we measure it by the predicted value from a regression of weekly meltings on seasonal variables (the sine and cosine defined over the week with an annual frequency) and a time trend. Letting $K_f$ indicate total fringe capacity, we then construct ASRC output as $\widehat{Q} - K_f$. Our initial value of the ratio of the incumbent and rival losses, is therefore $LR_1 = (\widehat{Q} - K_f)/K_e$, where $K_e$ is the entrant's capacity. $K_e$, and so $K_f$, change abruptly with the entry of Arbuckle Brothers, and then Doscher, and change gradually over a month or two after entry as effective capacity increased as equipment was tested and adjusted.

Figure 4 displays $LR_1$ and the proper margin (multiplied by ten for comparability) over the duration of the Arbuckle-Doscher War. At the beginning of the price war, with the proper margin near or below 16¢, our lower measure of marginal cost, $LR_1$ is very high and then falls sharply. Mechanically, the high value of $LR_1$ is due to the low initial capacity of the Arbuckle Brothers plant. But its economic meaning is that predation at this early stage was a very costly undertaking. The countervailing benefit must have been high as well, perhaps because predation at that point of could persuade the entrant to abandon its efforts, or convince wholesalers not to switch refiners. On the other hand, the loss ratio helps explain why predation did not start immediately with Arbuckle's initial production, as indicated in Figure 2; the price of predation at that stage was too high.

$LR_1$ reaches its maximum during the respite. The proper margin series demonstrates the existence of the respite. The loss ratio helps account for it. The respite occurs because the cost of continuing to price at marginal cost had grown too high. 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

[41] 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. The results for this alternative counterfactual are qualitatively the same as those presented in the text.

$4 to reduce Arbuckle and Doscher's 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

$$LR_2 = \frac{\$0.43(\widehat{Q} - K_f) - (p-c)(Q - K_f)}{\$0.43K_e - (p-c)K_e}$$

where $Q$ and $p - c$ are the observed industry output and price-cost margin, the latter under the assumption that $c_o$ is 26¢. We multiply the counterfactual output levels by the 43¢, the average real margin from 1893-1897, the years between our major entry episodes. Figure 5 displays $LR_2$. The pattern is very much like that of $LR_1$.

# 5 Claus Spreckels, Senior

Spreckels' entry was motivated not only by the prospect of profits on the East Coast, but by the opportunity to retaliate for the Sugar Trust's incursion into his California territory.[42] During this period, the West Coast constituted a largely separate market from the East Coast, where sugar production was concentrated.[43] In early 1888, the Sugar Trust, which was composed of East Coast and Louisiana plants, acquired a West Coast plant, in apparent violation of an understanding between Spreckels and the Trust about a division of markets. Shortly thereafter, Spreckels announced his intention to enter the Eastern market, and in May, 1888 began construction of a plant in Philadelphia. The initial capacity was 3000 barrels per day, but even before initial production, he made plans to double its capacity by duplicating the whole of the refinery's buildings.[44]

The aftermath of the Spreckels entry is apparent from Figure 6 which shows the (nominal)

[42] In discussing this episode, we must rely largely on Eichner's account. The oldest copies of Willett and Gray 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, but that publication has since gone out of business.

[43] This separation was due to the relative costs of water and land transportation. Refineries were located near the ocean in order to be able to receive imported raw sugar directly into their warehouses. Once refined, sugar is subject to a deterioration risk from prolonged exposure to moisture, ruling out ocean transport, and so sugar was shipped into the nation's interior by means of rail or rail/barge combinations. Consequently, there was potential competition between East and West coast refiners for business near the Missouri and Mississippi rivers, but otherwise their markets did not overlap. The United States population was then much more concentrated on the East Coast than now.

[44] *New York Times*, August 4, 1889 and December 28, 1889.

proper margin for 1889-1892, inclusive. We graph the unadjusted, nominal values of the proper margin to avoid introducing discontinuous changes from the use of an annual, general price index. 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.

The proper margin fell sharply at the end of 1889, and hovered at or below marginal cost for most of 1890, rising well above marginal cost only for a respite in high season. Price war conditions carried into 1891, although the decrease in raw sugar costs, consequent upon the abolition of the substantial tariff on raw sugar in April, led to a considerable increase in the proper margin. By November the margin was again declining. 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¢.

## 5.1 Pricing below marginal cost

As Figure 6 indicates, the proper margin was below our estimate of $c_o$ for a considerable number of weeks during the Spreckels war, indicating pricing below marginal cost. As in the Arbuckle war, this pricing behavior was noted by Willett and Gray. In January 1892 they reported that "there is a considerable loss of refining, owing to the renewed competition between" the ASRC and the Philadelphia refiners.[45] They even quantified the loss as 10¢ per hundred lbs, which given prevailing prices implies a nominal value of $c_o$ of 28¢, close to our 1890 value of 31¢, and well within our range of estimates.[46]

## 5.2 Price War Respites

As in Arbuckle-Doscher, the high season brought about a respite in the price war. In 1890, the proper margin rose from 23¢ on May 21 to 80 cents 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 relatively more costly for ASRC in high than low season. Again, this does not represent peak load pricing, as ASRC retained excess capacity even in high season.[47]

[45] Willett and Gray, January 14, 1892, p. 3.

[46] Deflating 31 cents by the 1892 value of our price index, we obtain 29 cents.

[47] Nor does this represent increasing marginal cost. The usual seasonal pattern of the proper margin is consistent with the direct evidence of constant marginal cost. As noted in Genesove and Mullin (1998), the

The proper margin rose in the spring and summer of 1891 as well. The usual high season respite argument applies here, as well, 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 New York raw sugar price from 5.68¢ to 3.53¢ per pound. As equation (1) indicates, decreases in the raw sugar price lead to increases in the competitive proper margin, 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 payments by the ASRC West Coast plant to JD Spreckels and Brothers, a shipping concern operated by Spreckels' sons, that begin at seventy thousand dollars in January 1891 and increased to two hundred thousand.[48] The agreement between Spreckels and ASRC is discussed immediately below.

## 5.3 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."[49] Spreckels rejected this offer, but subsequent negotiations resulted in the formation of a holding company, The Western Sugar Refining Company, which was equally owned by Spreckels and ASRC and which leased the two companies' West Coast plants. In return, Spreckels sold a 45 percent equity stake in his Philadelphia plant to Henry Havemeyer, ASRC's president for $2.25 million.[50]

Although the creation of the Western Sugar Refining Company became public knowledge by the spring or summer of 1891, the other arrangements remained a secret, although rumors of a detente were afoot. Most of these rumors had as their basis the respite in the price war the summer of 1891. Spreckels continued to deny that any deal had been struck.[51] We discuss the final disposition of the Spreckels-ASRC peace process in the next section.

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average proper margin over 1890-1914 was not substantially higher in high season (53¢) than in low (46¢); the sharp seasonal patterns created by the price war respites were atypical.

[48] Spreckels Financial Records, Bancroft Library, University of California, Berkeley.

