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VERTICAL RESTRAINTS IN THE BROMINE CARTEL: THE ROLE OF DISTRIBUTORS IN FACILITATING COLLUSION

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ABSTRACT

From 1885 to 1902 manufacturers and distributors in the American bromine industry cooperated to increase prices and profits. Like many sectors of the American economy at the time, the bromine industry was made up a large number of small manufacturers and a small number of national distributors. The manufacturers agreed to pool their output and sell only to two distributors. The distributors accumulated excess inventories rather than let the market price fall, but then used those inventories as a threat to deter cheating and new entry. Industry participants designed contracts to balance fluctuations in the costs and benefits from cheating. These contracts succeeded in stabilizing collusion until the entry of new, vertically integrated, mass production firm led to its demise.

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I. Introduction

This paper examines the role of wholesale distributors in facilitating collusion in the American bromine market during the late nineteenth and early twentieth centuries.[1] While the existence of collusive organizations during this period has received wide attention[2], most research has focused on relationships among manufacturers. This paper argues that distributors were critical to this cartel's success. The bromine distributors were better positioned to deter cheating and limit entry than were the manufacturers alone. Differences in the ability to employ similar vertical restraints may explain differences in the success of cartels in other industries. The increased frequency of price wars at the end of the century may be in part a result of the disruption of vertical restraints by newly vertically integrated firms.[3]

The use of vertical restraints by late nineteenth century chemical cartels was widespread. The existence of joint selling agencies, such as those created by the various salt pools, has

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[1]The description of the actions and contracts of the bromine pool and its constituent members is taken from internal correspondence, memoranda, and contracts of bromine industry participants found in the Herbert Dow Papers. All file numbers refer to documents in the collection.

[2]See, for example, such varied writings as Chandler (1977), Lamoreaux (1985), Ripley (1916), and Green and Porter (1984).

[3]See Chandler (1977).

been documented but little examined.[4] Recent work on the turn-of-the-century chemical industry suggests that independent wholesale distributors played a critical role in establishing and maintaining output restriction agreements in bleach, chloroform, and bromine markets[5]. These distributors consciously invested in reputations as forbearers of price cutting in order to play a similar role in a variety of chemical and pharmaceutical markets.

A closer examination of the role of distributors in facilitating collusion is thus in order. Bernheim and Whinston (1985 and 1986) argue that distributors, acting as "common agents," can facilitate collusion by permitting the alignment of manufacturers' incentives. Under certain conditions, optimal incentive schemes can be offered by manufacturers to distributors which induce the manufacturers independently to set their prices at the joint profit maximizing ("cooperative") level.

The contracts between manufacturers and distributors in the bromine industry resemble the Bernheim and Whinston (B-W) contracts in several respects. They were exclusive selling contracts; they were conditional on the signing of similar contracts by all other manufacturers; they used sales based compensation schemes. But they did not create the incentives B-W suggest. Because manufacturers were not in a position themselves to deter entry, they had to share cartel rents with the

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[4]See Dewing (1924), Eskew (1948), and Ripley (1916).

[5]See Levenstein 1991, chapter 3.

distributors who could.[6] Unable to capture all the rents earned by distributors, manufacturers did not have an incentive to restrict their own output to the joint-profit maximizing level. Instead, distributors restricted the supply of bromine to the market by accumulating inventories.

In other pools employing similar vertical contracts, but relying on a "captured" joint sales agency rather than an independent distributor, inventories proved the pool's undoing.[7] In the bromine industry, inventory stocks held by distributors increased the manufacturers' incentives to participate in the pool, by providing the threat of a large price reduction if cooperation was not obtained. With the participation of all manufacturers assured, the distributors could charge consumers a price high enough to make their own participation in the scheme profitable.

The bromine pool successfully controlled the bromine market for almost twenty years. Its demise was brought on by the successful entry of the Dow Chemical Company, a vertically integrated firm using a new, mass production technology. The pool and its distributors could not prevent the entry of a firm with its own distribution channels. The pool could not afford to inventory the output of a firm whose optimal size was twenty

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[6]Bernheim and Whinston assume that the number of manufacturers in the industry is fixed.

[7]See Dewing (1924) and Ripley (1916) for histories of the salt industry's attempts to use joint sales agencies to increase prices.

times that of the older manufacturers. The era of the pool, and of the distributor king, had come to an end.[8]

This paper addresses the following questions: What did the distributors in the bromine industry do to facilitate collusion? Why were the distributors in a better position than the manufacturers, either individually or as a group, to play such a role?[9] Were the conditions that allowed this cartel to succeed specific to the technology and organization of bromine production, or do they help us to understand the success and the demise of other late nineteenth century pools?

II. Collusion in the Bromine Market

The "bromine pool" controlled the market for bromine in the United States from 1885 to 1902. The successful implementation of the bromine pool contracts, described in detail below, increased prices and garnered profits for the participating manufacturers, distributors, and the pool itself. The price of bromine had fallen steadily from the commencement of commercial production during the Civil War through 1885. Between 1880 and 1884, the price of bromine fell forty percent.[10] After the

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[8]See Porter and Livesay (1971) for further discussion of the importance of merchants and distributors in the development of the American economy.

[9]The documentary evidence suggests that the distributors were earning rents. The exclusion of distributors from the pool would have increased the rents accruing to manufacturers, if the pool had remained viable without them.

[10]Reported prices are from weekly quotations in the Oil, Paint and Drug Reporter.

establishment of the bromine pool in 1885, the trend in prices reversed, increasing 23% during 1885. Except for three periods during which collusion in the industry broke down (September 1886-February 1887, October 1888-December 1888, and March 1891-September 1892) prices steadily increased (figure I).[11] Excepting these three periods, the average price under the pool (1885-1902) was almost 25% higher than the average price for the five years prior to the establishment of the bromine pool (figures I and II). The maximum price achieved by the pool, after several years in existence, was almost 50% higher than the pre-pool average (figure II).[12] By any reasonable measure, the pool was a success.[13]

A. The Industry

At the end of the nineteenth century, bromine production in the United States took place almost exclusively in southeast Ohio and northwest West Virginia, in the Kanawha and Ohio River valleys. In 1885 twelve firms produced approximately 310,000 pounds of bromine. No firm produced more than 50,000 pounds.[14]

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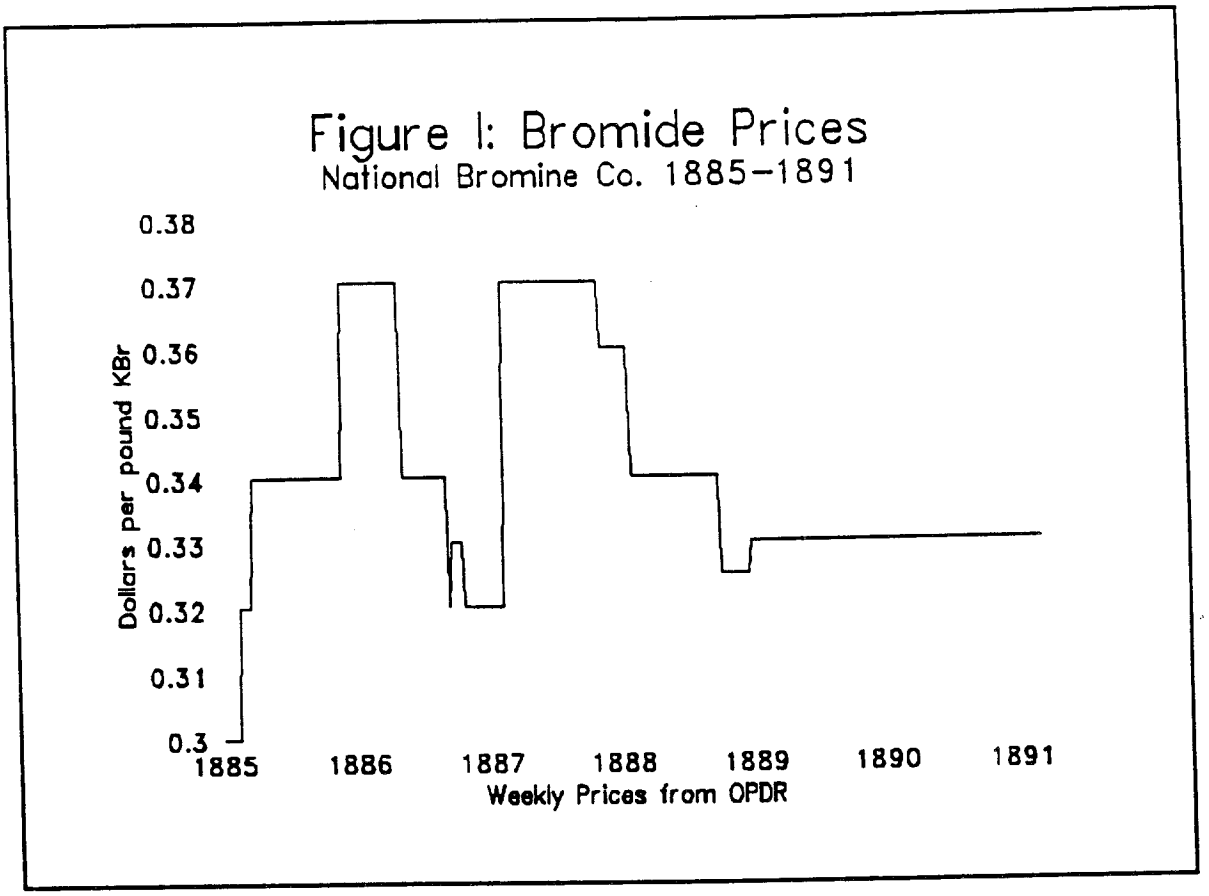
[11]See Levenstein (1993) for further discussion of these price wars.

[12]Prices reported in this paper are all nominal prices. Real prices are reported in Levenstein (1993). The trends are exactly the same.

[13]See Levenstein (1993) for a more complete evaluation of the success of the bromine cartel.

[14]U.S. Geological Survey, Mineral Reports of the United States 1885, "Bromine."



These firms all used an evaporation process that jointly produced elemental liquid bromine and sodium chloride salt.[15] Individual proprietors operated these small, technologically stable companies. The distributors, generally larger, urban, and technologically more sophisticated, converted the liquid bromine into potassium bromide. Their network of salesmen distributed it

[15]Bromine manufacturers pumped brine from underground. They heated it, using waste coal from local mines. They first extracted sodium chloride salt. Bromine was extracted from the remaining "mother liquor." The mother liquor was sometimes further processed to extract calcium chloride.

to pharmaceutical retailers and patent medicine producers around the country.[16]

Between 1885 and 1902 "the bromine pool" contracted to purchase the entire output of American bromine manufacturers.[17] The pool in turn sold the entire output of bromine to two distributors: Powers & Weightman of Philadelphia (P&W) and Mallinckrodt Chemical Works of St. Louis. The bromine pool engaged in no other business, but P&W and Mallinckrodt sold a wide range of chemicals and pharmaceutical goods to retail outlets and patent medicine producers around the country.

German potash mines also produced bromine as a by-product. A well-organized and officially sanctioned cartel established quotas and fixed prices for German bromine.

In 1892 Herbert Dow began to produce potassium bromide in Midland, Michigan in a newly founded firm, the Midland Chemical Company.[18] Mr. Dow, a young chemist and inventor, had developed a new process for separating bromine from brine. His process was electrolytic rather than thermal, and did not require the removal of sodium chloride salt from the brine. It introduced the

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[16]In 1885 virtually all of the demand for bromine in the U.S. was for potassium bromide. It was used as a headache remedy, a stomach settler, and a sedative.

[17]The "bromine pool," or the "bromine trust" as it was sometimes called, was known as the National Bromine Company from 1885-1891. Between 1892 and 1902 it was a proprietorship run by a Mr. W. R. Shields.

[18]Herbert Dow was the first general manager of the Midland Chemical Company, incorporated in 1892. The Dow Chemical Company, also of Midland, Michigan, was founded in 1897. The two companies merged in 1900.

vertically integrated, continuous production of potassium bromide, replacing the costly, time consuming, and dangerous procedure of all other manufacturers, in which elemental liquid bromine was put into small glass bottles and shipped to a distributor, who then emptied out each of the bottles and combined it with potassium.[19] Dow's process eventually produced potassium bromide at lower cost and higher purity than had previously been achieved.