[49] This account comes from Spreckels Jr.'s 1912 testimony in the ASRC monopolization case, cited by Eichner, p. 165.

[50] In rejecting the initial offer but accepting the final agreement, Spreckels sacrificed half of the West Coast monopoly in return for an additional 5 percent stake, and therefore control, of his Philadelphia plant. Retaining an East Coast presence both ensured multimarket contact in case ASRC should cause further problems on the West Coast, and reduced ASRC's net profits from reentering in the West at some future date.

[51] *New York Times*, August 27, 1891. The first mention of the Western in the ledger books of ASRC's West Coast plant is on April 15. Willett and Gray, August 27, 1891 report that although there is no factual basis for the rumors that Spreckels has been acquired by ASRC, they have reached some sort of arrangement, as evidenced by the advance in refined prices.

# 6 Was Predation Profitable?

Having established the fact of a predatory investment, we now turn to the related, but distinct, exercise of determining ASRC's rationale in making that investment.

To answer that question, we need to understand how predation actually works. One explanation, that the price wars were aimed at driving the newly added capacity itself out of the industry, can be rejected outright. That capacity was in the industry to stay. The expenditure on the plant was sunk, and though the original owners could themselves exit the industry, the salvage value of a sugar refinery plant was very small.[52]

Thus ASRC's goal must have been some outcome short of removing the new assets from the industry. We first evaluate and dismiss two rationales offered in the theoretical literature as unlikely explanations for this case: that ASRC sought to signal that its costs were low, or sought to exploit its "long-purse" advantage. Three complementary rationales provide the most likely explanation. ASRC sought to develop a reputation as a tough competitor in order to deter the entry of additional capacity. Moreover, ASRC used predation to lower the acquisition cost of both the immediate prey and existing incumbents. Finally, predation may have helped ASRC achieve a greater market share in a collusive equilibrium. We evaluate each of these theories by calculating an internal rate of return for predation. In doing so, we pose a tougher test than Burns (1986), by systematically considering not only the benefits of predation, but the costs as well.

We focus on the Arbuckle-Doscher war. We will need an estimate of ASRC's gross price war losses, the difference between its non-predatory 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 $21,132,816.

## 6.1 Unlikely rationales: signalling and long-purse

The first unlikely explanation is that ASRC was signalling that its costs were low. In Saloner's (1987) formalization, since the entrant's profits are decreasing in the incumbent's

[52] See Section 3.2. Compare turn of the century British shipping cartels. Costs, at least on any particular shipping route, were not sunk, and so predation could hope to remove new capacity from a particular route, as Scott Morton (1997) has argued. At the opposite extreme, the Joint Executive Committee, a 19th century railroad cartel, allocated entrants a share of cartel business. According to Porter (1983), this policy was dictated by the sunk costs associated with the railroad industry, as reinforced by the prevailing bankruptcy law. Debts incurred by a bankrupt railroad could be effectively dismissed by the receivership court, allowing the incumbent management to reorganize and set rates as low as necessary to generate traffic. Thus predation could neither remove the capacity nor alter its control.

costs, proof that an incumbent has low costs will lower the minimum price that the entrant would be willing to accept in a buyout. Assuming that an entrant produces at capacity (as in the dominant firm equilibrium), that price would be the net present value of $(p - c_e)K_e$, where $c_e$ is the entrant's cost and $K_e$ its capacity. By this logic, the gross per-period return to ASRC of predation was $K_e \Delta c \frac{dp}{dc}$, where $\Delta c$ is the difference between high and low cost, and $dp/dc$ is the responsiveness of price to increases in the incumbent's cost in non-predatory periods.

Signalling cost by a sudden cut in price might seem an unconvincing strategy for an incumbent that has been setting prices daily for several years before entry, although it might be argued that price is more revealing about cost the more competitive the circumstances. Whatever the case, the plausible range of an entrant'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. The Industrial Commission of 1897 was told that: "it is possible that the ASRC, or the Havemeyer & Elder house and the Spreckels house at Philadelphia 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 [pounds] would perhaps represent the difference."[53] Several industry participants testified before the Hardwick Committee in 1911 that the "full cost of refining" was between 60 to 65¢, indicating a cost range of 5¢ per hundred pounds (3.75¢ in 1898 dollars). Using the higher real 5¢ figure for $\Delta c$, a value of .93 for $dp/dc$ (from our estimate of the response of the refined price to the raw price, from Genesove and Mullin (1998), adjusted for the loss in sugar refining), and Arbuckle and Doscher's combined capacity of 2 million pounds, we obtain a yearly gross return of $(365 \times 2 \text{ million } lb.) \times 0.05¢/lb. \times .93 = \$339,450$. This implies an internal rate of return to predation of $\$339,450/\$21,132,816$, or a meagre 1.6 percent.[54]

A more likely, but still problematic explanation is the "long-purse" hypothesis. In this view, of which Bolton and Scharfstein (1990) and Fudenberg and Tirole (1986) are variants, new entrants are typically financially constrained, so that predation serves to hinder their

[53] James Post, *IC*, Volume I, Part 2, 1900, p. 151. The cost range in the U.S. Tariff Commission's survey of refining plants is much larger. The gap in the average non-sugar costs of the costliest and least costly plant in 1917 was 35 cents, or 17 cents in 1898 dollars. There are a number of reasons to expect the higher range. First, this survey included all U.S. plants, not simply the East Coast ones. Second, 1917 was an inflationary year, so differences in the distribution of production over the year across plants would induce differences in measured costs. Finally, production took place under war-time regulation, which may have generated true cost heterogeneities that would not have occurred in a market environment. U.S. Tariff Commission, *Refined Sugar: Costs, Prices and Profits*, Washington 1920.

[54] In all our calculations of an internal rate of return, we assume that all losses are incurred in the first, predatory, period, and this investment is then followed by a perpetual stream of identical benefits per period, which gives rise to our simple formula.

expansion. If every dollar of profits denied Arbuckle Brothers and Doscher would have gone to capacity expansion, then the additional capacity thus deterred was $1,575,000$ pounds per day. This is obtained by dividing Arbuckle Brothers and Doscher's price war losses of $6.30 million by the four dollars required in physical and working capital to increase capacity by one daily pound. To a first approximation, every unit increase in the fringe's capacity reduces ASRC profits by the price-cost margin.[55] Using the pre-price war average margin of 43¢ per hundred pounds, this translates to a yearly gross return to predation of $(365 \times 1,575,000 lbs.) \times 0.43¢/lb. = \$2.47$ million, and an internal rate of return of 11.7 percent. This hypothesis might not be completely applicable, however. In Bolton and Scharfstein, predation operates by "adversely affecting the agency relationship" between the prey and outside creditors. Arbuckle Brothers possessed internal funds, and so was not as vulnerable to this effect. Another weakness of this rationale is that in a multi-period setting, it must rely on a model of the incumbent's reputation in order to explain why entry does not occur when the incumbent raises price after inducing exit.