B. The Pool

In 1885 the newly formed National Bromine Company (the "bromine pool") contracted with "nearly all" the bromine manufacturers in the United States to purchase their entire bromine output over a five year period.[20] It also "had an understanding with some of the largest consumers in this country concerning the sale of bromine."[21] These "consumers" were Powers & Weightman and Mallinckrodt Chemical Works. Mallinckrodt and P&W contracted with the National Bromine Company to purchase all of its bromine.[22] In the four months following the signing of the National Bromine Company agreements, the price at which Mallinckrodt and P&W sold potassium bromide increased almost

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[19]Campbell and Hatton (1951) and Whitehead (1968).

[20]Mineral Reports of the United States (hereafter, MRUS) 1885, pp. 486-487. See also Haynes (1954) v. I, p. 325, and Oil, Paint and Drug Reporter (hereafter OPDR), v. 39, January 7, 1891, p. 40.

[21]OPDR Anniversary Supplement, March 3, 1897.

[22]MRUS 1885, pp. 486-487, OPDR Anniversary Supplement March 3, 1897, and OPDR v. 28, July 28, 1885, p. 38.

thirty percent, from 26.5 cents to 34 cents per pound (figure I). P&W and Mallinckrodt in turn had an agreement with the Germans not to export American bromides abroad in return for their refraining from exporting to the United States. After 1892, the Germans agreed to purchase $25,000 of bromine (approximately 125,000 pounds) from the American distributors each year.[23]

The National Bromine Company went out of existence with the expiration of its incorporation charter in 1891. It was replaced in 1892 by a new pool organization employing similar contracts.[24] W. R. Shields, of Columbus, Ohio, was the principal of the new pool. Shields had owned a salt and bromine plant in Ohio, and was closely connected to the management of several Ohio River manufacturers. Shields helped negotiate each of the bromine industry's collusive accords up until 1910. At different times, Shields was on the payroll of both the Dow Chemical Company and Mallinckrodt Chemical Works.[25]

Shields contracted with each of the U.S. bromine manufacturers to purchase its entire output for the next five years. The manufacturers received a fixed price per pound of output; that price increased each year the agreement remained in

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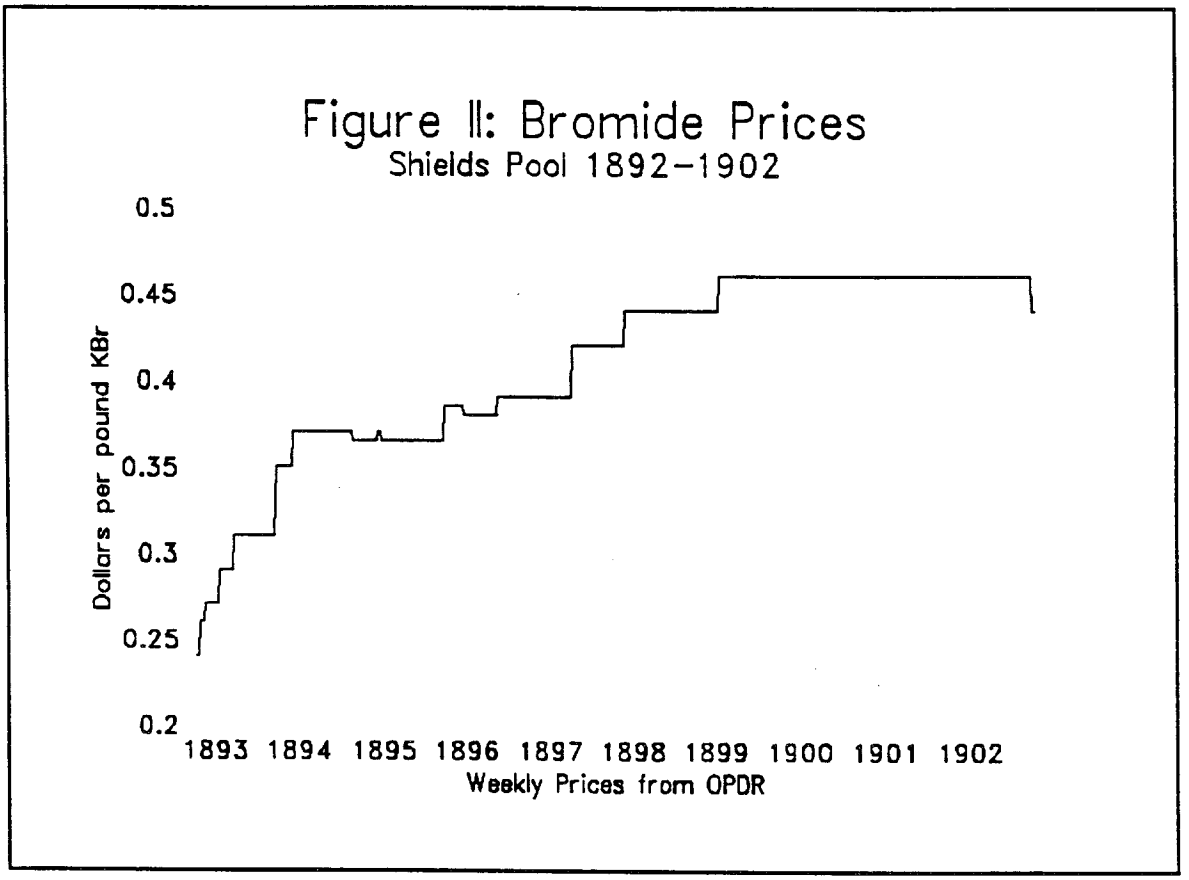
[23]Letter from J. H. Osborn to Herbert Dow, November 18, 1896, file #960005x.

[24]OPDR v. 42 October 3, 1892, p. 38 and October 10, 1892, p. 7. See also letter from W. R. Shields to H. H. Dow, December 9, 1892, file #920004x.

[25]See letters from Herbert Dow to H. E. Hackenberg, June 11, 1909, (file #090019x), February 12, 1910, (file #100011x), May 12, 1910, and June 6, 1910 (file #100013x).

effect.[26] He contracted with Mallinckrodt and P&W to sell them all the bromine that would be converted into potassium bromide salts. Bromide prices began to increase again (figure II).