Turning to our preferred explanations, we offer three complementary rationales that correspond to the three possible sources of predatory gains: deterrence of future entry, a lower buyout price for Doscher and the two acquired incumbents, and a greater market share in a collusive equilibrium with Arbuckle Brothers, the entrant which remained in the industry after the war.

## 6.2 Reputation

We first consider whether ASRC might have been attempting to establishing a reputation for toughness so as to dissuade the entry of additional fringe capacity. As demonstrated by Kreps and Wilson (1982) and Milgrom and Roberts (1982), incomplete information about an incumbent's "type," or its willingness to engage in predation, makes developing a predatory reputation rational. A history of predatory responses will cause prospective entrants to view the incumbent as more likely to prey upon them, leading to diminished entry. To assess the profitability of such a strategy requires knowledge of the supply of potential entering capacity with and without predation by ASRC. A natural candidate for the former is the actual entry that occurred after the end of the Arbuckle-Doscher price war. Between June 1900 and August 1914, an average of 1040 barrels per day (bpd) of additional fringe capacity entered the industry every year. (3000 barrels was equivalent to 1 million pounds).

[55] This comes from a standard application of the envelope theorem to ASRC's dominant firm profits of $\pi(K) = \max_p[(p-c)(D(p)-K]$. The price cost margin overestimates the fall in profits as it ignores the opportunity to adjust the price optimally.

We calculate the internal rate of return for predation according to the reputation hypothesis as that interest rate such that the difference between ASRC's dominant profits given an entry flow contingent on predation and that given an entry flow contingent on no predation equals its gross loss of $21.13 million. This calculation requires an assumed price of raw sugar, and an 'initial' fringe capacity level. We consider raw sugar prices of 3.0¢ (the post entry average), 3.35¢ (the 'interwar' average - and our preferred value) and 3.5¢ (the average over 1890-1897). As initial fringe capacities, we consider 14,100 bpd - fringe capacity once Arbuckle Brothers and Doscher had reached planned capacity, and 9,200 bpd - the capacity of the fringe less that of the National consolidation in June 1900 (which was under the control of ASRC's president).[56]

Table 2 shows our results. Predation was clearly profitable if, without it, one or two 3000 bpd plants would enter a year. Although that was the rate of entry experienced at the time of the price war, we doubt that ASRC could have expected it to continue; after all, with its patented packaging machine, Arbuckle Brothers was a special case. On the other hand, had ASRC expected a return to the entry rates in the 1892-1897 period, which was 1125 bpd a year, then predation would have been clearly unprofitable.

More reasonable no-predation entry rates are 1600 or 1840 bpd, which were the average entry rates between the March 1892 consolidation up to, and including, the entries of Arbuckle Brothers and Doscher. Interestingly, at these rates, predation could be justified, but only if ASRC had anticipated consolidating the pre-existing fringe firms into the National.

That suggests a complementary rationale, that ASRC engaged in predation in order to receive a more advantageous buyout price of both entrants *and small incumbents*. This parallels Burns' (1986) finding that American Tobacco's alleged predatory episodes lowered the buyout prices for both the victims and other incumbents. As noted earlier, ASRC could not have lowered these buyout prices appreciably by signalling that its costs were low. Instead, buyout prices were reduced through ASRC's strengthened reputation as a "tough" competitor, which made existing competitors expect the current predation to persist, and for future prices to be low.

[56]We assume that entry stops when fringe capacity has reached its long-run level - that level such that dominant firm price just equals the sum of marginal production cost and the annuatized per unit cost of capacity. Calculation of the long run capacity level requires an assumption of the unit cost of capacity. In the calculations we present, we assume a cost of $2 per hundred pounds - corresponding to the cost of physical capital discussed in Section 3.2. The results were invariant to the choice of two other numbers - zero and $4 per hundred pounds a day (to include working capital).

Table 2: Internal Rate of Return of Predation: Reputation Hypothesis

| | Initial Fringe Capacity | | | | | |
|---|---|---|---|---|---|---|
| | 9,200 | | | 14,100 | | |
| Additional Yearly Capacity | Raw Sugar Prices | | | | | |
| without Predation | 3.0¢ | 3.35¢ | 3.5¢ | 3.0¢ | 3.35¢ | 3.5¢ |
| 1125 | 0% | 0% | 0% | 0% | 0% | 0% |
| 1600 | 11.2% | 6.6% | 3.2% | 0.4% | 0% | 0% |
| 1840 | 14.8% | 10.0% | 6.6% | 3.2% | 2.0% | 0% |
| 3000 | 28.2% | 19.7% | 15.6% | 20.6% | 9.5% | 3.6% |
| 6000 | 46.9% | 33.1% | 26.2% | 34.0% | 17.9% | 9.5% |

## 6.3 Predation for buyout and bargaining

In order to understand the buyout rationale, it is instructive to step back and note the common pattern to ASRC's behavior throughout 1887-1914. 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 sizeable addition to independent capacity) triggered a predatory response. And each predatory episode ended with ASRC's purchase of not only an entrant, but also a number of the small, incumbent independents. The explanation for this pattern of predation is directly related to the cost of predation, just as are the seasonal respites within the predatory episodes themselves. The cost of predation, measured as the ratio of the predator to prey's losses, is greater the smaller the entrant and the smaller the total fringe. In our discussion of the seasonal respite and $LR_1$, we found that ASRC was willing to suffer up to \$4 dollars in losses to reduce its rivals profits by a dollar. Strikingly, as Table 1 indicates, ASRC's predatory response was triggered only when its (adjusted) share of industry capacity was due to fall below 80%. At that capacity share, ASRC was 4 times the size of the fringe, and using $LR_1$, the price of predation was 4 as well.[57]

[57]Several objections may be raised against this as an equilibrium argument. We discuss this in greater depth in the next section. If ASRC had announced that it would prey if and only if its industry capacity share fell below 80%, then why would a firm that knows it is going to trigger predation, enter? First, even if ASRC had made such an announcement, it might not be credible. Second, if ASRC was following a "trigger" strategy, with an unknown threshold value, then previous accommodations would reveal only an upper bound to that threshold, not the bound itself, so an entrant might enter recognizing that with some probability it might be preyed upon. Third, this pattern could be an industry feature that is clearer ex-post than it was to industry participants. Similarly, if relative capacity was known as the sole determinant of a predatory response, then the high capacity shares ASRC achieved after predatory buyouts should invite, not deter, immediate small-scale entry. But there must have been incomplete information about ASRC's willingness to prey upon any entrant, just as required by the reputation models. And so a predatory response would

An explanation along these lines was offered by Havemeyer, in testimony during the Arbuckle and Doscher War, when asked about the war of 1890-1891: "Harrison [an incumbent Philadelphia refiner] was there [in 1889]. We did not fight him; we could make our dividend without fighting him, but when 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."[58]