The pool contracts were exclusive selling contracts; the dozen Ohio River manufacturers were prohibited from selling to any party but Shields. They were not exclusive dealing contracts; Mallinckrodt and P&W were permitted to purchase



[26]Bromine manufacturers received 16.5¢ for their stock on hand, 18¢ in the first year of the contract, 20¢ in the second, 20¢ in the third, 21¢ in the fourth, and 22¢ in the fifth (and final) year of the contract. See letter from W. R. Shields to H. H. Dow, December 9, 1892, file #920004x. 16.5¢ was probably approximately the competitive price of elemental liquid bromine prior to Dow's entry.

bromine from others, as they did when the Midland Chemical Company (Dow's firm) entered the market.

These contracts were explicitly conditioned on market structure. Shields's agreement to purchase the output of any Ohio River firm continued only so long as every manufacturer agreed to sell him its output. Entry of a non-participant into the industry nullified all the agreements.[27]

These contracts did not explicitly limit the output of the Ohio River manufacturers. The price of sodium chloride salt and the concentration of bromine in individual brine deposits determined the (short run) bromine capacity of each manufacturer. The maximum output ranged from 30,000 to 60,000 pounds per year.[28]

Because the pool contracts required Mallinckrodt and P&W to purchase the entire output of the Ohio River manufacturers, they

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[27]The contract permitted, but did not require nullification in the event of entry. W. R. Shields wrote to Herbert Dow,

> In October last I purchased the entire out-put of bromine for 5 years ... I have a clause in each contract that should a new producer of bromine appear, producing 20,000 of bromine or its equivalent in bromides, I reserve the right to annul the agreement by giving 4 months notice (December 9, 1892, file #920004x).

In fact, at least in this case, Dow's entry was accommodated once he agreed to cooperate with the pool.

[28]See annual reports on bromine production in the Mineral Reports of the United States and Report by H. H. Dow, December 28, 1907, file #070001x, for information about average and individual output capacity (respectively) of bromine manufacturers.

accumulated large inventories of bromine.[29] These inventories served a strategic purpose. Mallinckrodt and P&W threatened to dump them on the market if all manufacturers did not cooperate with the pool.[30]

Shortly after the Midland Chemical Company began producing potassium bromide it signed a one-year exclusive selling contract directly with P&W and Mallinckrodt Chemical Works (i.e. bypassing Shields). The contract specified a price per pound which Midland would receive, and prohibited Midland from selling output to anyone else.[31] The contract limited the total output of the

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[29]As discussed below, Mallinckrodt and P&W chose to convert the bromine they purchased into potassium bromide, and store it in that form, rather than storing elemental liquid bromine.

[30]See letter for from B. E. Helman, treasurer of the Midland Chemical Company, to H. H. Dow, November 23, 1896, file #960035x.

> I think you and Cooper [general manager] are completely 'off' on the matter of over-production... You men must reconstruct your policy unless you can prove there is no over-stock in warehouses. If there are in storage today 500,000 [pounds] (and I am low) how would that affect us if we were to roll up our sleeves and get into the ring? The answer is in sight. ... I believe and repeat that if we want a fight, <u>now</u> or <u>soon</u> is a good time <u>but</u> we would come out of it with feathers gone, minus a leg, wings broken, and breath spasmodic. Prices would be low. If the market is low as I long supposed then we could do it but if there is on <u>hand</u> a large surplus we would be ruined. There is no question about the outcome.

See also letter from H. H. Dow to A. E. Convers, president of the Dow Chemical Company, February 26, 1902, file #020026x.

> If we worked independently of Mr. Shields, Powers and Weightman and Mallinckrodt Chemical Works might put on the market something like two years supply that they have already accumulated....

[31]Letter from B. E. Helman to H. S. Cooper, general manager of the Midland Chemical Company, March 23, 1894, file #940003x.

Midland Company. The Dow Company renewed this contract, with similar terms but an increased output quota, until 1902.[32]

C. The End of the Pool

Seventeen years of cooperation through the bromine pool ended in 1902 when the Dow Chemical Company decided not to renew its contracts with Mallinckrodt and P&W.[33] It signed contracts with two competitors of Mallinckrodt and P&W, Rosengarten & Sons and George Merck & Co., to sell its potassium bromide to the wholesale drug trade.[34] These contracts were nominally "exclusive sales" contracts; Dow agreed not to sell its potassium bromide to any other distributor without the agreement of these two firms.[35] Dow also established its own sales office, so that for the first time, it had direct contact with its own customers. Unlike the contracts with Mallinckrodt and P&W, these contracts neither limited Dow's output nor specified a fixed price that Dow would receive (though there were both minimum and maximum prices

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[32]The original output quota was 110,000 pounds per year. It had been increased to 250,000 by 1902 (Minutes of Midland Meeting, January 27, 1902, file #020026x).