The Arbuckle-Doscher 'fight' 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 the common stock, and hence control of the new firm. The three exiting refiners received preferred stock, with dividend payments of $423,984 per year guaranteed by ASRC.[59] Predation was successful if, absent it, the buyout price would have been higher. That buyout price would be the net present value of $(p-c)K_I$, where $K_I$ is the target fringe's capacity and equilibrium output. The three firms had a combined capacity of 2.867 million pounds per day. The non-predatory buyout price would then depend on the targets' expectations of future prices, given that predation did not occur. At their most optimistic, they might have expected the mid-1890s margin of 43¢ to continue. Then their anticipated profits would be $(365 \times 2,867,000 lbs.) \times 0.43¢/lb. = \$4.50$ million per year. At their most pessimistic, the targets might have anticipated Bertrand competition. The Lower Bertrand proper margin averaged 39¢ over 1900-1914, and so the corresponding real price-cost margin averaged 13¢. Combining these very pessimistic expectations would yield anticipated target profits of $\$1,360,233$ per annum. Even the latter amount is over three times the observed buyout payments, and so this establishes that predation reduced buyout prices.[60] Under the former expectations, predation produced an annual gain to ASRC of $\$4,500,000 - \$423,894, = \$4.07$ million. The resulting internal rate of return was \$4.07/\$21.13, or a healthy 19.3 percent. With the latter expectations, the internal rate of return to ASRC was 4.4 percent. Because the buyout rationale is complementary to the reputation rationale, one should *add* the internal rates of return from reputation and buyout in computing an overall return to predation. Adding even 4.4 percent to the numbers in the Table 2 broadens the set of situations in which predation was a profitable strategy.

Arbuckle Brothers was not bought out, but predation could still have resulted in a shift of

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deter future entry.

[58]Industrial Commission, Volume I, part 2, 1900, p. 108.

[59]As holders of *preferred* stock, the exiting refiners would receive only these payments and no share of residual profits. All values are expressed in 1898 dollars. The details of the transaction are given in Eichner, pp. 223-224.

[60]These reductions are more dramatic than those documented by Burns (1986), who argued that predation could push buyout prices toward "distress asset values." Since a sugar refinery had very little value outside the industry, these distress asset values could be quite low.

its profits to ASRC. As we have noted, there is a range of fringe output and hence profit that is sustainable as part of a collusive equilibrium. Under this "bargaining" rationale, the most ASRC could have hoped to gain from predation would be the difference between Arbuckle's part of collusive profits when producing at capacity and the latter's competitive profits. The collusive price-cost margin could not have been expected to be greater after entry than before, so we will set that at 43¢, the average real margin from 1893-1897. Fringe competitive profits are lowest under Bertrand competition, when it is equal to $K_e(\underline{p}-c)$. Thus ASRC's maximum possible gain was $K_e(43¢-(\underline{p}-c))$. During the price war, the Lower Bertrand proper margin averaged 39¢ (also its average over the 1900-1914 period), and so the corresponding real price-cost margin averaged 13¢. Thus, given Arbuckle's capacity of one million pounds per day, an upper bound for the yearly gross gain was $(1,000,000lbs. \times 365) \times 0.30¢ = \$1,095,000$, or an internal rate of return of 5.18 percent. This is an upper bound, but since this rationale is also complementary to the reputation and buyout rationales, any gain from this source makes predation more profitable.

## 6.4 "Bogus Independent"

That the predatory actions were designed in part to affect buyout terms is most cleanly illustrated by the fate of the incumbent Philadelphia refiners in the aftermath of the Spreckels War. By the middle of 1891 ASRC's Havemeyer had secretly obtained a 45 percent stake in Spreckels' Philadelphia plant; peace with Spreckels was at hand. In the fall of 1891 ASRC began discussions with Spreckels about buying out his majority share in the Philadelphia operation. ASRC kept both these discussions and Havemeyer's minority stake secret, for ASRC also wished to purchase the three remaining independent Philadelphia refiners who had refused to join the Sugar Trust at its formation in 1887. At that time, those refiners evidently felt that free-riding on the Trust's output reduction was more profitable than joining in. Their implicit buyout price was raised by the Trust's creation.[61] But the price war ASRC launched upon Spreckels' entry would have reduced their implicit buyout price. Knowledge of Spreckels' partial or complete acquisition would raise that price again, and so ASRC kept those negotiations secret.

The final acquisition of Spreckels and the other Philadelphia refiners was worked out from late 1891 to early 1892, and became public in March, 1892.[62] As Figure 6 shows, the proper margin fell in October 1891, and reached at or below marginal cost in early 1892. This

[61] With its 80% of industry capacity, the Trust could have launched an immediate price war but chose not to, presumably due to cost.

[62] Eichner, pp. 169-173.

decline was a predatory act designed to aid the acquisition of these other refiners. If ASRC's minority stake would have assured continued peace with Spreckels, then the foregone profits during the resumption of the price war represent a predatory investment which 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 conclusion reached by Willett and Gray. Their report of January 21, 1892 noted a belief that a minority interest in Spreckels had passed into hands friendly to ASRC in early 1891 when the California combination occurred. They concluded, however, that such an interest had been insufficient to soften competition, so that the profit outlook for 1892 was grim.

ASRC's actions are reminiscent of those of American Tobacco. As Burns (1986) explains, much of American Tobacco's price cutting was channeled through some "bogus independent," a secretly controlled subsidiary, so that victims would erroneously infer that competition was, and would remain, very vigorous. After the secret detente, Spreckels served as a "bogus independent." The immediate success of this strategy required secrecy, and ASRC's long-run reputation as a tough competitor would benefit from preserving that secret. Strikingly, Eichner notes that many of the independent Philadelphia refiners did not know of Havemeyer's minority stake in Spreckels's Philadelphia plant even after they sold out, learning of it only in 1912 testimony in ASRC's monopolization suit.

The Philadelphia acquisitions raised ASRC's capacity share to 95 percent. ASRC wasted little time in earning a return on its investment, increasing the proper margin from 25¢ in late February, 1892, to 92¢ in late March, as displayed in Figure 6. The proper margin fluctuated around this higher level until the end of 1894.

The profitability of this strategy was substantial. In computing an internal rate of return to the "second-stage" Spreckels war, we assume that ASRC's minority stake would assure it peace with Spreckels, and that its subsequent pricing behavior would not affect Spreckels' buyout price. We therefore focus on the effects on the buyout prices of the remaining independents. ASRC was faced with two choices, either to resume the price war and keep the Spreckels detente secret, or to price more profitably and reveal the Spreckels peace.[63] We observe the payoffs from the former choice and need to compute the payoffs to the latter. Equivalently, we need the actual buyout price, the counterfactual buyout price, and ASRC's

[63]One might argue for a third way, that ASRC price profitably yet still keep secret the Spreckels' deal and discussions. As we have noted, pricing behavior and inferences about future cooperation were inextricably linked. The summer price war respite raised hopes that the war was over. The return to war conditions in late 1891 ironically gave credibility to claims that no deal had been struck. From the point of view of the independents, a durable return to higher prices would be viewed as peace.