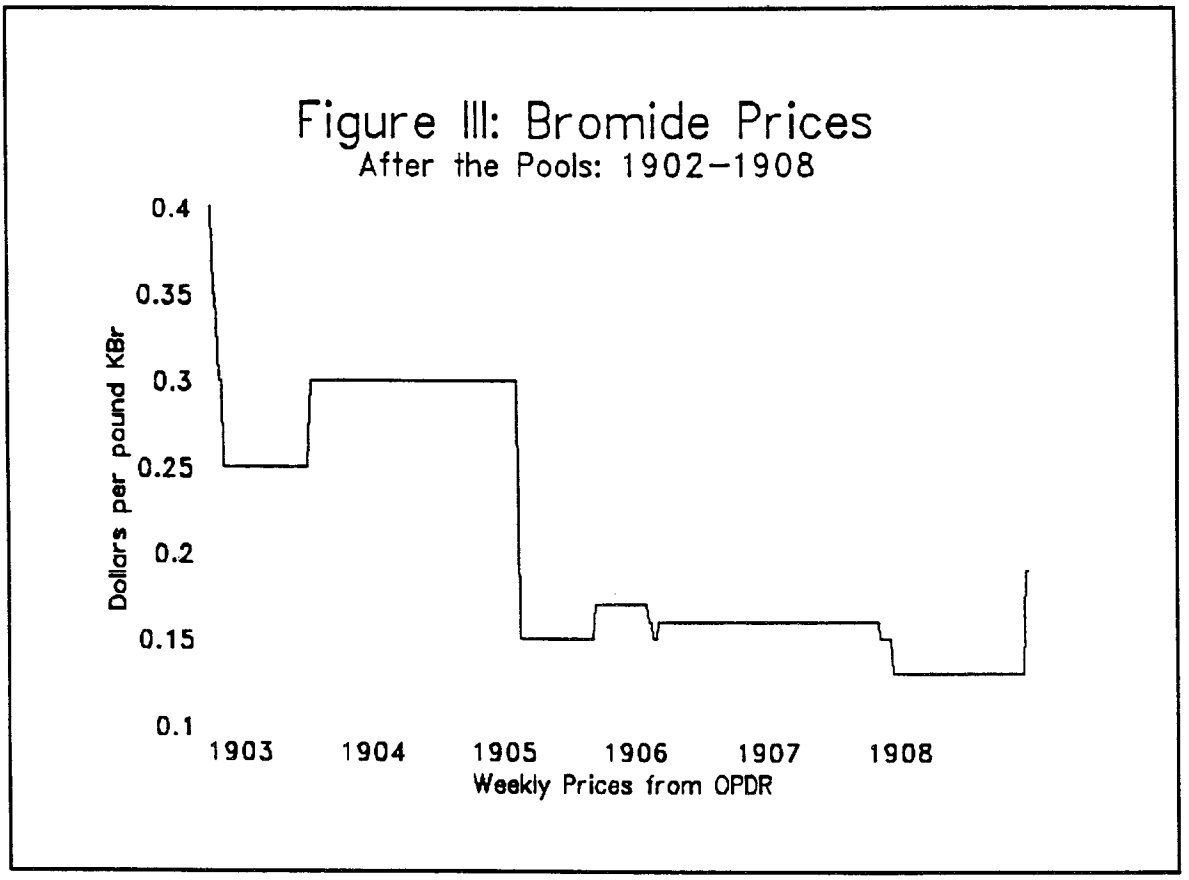
[33]"The bromine trust has come to an end...." OPDR October 6, 1902, p.42.

[34]Letter from Rosengarten & Sons to Herbert Dow, April 14, 1902, file #020062x. See also Minutes of Midland Conference, April 14, 1902, file #020027x, and Minutes of Company Conference at Midland, July 14, 1902, file #020028x.

[35]The initial agreement with Merck and Rosengarten allowed Dow to sell directly to one patent medicine producer, Meyer Brothers of St. Louis, Missouri. In 1903, Dow agreed to sell bromides to Mallinckrodt as well, under similar terms to Merck and Rosengarten's contracts. Other large patent medicine producers, such as Emerson Drug Company, the manufacturer of Bromoseltzer, purchased directly from Dow after 1905.

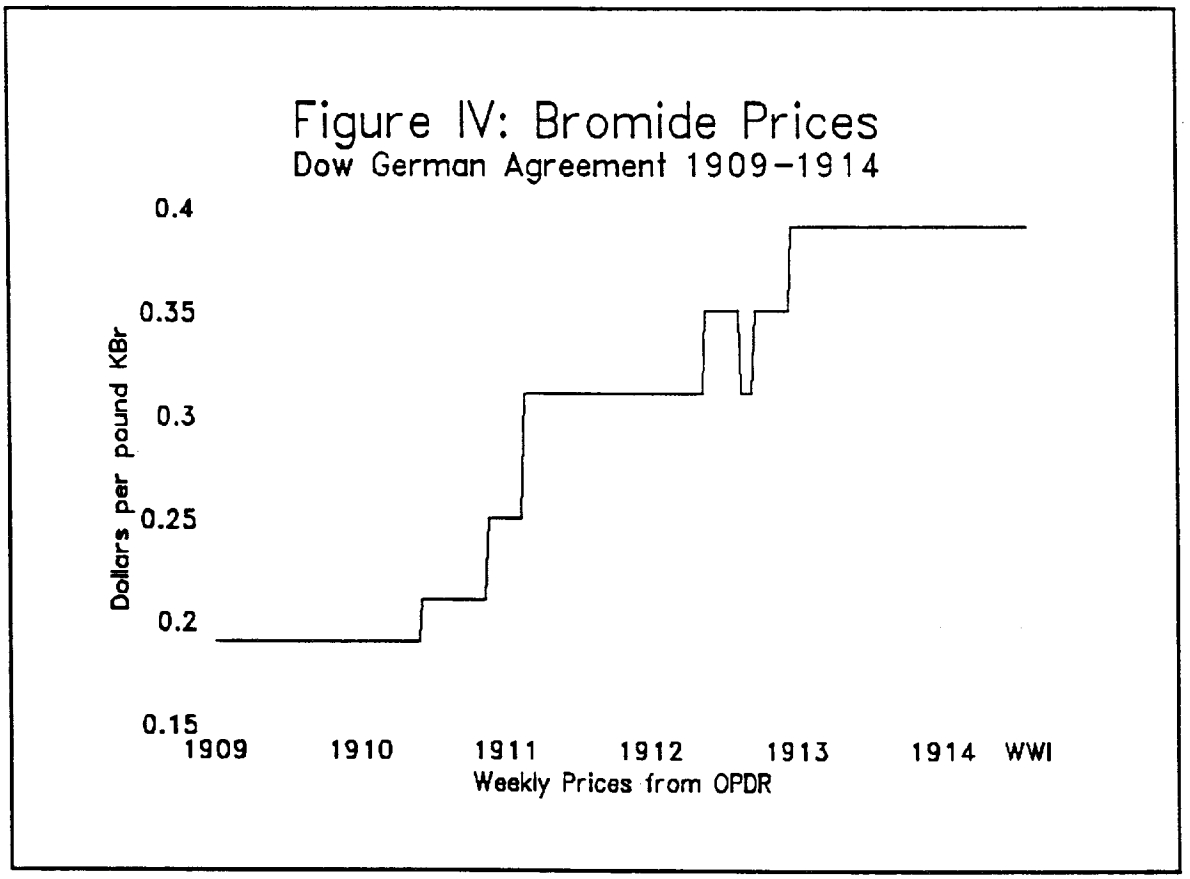
in the contract). Instead, Dow received a percentage of the price Merck and Rosengarten charged their customers for potassium bromide.

With the dissolution of the pool, the price of potassium bromide fell 45% in two months.[36] After an exchange of correspondence between Herbert Dow and Edward Mallinckrodt, in



[36]See letters from Rosengarten & Sons to Herbert Dow, October 21, 1902, enclosing Mallinckrodt's circular, and October 25, 1902, enclosing Powers & Weightman's circular, file #020062x. See also OPDR v. 62, October 27, 1902, p. 40, November 7, p. 40, December 1, p. 39, December 8, p. 39, and December 29, pp. 39-40, which report two price declines in October, after which the market remained "unsettled" for several weeks, but no further reported price reductions.

which each agreed not to undercut the price published in the Oil, Paint and Drug Reporter, the price of potassium bromide stabilized at 25¢ per pound (21¢ below the price that had prevailed until Dow withdrew from the pool; see figure III).[37]



These informal arrangements broke down in the beginning of 1905 with the outbreak of an international price war (Levenstein 1993). In response to Dow exports to Europe, the Germans offered bromides in New York at fifteen cents a pound, half the current market price. Dow, Mallinckrodt, and Merck ignored the offering, believing (as it turned out, correctly) that the Germans did not

[37]Letter from Herbert H. Dow to Edward Mallinckrodt, November 29, 1902, file #020040x.

intend to sell more than a few hundred pounds at the low price. But Rosengarten met the German price. He had recently acquired the firm of Powers & Weightman, including its inventory stock of potassium bromide. Concerned that he had over-extended himself financially and that the price of potassium bromide would fall further, he dumped P&W's thirteen year accumulation of potassium bromide inventories on the market. Cooperation in the bromine industry vanished. The price of bromides fell to ten cents a pound (figure III). Prices only began to increase in 1908 when Dow and the Germans came to an agreement to set prices jointly and divide the world market (figures III and IV).

III. How the Pool Worked

The operation of the pool contracts can be represented in a simple diagram. The following discussion focuses on the period 1885 to 1902, before the Dow Chemical Company decided to market its product independently of the pool. For simplicity, I treat the two distributors and the pool itself as a single distributor. I assume that there are several manufacturers, all using the same technology. In section III, I assume that there is no entry and neither manufacturers nor the distributor cheat. Those assumptions are relaxed in section IV, and the implications discussed.

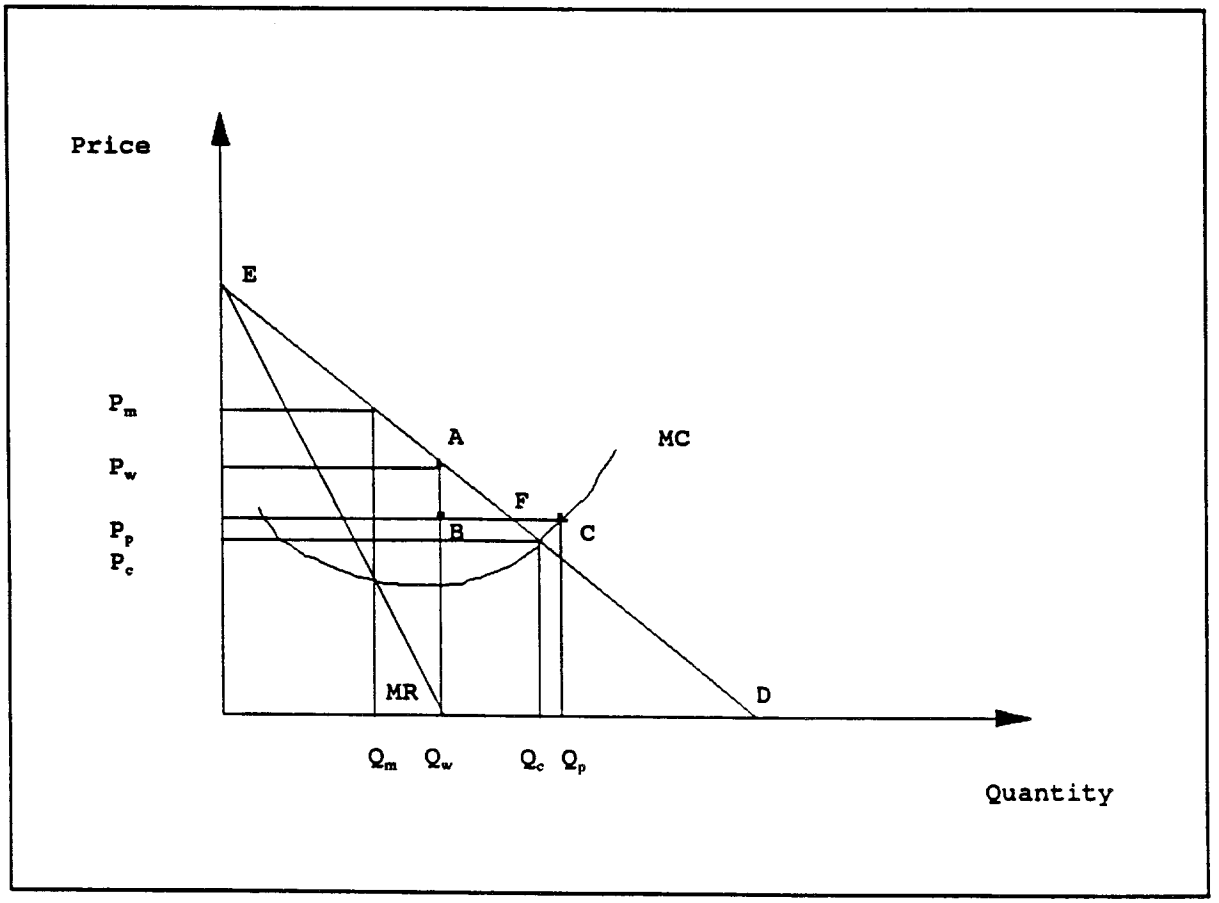


Figure V

P_m is the joint maximizing price, Q_m the joint maximizing output. P_c is the competitive price, Q_c the competitive output. P_p is the price specified in the pool contracts which the distributor has agreed to pay the manufacturer. The manufacturer produces, and sells to the distributor output Q_p. Because the distributor must purchase Q_p no matter how much it sells, the marginal cost of an additional sale is zero. Thus the distributor sells output Q_w (where MC=MR=0) for price P_w, and accumulates inventories Q_p-Q_w.

For any price $P_p > P_c$, the manufacturer will prefer this contract to the competitive equilibrium which would otherwise prevail. For any $P_w > P_p$, the manufacturer has an incentive to "cheat," that is, to sell output outside the pool. An increase in output sold to the pool did not constitute cheating.