price war losses (relative to the counterfactual). The three Philadelphia refiners sold out for ASRC stock. We convert these to cash by using stock values from April, 1892, shortly after the Philadelphia acquisitions were made public. This is a conservative choice, since this news and the end of the price war raised the value of ASRC common stock 15% from February to April.[64] The resulting real buyout price is $10,812,545. As before, the counterfactual buyout price would be the net present value of $(p-c)K_I$, where $K_I$ is the capacity of the Philadelphia refiners excluding Spreckels, or 2,833,333 pounds per day. Knowledge of the Spreckels' deal could reasonably yield an expected price-cost margin of 43.4¢. The Spreckels deal would essentially restore the market structure at the creation of the Trust, which resulted in an average margin of 43.4¢ from 1888-November 1889. Moreover, 43¢ was also the average margin from 1893-1897. With these expectations, anticipated target profits would be $4,448,283 per year. In computing ASRC's price-war losses, we first restrict ourselves to this "second-stage" of the war, from October 1891-March 1892. Ignoring the earlier periods in the war is appropriate since those earlier losses were sunk. We again take 43.4¢ as the real margin that ASRC would have chosen over this time period if it had declared peace early. Compared to the prices actually chosen, ASRC's second-stage price war losses were $2,585,310.[65] To compute an internal rate of return, we add the price war losses to the actual buyout price to obtain ASRC's investment cost of $13.4 million. With an annual gain of $4.5 million, the internal rate of return is a whopping 33.5 percent.

Even if we consider the whole of the Spreckels war as the predatory investment, and ignore the benefits to ASRC of inducing Spreckels' acquisition, the return from reducing the buyout prices of the other refiners was still large. Employing our usual counterfactual,[66] ASRC's losses over the whole price war would be $12,158,726. The resulting internal rate of return, 19.5 percent, indicates the attractiveness of predation as a strategy to reduce the acquisition cost of competitors.

# 7 Explaining Equilibrium Predation (Preliminary)

A complete account of rational predation must include the behavior of (potential) entrants and fringe incumbents, since their decisions determine the viability of ASRC's predatory

[64] The value of a preferred share rose 4%. These values are monthly averages, and are reported in U.S. Industrial Commission, Part I, p. 67.

[65] Here 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.

[66] For the first stage of the war, we compute ASRC's actual and counterfactual output as observed Industry Output less total fringe capacity.

strategy.

A key feature of the sugar refining industry, central to understanding entry decisions and ASRC's responses, is the very high degree of industry-specific sunk costs. As discussed in 3.2, once constructed, the expenditure on the plant was sunk, and though the original owners could themselves exit the industry, the salvage value of a sugar refinery plant was very small. As 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."[67]

"Hit and run" entry was therefore not a viable option; entry into sugar refining constituted the purchase of an industry-specific asset. The expected return on holding that asset would reflect the prospects of future entry and predation. As a result, predation could benefit ASRC in two distinct but related ways through reduced acquisition costs and the deterrence of future entry through a predatory reputation. And as we will see, even if ASRC employed a "trigger" strategy based on the fringe's share of industry capacity, knowledge of that strategy should/could retard entry even when the fringe's share was well below the expected trigger.

## 7.1 A Framework for Entry Decisions

The essentials of a model may help clarify the factors influencing an entry decision.

For simplicity, assume that every fringe firm and potential entrant has the same capacity, and that both ASRC's capacity and the industry demand curve are fixed. So in this framework, the "size of the fringe" is interchangeable with the number of fringe firms, and we will use the latter measure.

Each period $t$, there is a new potential entrant $j$. Entry requires the firm to sink $F$ in construction costs. Future costs and benefits are discounted at the risk free rate $r$. The benefits of entry consist of two components, $V_i^t(x)$ and $U_j$.

$V_i^t(x)$ is the expected discounted value as of time $t$ of profits from operating one of $i$ fringe firms, when the other state variables, including the history of play, are $x$. This is the refinery's value as a "going concern," after its sunk cost has been paid, and therefore also represents its resale value. We return to the asset market elements shortly.

$U_j$ is the expected discounted value of firm-specific, idiosyncratic net benefits and costs from operating in the industry. It reflects the opportunity costs of entrant $j$'s owner, as well as any strategic benefits $j$ would obtain from entry. To capture heterogeneity across potential entrants, we assume that $U_j$ is an i.i.d. random variable, distributed according to cdf $G(\cdot)$. We interpret $U_j$ as close to zero for most potential entrants, but substantially

[67] *IC,* Volume I, Part 2, 1900, p. 97.

positive for entrants such as Spreckels Senior and Arbuckle Brothers, who had strategic motives for entry. Since $U_j$ represents idiosyncratic or private benefits to operating, it will not directly affect resale values.

Decisions are governed by the following time line:[68]

| TIME: | $\tau$ | $\tau + 1/4$ | $\tau + 1/2$ | $\tau + 3/4$ | $\tau + 1$ |
|---|---|---|---|---|---|
| | | Potential entrant: | ASRC: | Fringe members: | |
| | | Learns $U_j$ | Learns $j$'s entry decision | Each receives flow profits $\pi(x)$ | |
| | | Enters or does not enter | preys or not preys or not | $x$ includes entry, predation | |
| | $V_i^\tau$ evaluated | | | | $V_i^{\tau+1}$ evaluated |

Potential entrant $j$ draws and observes $U_j$. He then decides whether to enter, in what we assume is that firm's only opportunity to enter. ASRC then decides whether or not to prey, and can prey even if no (new) entry occurred. That period's flow profits to each fringe member, $\pi(x)$, are a function of both current predation and recent entry decisions.[69]

Firm $j$ will enter if and only if

$$U_j + V_i^t(x) \geq F \tag{2}$$

where the entrant calculates $V_i^t(x)$ taking into account the effects of its entry. The likelihood of entry is therefore

$$\Pr(U_j \geq F - V_i^t(x)) = 1 - G(F - V_i^t(x)) \tag{3}$$

Our analysis of the effects of predation centers on $V_i^t(x)$.[70] Although defined as an expected present discounted value of profit streams, it equivalently represents the price of an active sugar refinery in a hypothetical resale market.[71] Under standard assumptions,[72] this asset price can be expressed in a recursive formulation:

[68] The subperiods, such as $\tau + 1/2$, are designed to indicate the order of information and decisions. They do not influence the discounting of payoffs.

[69] One can imagine that $\pi(x)$ could also directly depend on $i$, as ASRC could lower its dominant firm price in response to an enlarged fringe. We abstract from those considerations here.

[70] Predation, by inducing acquisition, would also affect $U_j$, since it would change the effective discount rate. But this effect is second order.

[71] The active resale market was dominated by post-predation buyouts by ASRC. But this formulation is useful even if resale was rarely observed.

[72] All agents are risk-neutral, and $r$ is the risk free (discount) rate. For a similar formulation in a continuous time setting, see Dixit and Pindyck (1994).

$$rV_i^t(x) = E_t[\pi(x')] + E_t[V_i^{t+1}(x') - V_i^t(x)] \tag{4}$$

This is an arbitrage equation: given the discount rate $r$, the expected one-period return on the asset equals the expected dividend, or single period flow profit, plus the expected capital gain (or loss). Note that $E_t[V_i^{t+1}(x')]$ is the expectation with respect to the date $t$ information set, and $i$ and $x$ are allowed to change over the period.