The contract is profitable for the distributor only if rectangle P_wABP_p is larger than rectangle Q_wBCQ_p. The distributors in the pool always had the option of withdrawing from participation in the bromine market. Since they did not, this condition must have been satisfied, in this industry, at this time. There are five (not mutually exclusive) explanations of how this condition (the distributor's individual rationality constraint) was satisfied. The first two suggest that the nature of technology and demand in the bromine industry allowed this condition to be satisfied. Both these conditions are more likely to have been satisfied in the small, vertically dis-integrated, craft-based industries of the nineteenth century than was the

case after the entry of mass producing, mass marketing firms. The latter three are strategic explanations; firms in this industry may have engaged in behavior in order to satisfy the distributor's constraint.

First, P_wABP_p would be more likely to be larger than Q_wBCQ_p, and the distributor's constraint satisfied, if manufacturers faced rapidly increasing marginal costs for output levels greater than Q_w. The bromine capacity of individual Ohio River manufacturers was determined by the concentration of bromine in their local underground brine and the capacity of their sodium chloride salt operations to process this brine. At output levels between thirty and sixty thousand pounds, manufacturers faced a short run capacity constraint which would give rise to steeply increasing marginal costs. But, if manufacturers were truly capacity constrained at a level below Q_c in the long run, the pool would have been without a *raison d'être*. In the short run, capacity constraints limited the rate of accumulation of inventories. In the long run, entry or expansion could still bankrupt the pool.

Second, a steep marginal revenue curve would increase the distributor's profit and help to satisfy this constraint. Most of the participants in the industry believed that demand was quite inelastic.[38] If that was the case, it may be that P_w was

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[38]See, for example, letter from J. H. Osborn, president of the Midland Chemical Company, to Henry Cooper, its General Manager, November 18, 1896, file #960005x.

... There is no way of getting rid of the overplus [of

quite close to P_m (and P_p was sufficiently close to P_c) to satisfy the distributor's constraint.

Third, this constraint might have been satisfied by manufacturers voluntarily and independently limiting output below Q_p because they recognized that excessive inventory accumulation would bankrupt the pool.[39] There is no evidence in the documentary record of such a voluntary restriction of output. To the contrary, when the pool considered restricting some manufacturers' output to zero in return for a fixed payment equal to the expected profit on normal output (a practice the participants called "dead renting"), there was serious concern that at least this kind of extreme output restriction would be violated. This was the case even though detection of cheating would have been much simpler than in the case where the plant continued to operate at a lower output level.

Fourth, a low P_p would help to satisfy the distributor's constraint. The existence of large inventories was used to bargain down P_p when the pool's contracts with manufacturers came up for renewal. Shields argued that the pool could not afford higher prices because of the large "over-plus" (as he called it),

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bromine] that I can see except to reduce the production as the market will only take so much and even if you drop the price to 10 cents no more could be sold.

[39]This is the case in Bernheim and Whinston (1985) and (1986) where manufacturers limit output in order to increase the distributor's profit. Manufacturers are able to capture the entire profit in that case, however. The inability to capture all rents accruing to the pool may explain why manufacturers behaved more "shortsightedly" in this industry.

so concern about the over-accumulation of inventories may have led manufacturers to agree to a lower P_p, and indirectly a lower Q_p, than would otherwise have been the case.

Fifth, it may be that the rectangle P_wABP_p does not capture all of the distributor's profits. In particular, if the distributor was in a position to price discriminate, some customers may have paid more than P_w and some excess inventories may have been sold below P_w. Some of the surplus in the triangles P_wAE and ABF would then have been captured by the distributor. The published price quotations in the industry press include a discount for large quantity purchases. This might reflect price discrimination as well as lower packaging and transportation costs. There is evidence in the documentary record that large patent medicine producers, some of whom required a slightly different product (e.g. a fine powder or crystals), had long term contracts for their potassium bromide. These contracts presumably specified a different price from the published quotations. In these cases the distributors could distinguish between individual customers and prevent arbitrage because of the slight differences in the final product. The national sales force employed by the distributors may well have put them in a better position to price discriminate than the bromine manufacturers themselves.

Thus, inelastic demand, short run capacity constraints, some ability to price discriminate, and distributors' control of large inventory stocks all contributed to making participation in the

pool profitable to the distributors.

IV. Why the Pool Worked

We have established the conditions under which the participants in the industry would find this contract profitable. But as with all schemes to collude, the conditions that make it profitable to participate also created incentives for the destruction of collusion (Stigler 1964). Insiders had an incentive to cheat on the agreement; outsiders had an incentive to enter to become insiders. The bromine pool attempted to prevent cheating and entry by accumulating large stocks of bromides and using them to threaten price wars. These stocks themselves created a new source of instability as storage costs created an incentive to dump the inventories even in the absence of cheating. The bromine pool managed to limit or counterbalance these destabilizing incentives for seventeen years, either within formal contracts or with implicit or ad hoc agreements. In each case we find that distributors were better situated to stabilize the cartel - to deter entry, to deter cheating, and to hold large inventory stocks - than were the manufacturers themselves.

A. Barriers to entry

The distributors' participation in the bromine pool increased barriers to entry in four distinct, though related, ways. First, they used market power in other pharmaceutical markets to deter customers from purchasing bromine from other

distributors.[40] Second, by contractually tying all manufacturers to the distributors, they forced any firm trying to enter the industry independently of the pool to enter vertically integrated. This increased the capital requirements as well as the expertise necessary for entry. Third, by putting their own brand names on the potassium bromide they sold, they created reputational barriers to entry for new entrants who did not have the long standing in pharmaceutical products that Mallinckrodt and Powers & Weightman did.[41] Finally, they threatened to dump their accumulated stocks of bromides onto the market if new

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[40]See Bernheim and Whinston (1990) for a theoretical discussion of the role multi-market contact may play in supporting collusion. See letter from Herbert Dow to John Osborn, November 1903, discussing the necessity of Dow's offering a full line of bromine products if it were to work independently of the pool (file #030030x). Similar cross-market concerns were reported by Herbert Dow during 1907 when the industry was engaged in a bitter international price war. He wrote to the Company's president, A. E. Convers,

> We recently secured the contract of the Emerson Drug Company for their requirements of Bromide over 1908, amounting to about 100,000 pounds, at 14.5 cents f.o.b. Baltimore. The Germans had made them a price of 15 cents, and as some of the other constituents of Bromo Seltzer are of necessity purchased from Roessler & Hasslacher, they felt under obligation to buy of that firm (October 31, 1907, file #070018c).