Let us put a little more structure on this. Begin with $V_1^t(x)$, the value when there is only a single fringe firm. The two sources of uncertainty over a single period are the probability of predation, and the probability of an additional entrant. Let $e_2$ denote the probability that a second fringe firm enters, and $\rho_i$ denote the probability that predation occurs when there are $i$ fringe firms. For notational convenience, the dependence of $e_2$ and the $\rho$'s upon $x$ has been suppressed.

The corresponding form of (4) is:

$$\begin{aligned} rV_1^t(x) \;=\; & E_t[\pi(x)] \\ & +(1-e_2)(1-\rho_1)V_1^{t+1}(x; noentry, noprey) + (1-e_2)(\rho_1)V_1^{t+1}(x; noentry, prey) \\ & +(e_2)(1-\rho_2)V_2^{t+1}(x; entry, noprey) + (e_2)(\rho_2)V_2^{t+1}(x; entry, prey) \\ & -V_1^t(x) \end{aligned} \tag{5}$$

Here $(x; noentry, noprey)$ denotes the state when the start of period state was $x$ and neither entry nor predation has occurred during this period. Similar notation is used for other situations.

The right hand side of the first line is the expected flow profit. The second line is the expected continuation value if a second entrant does not appear. The third line is the expected continuation value if a second fringe firm does enter. The fourth line subtracts the initial value of the asset.

Consider a special case to clarify. Suppose that the probability that ASRC will prey when there is only a single fringe firm is known to be 0, so $\rho_1 = 0$. In that case it seems reasonable to assume that $V_1^t(x) = V_1^{t+1}(x; noentry, noprey)$; the mere passage of time, in the absence of predation or entry, should not change the valuation.

So the formula (5) then reduces to

$$
\begin{aligned}
rV_1^t(x) \quad &= \quad E_t[\pi(x)] \qquad (6)\\
&+(e_2)[(1-\rho_2)V_2^{t+1}(x; entry, noprey) \quad +(\rho_2)V_2^{t+1}(x; entry, prey) - V_1^t(x)]
\end{aligned}
$$

The second line is the expected capital loss, which is due to the possible entry of a second firm. This example illustrates how preying on later entrants ($\rho_2 > 0$) can lower $V_1$ and hence reduce the likelihood for the *first* firm's entry. As long as predation hurts the second entrant's continuation value (i.e., $V_2^{t+1}(x; entry, prey) < V_2^{t+1}(x; entry, noprey)$), increasing $\rho_2$ reduces $V_1^t$.

This requires a positive probability that a second firm will enter ($e_2 > 0$). That will be met, if the probability of being immediately preyed upon ($\rho_2$) is not too high, or if the distribution $G$ of the private benefits of entry includes some high realizations. Here the heterogeneity among potential entrants is important. The first firm may enter recognizing that there is a positive probability that it will be preyed upon some day, since a future potential entrant could draw a high realization of $U_j$. But it could still be rational to enter ex-ante.

Because of the industry-specific sunk costs, an entry decision is the purchase of an asset. And the implicit market for that asset is forward-looking. Since relationships such as (5) hold recursively for $V_2$, $V_3$, et cetera, the likelihood of predation in some future state of the world, with an enlarged fringe, can affect earlier payoffs and therefore entry decisions.

## 7.2 Entrants' Beliefs and ASRC's Reputation

Although we have referred to $\rho_i$'s as the probabilities of ASRC's predation, they are more properly the *entrants' beliefs* that predation will occur in various contingencies. These are formed given initial beliefs, the equilibrium strategies, and the observed play of the game.

Although ASRC did not, of course, directly choose entrants' beliefs, it could significantly influence them through its responses to entry. The reputation literature addresses how the actions by a long-run player can influence other players' beliefs when there is uncertainty about the long-run player's preferred action. In our context, it seems reasonable to specify that entrants were uncertain about ASRC's willingness to tolerate market share erosion. To make this concrete, assume that entrants initially are very uncertain about ASRC's threshold for predation; ASRC preys if and only if its market share has fallen to or below this (unknown) threshold. Formally, assume entrants initially assign positive probabilities that ASRC's predation threshold is 99%, 98%, 97%, ... 3%, 2%, 1%, 0%.

The higher this threshold, the "tougher" is ASRC. This "toughness" could be a taste of the firm's managers, who value both profits and market share, and are willing to sacrifice (some) profits for market share. The more market share is valued, ceteris paribus, the greater profits the firm is willing to sacrifice, and so the higher is the predation threshold.

Note that if ASRC did not gain additional utility from preying, its (true but unknown) predation threshold would be 0%. So its utility/payoff would simply equal its expected present discounted profits.

Models of rational predation based on reputational concerns suggest that a firm with a true threshold of 0, i.e., one concerned only with profits, can in fact raise its profits by "acting like" a "tough" firm, i.e., a firm that derives some additional benefit from preserving its market share.

We observe only ASRC's actions, not its true objective function. But our null hypothesis is that ASRC only acted like a tough firm. Our calculations of ASRC's internal rate of return indicate that predation was consistent with expected profit maximization, via reputational factors.

A strong and analytically useful prediction from the reputation literature is that a single long-run player, such as ASRC, facing a sequence of short-run players, such as fringe entrants,[73] can use reputation as a commitment device. In particular, Fudenberg and Levine (1989, 1992) show that a single long-run player, if sufficiently patient, can achieve asymptotically the same payoff via reputation that it could achieve by an ex-ante commitment to a strategy. Intuitively, if a dominant firm is observed to prey if and only if its capacity share falls below 80%, then in the long run entrants come to be convinced that the dominant firm will act that way in the future.

Our assumption that entrants were uncertain about the market share at which ASRC would engage in predation is admittedly designed to account for observed behavior. But other features make it an appealing assumption.

Logically, a "trigger strategy" economizes on the costs of preying. The intertemporal linkages highlighted in (5) gave ASRC the opportunity to trade off between predation with smaller and larger fringes. And since the cost to ASRC of preying in a period was increasing in its contemporaneous market share, ASRC's total costs of preying may very well have been convex in the size of the fringe. For example, preying two separate times on 10% fringes would be costlier than preying once on a 20% fringe. Our conjecture is that a trigger

[73]The defining characteristic of "short-run" players is that they play static best responses against the long-run player. Since fringe entrants behave competitively in their output, entry, and exit decisions, they are "short-run" players even if their actions span several periods.

strategy may be optimal, another example of an (s,S) rule, which is a common solution to firm inventory and investment problems.

So a trigger strategy, like the seasonal respites, could allow ASRC to prey at the lowest cost. That may seem at odds with the notion that a firm developing a predatory reputation will want to engage in "crazy/irrational" acts. Perhaps reputation does work that way in other settings. In our context, however, predation works by imposing losses on rivals (and making future entrants anticipate the same). Minimizing the costs of imposing those losses makes the dominant firm an even tougher opponent.[74]

An incident during the Spreckels war illustrates contemporary beliefs. Francis O. Matthiessen, a director of the Sugar Trust, became very concerned about the unprofitability of the price war. He quietly bought a controlling interest of the trust certificates, and then approached Spreckels about ending the war. He presented this tentative agreement to Havemeyer, the president of the Trust, as a *fait accompli*. Havemeyer, however, threatened to resign and build new competing refineries if the war with Spreckels did not proceed, and Matthiessen bowed to this threat. Strikingly, later testimony indicates that Havemeyer was bluffing. Matthiessen failed to realize that "it would take them a couple of years to build a refinery, that they would not have have built it because it would take too long."[75]

This incident suggests early entrants had reason to be uncertain about the incumbent's response to entry. Spreckels could believe that predation might not occur, or might not last long. After all, even a director of the Trust thought predation was too costly to pursue for long. And had Matthiessen held his ground against Havemeyer, he would have ended the first war after less than a year. Moreover, this episode illustrates reputation at work, through Havemeyer's bluff against Matthiessen.

Of course, as entry and predation took place, the entrants would revise their beliefs about the likelihood of predation. As we discuss for particular entrants, we think there was still residual uncertainty about ASRC's actions among all the entrants we study. But in the long run, continued application of ASRC's strategy would have caused entrants to become certain that ASRC would prey if and only if its revealed predation threshold was crossed.

So suppose the observed threshold of 80% is known with near certainty. To translate this into the model, assume that entrants believe the fourth entrant will trigger predation: $\rho_1 = \rho_2 = \rho_3 = 0$, but $\rho_4 = 1$ (and predation is also certain for all larger fringes). There are two possible ways entrants will respond, depending upon the distribution $G$ of private

[74] One is reminded of George C. Scott's speech as Patton: "no bastard ever won a war by dying for his country. He won it by making the other poor dumb bastard die for *his* country."

[75] Claus Spreckels, Jr's., 1912 testimony, recounting his conversations with Matthiessen and Havemeyer, in Eichner, pp. 163-164

benefits.

One possibility is that no one will enter beyond the (known) threshold. That will occur if there are no private benefits ($U_j$) to operation high enough to overcome the punishment of certain predation. In that case, entry will occur just up to the threshold. But since entry beyond that threshold is completely and credibly deterred, the dominant firm benefits greatly from its reputation, since it holds a market share of 80%, earning continuing profits, without incurring further predatory costs.[76]

The other possibility is that entry occurs which trips the threshold. Despite this, predation does have an (incomplete) deterrent effect, making entry less likely (and less frequent), benefitting the dominant firm. First, certain predation raises the cutoff value of private benefits $U_j$ for the "trigger entrant." Only the rare potential entrants with very large private benefits will enter. Second, since predation has a positive probability of occurring, entry well before the trigger will still be slowed. The cutoff values for these earlier entrants will be raised due to forward-looking concerns encapsulated in the recursive application of (5).

## 7.3 Was entry rational? – calculations

The rationality of entry should be assessed ex-ante, when the investment was sunk. Nonetheless, it is instructive to begin with the ex-post outcomes.

The entrants of the mid-1890s, who were acquired by ASRC after the Arbuckle-Doscher war, did make money overall. For example, consider the (original) National sugar refining company, which began production at the start of 1894. It received non-predatory profits for nearly its first five years before the 1898-1900 price war and acquisition. These loom large in calculating the *entrant's* internal rate of return. We take its capital costs as \$3.2 million for a 2300 barrel per day plant.[77] With a real margin of 0.43 cents per pound in the mid 1890s, its non-predatory profits were \$1.203 million annually. We take its annual operating losses during the almost two year Arbuckle-Doscher war as \$203,500.[78] Its buyout price was \$2.25 million. All told, ex-post the internal rate of return for entry was over 28 percent. The

[76] The result that reputation serves as a commitment may be helpful here. If a binding commitment were made to prey at 80%, the firm would be forced to execute that commitment if that threshold were crossed. Similarly, a firm with an established reputation will prey at 80% since it otherwise would forfeit the value of its reputation. Reputation serves as a bond.

[77] This the sum of \$1.7 million in plant construction costs and \$1.5 million in working capital. Although the working capital was not a sunk cost, it is included in the startup costs because it was acquired by ASRC in the 1900 buyout. For example, it included inventories of raw sugar.

[78] This is based upon the real average margin of $-0.073$ cents. This ignores possible shutdown behavior, but the effects of incorporating that are small.

earlier post- Spreckels entrants, such as Mollenhauer, did even better since they received additional years of non-predatory profits.

The only entrant who clearly lost money ex-post was Claus Doscher, who faced immediate predation and exit. Doscher's capital costs were $4.0 million for a 3000 barrel per day plant.[79] Doscher's annual operating losses during the war were $265,435, followed by an acquisition for $2.25 million. This is a negative net present value investment for any positive discount rate.

What beliefs would have made entry a fair bet ex-ante? Suppose Doscher's entry had initially been met by only two years of non-predatory profits,[80] followed by the same predation and buyout terms as actually occurred. The resulting internal rate of return for Doscher would have been 16 percent, which would have made his entry profitable.

Two years is not a long time given the lead time required for additional entry. The construction of a new refinery took nearly two years, and Doscher knew that no one else besides Arbuckle Brothers was constructing a new refinery.[81] Thus, Doscher could have believed that if his entry and that of Arbuckle Brothers did not trigger predation by ASRC, then predation would be unlikely to occur for *at least* two years.

And of course, if predation did not occur for an even longer period, the return to Doscher's investment would grow larger. So Doscher could have assessed a positive probability of facing immediate predation, but thought the prospects of better outcomes made entry rational.

But the striking element, of course, is that Doscher faced immediate predation. What might have been Doscher's foundation for assessing a low probability of immediate predation?

First, at that point, the only predatory response had come against Spreckels, Senior. That a single episode would reveal ASRC's predation threshold only imperfectly. The Spreckels plant reduced ASRC's share of industry capacity by 6.3 percentage points, from about 79% to 73%.[82]

In 1896-97, while construction on the Doscher plant began, ASRC's capacity share was 87.5%. The Doscher and Arbuckle Brothers plants, if both became operational, would each reduce ASRC's capacity share by 5 percentage points. Doscher may have doubted Arbuckle's

[79] This the sum of $2 million in plant construction costs and $2 million in working capital. Although the working capital was not a sunk cost, it is included in the startup costs because it was acquired by ASRC in the 1900 buyout. Even excluding working capital costs, Doscher lost money overall.

[80] Assuming the mid-1890s real margin of 0.43 cents.

[81] Construction of a new refinery was observable. Any new plant would be located on the waterfront in a northeast city, probably New York.

[82] These are derived from the underlying data summarized in Table 1. The evolution of the capacity figures in that table must be interpreted with caution, however. Those figures are reported for the first quarter of each year, and reflect that new entrants took several months of production to reach full capacity.

ability to build and operate a working sugar refinery. After all, Arbuckle's experience and therefore perhaps expertise lay only in the packaging and merchandising of sugar, not its production. Ex-post, Arbuckle Brothers became the first entrant from outside the sugar industry to construct and operate a workable refinery, but that was not a sure bet ex-ante. And had Arbuckle Brothers failed, then Doscher's solo entry would have left ASRC's capacity share at 82.5%. From the Spreckels episode, he could have reasonably believed that would be above the predation threshold.

# 8 Conclusion

Although the observed predation can be viewed as a profitable strategy, it nevertheless involved substantial costs, and was not completely successful, given that some entry occurred. A natural question is whether ASRC could have done better in deterring entry. A review of the most obvious alternatives suggests not.

We see no strategic activity by ASRC in the period before an entrant's plant is completed, when the prospective cost savings from halting construction would have given the entrant a greater incentive to abandon the entry attempt. The multiple stages of entry - the announcement of intent, the purchase of land, and the actual construction over a year or two - gave ASRC ample opportunity to identify the 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. The standard ploy recognized by the deterrence literature is to accumulate excess capacity. Because adding capacity to existing plants typically takes much less time than building a new plant, as Lieberman (1987) in particular has emphasized, ASRC might have met an entrant's announcement and start of plant construction by increasing its own capacity. But at the time of the 1887 consolidation, ASRC already had enough capacity to accommodate the entire market at marginal cost,[83] so that additional capacity accumulation would not have been a credible threat.

Nor could ASRC have used long term contracts with buyers to foreclose entry. That would have been a monumental task, given the number of small grocers who sold sugar for consumer use. Foreclosure through contracts with brokers would surely have failed as well, given the ease of entry into brokerage. Arbuckle Brothers' leapfrog over wholesalers in

[83]Assessments by both market observers and participants make that clear. For example, Havemeyer testified in the midst of the Arbuckle-Doscher war that ASRC's capacity was 20% greater than the current market "demand" (*IC*, Volume I, Part 2, p. 107).

New England to deal directly with retailers during the price war shows that intermediate distribution stages did not constitute insurmountable bottlenecks.[84] Nor would a strategy of long term contracts with large buyers, such as the fruit canners, have been successful. That demand was concentrated in the summer months, when overall demand was high, so that locking those buyers in would not have locked out entrants.

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. Adolph Segal's Camden plant, which ASRC bought from him for about $50,000 to $100,000 above his construction costs, reportedly had an inadequate water supply, and was therefore inoperative.[85] Segal was a business promoter with no prior experience in the sugar refining industry, but a history of constructing plants which he would then sell to the dominant firm in the industry.[86]

ASRC's most notable failure would appear to be that Arbuckle Brothers remained in the industry after the predatory period. This does not contradict the profitability of predation, as it is already incorporated into the calculations of the buyout, bargaining, and reputation rationales. Nevertheless, one wonders what set Arbuckle Brothers apart. The contrast between the final outcome of the near simultaneous Doscher and Arbuckle Brothers entries 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 capacity of 3000 barrels per day. But strategically, the entrants were quite distinct. Doscher was motivated solely by profits from refining sugar. The product differentiation inherent in pre-packaged goods gave Arbuckle Brothers some degree of market power; and 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. Absent a credible long term contract by ASRC to supply it with sugar at cost, Arbuckle Brothers could only achieve that by retaining its independence in the refining market.

[84] Eichner, p. 219.
[85] Zerbe, p. 283 and 356.
[86] Eichner, p. 282.

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# A Repeated Games

*Price Setting.* Demand is assumed identical in each period and competition is by price setting, with recursion to the Nash-Bertrand equilibrium after a deviation.[87] Equilibrium is described by outputs $\{q_{ASRC}, q_f\}$.

For every $p$, $q_f$ must be such that the fringe has no incentive to deviate:

$$(p-c)q_f \geq (1-\delta)(p-c)K + \delta\pi_f^B \tag{7}$$

where $\pi_f^B$ is the fringe's static Bertrand profits. Thus the minimum $q_f$ is

$$q_f^*/K = 1 - \delta(1 - \frac{\underline{p}-c}{p-c})$$

ASRC will not undercut if and only

$$(p-c)[D(p)-q_f] \geq (1-\delta)(p-c)D(p) + \delta\pi^d \tag{8}$$

The maximum $q_f$ that ASRC can accept is therefore

$$q_f^{**} = \delta[(p-c)D(p) - \pi^d]/(p-c) = \delta\{D(p) - \frac{\underline{p}-c}{p-c}D(\underline{p})\}$$

Collusion at price $p$ is possible, then, if we can find a $q_f$ such that $q_f^* \leq q_f \leq q_f^{**}$. Thus we require $q_f^* \leq q_f^{**}$, that is

$$\{(1-\delta)(p-c) + \delta(\underline{p}-c)\}K \leq \delta\{(p-c)D(p) - (\underline{p}-c)D(\underline{p}))$$

$$\pi_f^B + \pi^d = (\underline{p}-c)(K + D(\underline{p})) \leq (p-c)[D(p) - \frac{(1-\delta)}{\delta}K] \tag{9}$$

The term on the far left is expected industry profits in the static Bertrand game. The term on the right is maximized by the dominant firm price corresponding to fringe capacity $\frac{(1-\delta)}{\delta}K$. When $\delta = 1$, (9) holds for the monopoly price and some range of prices beneath it, since monopoly profits exceed the Bertrand industry profits. The condition does not hold for $\delta = 1/2$, at which point the hypothetical fringe capacity equals $K$ itself, so that the right hand side's maximal value is $\pi^d$. Thus collusion is only sustainable for $\delta \geq \delta^* > 1/2$.

Given the speed of price recognition and reaction in this industry, it is interesting to

[87] We are examining subgame perfect equilibria throughout.

consider the case of $\delta = 1$. Then, when, $q_f = q_f^{**}$, ASRC earns its dominant firm profits, whereas for the same $\delta$ and $q_f = q_f^*$, the fringe earns its static Bertrand profits.

In repeated *quantity setting*, with $K$ an effective constraint, the deviation profits in the future are those of the dominant firm model. The fringe's optimal deviation is to produce $K$, so the condition for no profitable deviation is

$$(p-c)q_f \geq (1-\delta)(p-c)K + \delta(p^d - c)K$$

$$q_f/K = 1 - \delta + \delta\frac{p^d - c}{p - c} \tag{10}$$

ASRC's optimal deviation is to dominant firm output or pricing with fringe capacity $q_f$. Thus its incentive compatibility constraint is

$$(p-c)(D(p) - q_f) \geq (1-\delta)\max\{(p-c)(D(p) - q_f)\} + \delta\pi^d \tag{11}$$

If we consider the case $\delta = 1$, and $p = p^M$, we obtain from (10) and (11)

$$q_f/K \geq \frac{p^d - c}{p^M - c}$$

$$(p^M - c)q_f \leq \pi^M - \pi^d$$

Again, the maximum fringe production is that which gives ASRC its dominant firm profits, while the minimum fringe production is that which gives the fringe not its repeated Bertrand profits, but its profits in the dominant firm equilibrium.