[41]See letter from Herbert Dow to F. G. Trimble, September 20, 1905, indicating that a non-integrated attempt to enter the bromide market had failed, in part because of reputational considerations.

> Some 12 or 15 years ago we attempted to dispose of some Bromide on the open market, and we went all over the country offering it at about 60% of the recognized market value and could not dispose of it although our Bromide was better than the competing article. The wholesale Drug [sic] houses told us they had no demand for KBr of an unknown make, their demand being solely for P&W's ... Bromides (file #050039x).

entrants did not cooperate with the pool.[42] This strategy was apparently successful. Except for the Dow Chemical Company,

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[42]Threats of price wars both encouraged potential manufacturers to participate in the pool, and discouraged potential distributors from entering the market by distributing the output of "outside" manufacturers. When Dow entered the industry (as the Midland Chemical Company), the pool's representative explicitly threatened a drop in price if Dow did not cooperate with the pool (letter from W. R. Shields to H. H. Dow, December 9, 1892, file #920004x).

> ... After the dissolution of The National Bromine Co. in March 1891, the price of bromine came down from 25 to 15 cents last September, and at that price was a drug in the market. ... In October last I purchased the entire out-put of bromine for 5 years ... I have given your Mr. Hellman [sic] a copy of the contract. I am willing to buy your product at same price and terms provided we can agree as to what that product shall be. I am assured by Mr. H. that he will call a meeting of the company and act in the matter. The matter is in your hands. The party who gets the goods will not continue unless all are in and again I could not hold them together with anyone outside. In fact do not wish to.

When the Midland Company tried to sell independently of the pool, they found no buyers. While there is no concrete evidence that this was the result of fears of retaliation by the bromine pool's distributors, such fears are documented in 1897 when Dow was negotiating new contracts for the distribution of its bromides. See, for example, February 26, 1897 letter from B. E. Helman, Midland treasurer, to H. S. Cooper, Midland General Manager, indicating that negotiations with Merck to distribute Midland bromides had fallen through because Merck was afraid that a sharp fall in the price would follow such an agreement.

> ... I see no hope with Merck. They want us to take all the chance and are unwilling to fix any base price or guarantee any sale at all ... (file #970079c).

Similar negotiations in 1902 did result in agreement with two "outside" distributors, Merck and Rosengarten. The distributors continued to be unwilling to contract to any fixed price, so the 1902 agreement specified that each firm would purchase

> 250,000 lbs. of bromid per year for five years from Oct. 1st, 1902, at a price of 33 cents per lb. delivered, or 80% of the market price, at their option (Minutes of Midland Conference, April 14, 1902, file #020027x).

which entered the industry with a new, vertically integrated, and patented technology, there was no new entry into the industry in the United States at either the manufacturing or the distributing level between 1885 and 1902.

B. Disincentives to cheat

As discussed above, manufacturers had an incentive to cheat by selling some of their output to an outside distributor at a price in between P_p and P_w.[43] Not surprisingly, the pool used both "carrots" and "sticks" to discourage cheating. The most important "stick" was the threat of a price war in which bromide prices (and bromine prices) would fall sharply (Friedman 1971). The accumulation of large inventories as part of the regular operation of the pool made the implementation of this threat less expensive, and therefore more credible. The pool engaged in direct monitoring to increase the likelihood of detection, and therefore decreased the likelihood that price war punishments would be required.[44] The pool also attempted to deter cheating with "carrots," increasing an individual firm's profits from cooperating as the potential profits from cheating decreased.

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[43]As Stigler (1964) argues, the incentive to cheat is negatively related to the number of customers each firm has. There were many more pharmacies per distributor than distributors per bromine manufacturer. Thus the incentive to cheat was less at the distributor than the manufacturer level.

[44]See Green and Porter (1984) and Abreu, Pearce and Stacchetti (1986) for further discussion of optimal price wars under uncertainty. See Levenstein (1993) for more on the role price wars played in stabilizing the bromine pool.

Distributors monitored cheating by manufacturers. Shields, the "proprietor" of the bromine pool, monitored activity by manufacturers, such as shipments and the operation of plants in West Virginia and Ohio. Mallinckrodt and Powers & Weightman had salesmen who travelled the country and kept track of the bromine purchases of thousands of small pharmacies and patent medicine producers. They could observe fluctuations in the demand for other pharmaceutical products. This helped them to distinguish fluctuations in demand from the appearance of non-pool bromine supplies.[45] Their sales networks put distributors in a better position than a manufacturer to determine if another manufacturer was selling bromine outside the pool.

Distributors punished cheating when it occurred by releasing stocks of inventoried bromides onto the market. The existence of these inventory stocks, and the threat of a low market price they implied, decreased a manufacturer's incentive to cheat.[46] This threat was frequently not only implied but made quite explicit.[47] As the stock of inventories increased, the cost of cheating also increased. This helps to explain the gradual increase in market

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[45]See Green and Porter (1984) for further discussion of the implications of the inability to distinguish cheating and demand fluctuations.

[46]See Rotemberg and Saloner (1989) for further discussion of the strategic role of inventory accumulation.

[47]See footnote 42 above for a discussion of these threats by executives of the Midland and Dow Chemical Companies. See letter from W. R. Shields to H. H. Dow, December 9, 1892, file #920004x, in which he warns Dow of a drastic price reduction in the event that he does not cooperate with the pool.

price (P_w) following the signing of pool contracts in 1885 and 1892 (figures I and II).[48]

Pool contracts also deterred cheating by increasing the benefits of cooperation as the benefits of cheating increased. There were variations over time and across firms in their incentive to cheat. As discussed above, the market price of bromides (P_w) increased gradually after cooperation was established. As P_w-P_p increased, so did manufacturers' incentive to sell outside the pool. After 1892, the pool contract attempted to counterbalance this increased incentive to cheat with an increased incentive to cooperate. Each year the contractually specified P_p increased.[49] That is, as P_w increased, the benefits to cheating increased; the pool contracts simultaneously increased P_p to increase the benefits to cooperation as well.[50] There was no direct tie between the market price and the price paid to the Ohio River firms, so that at any point in time the distributors still faced a fixed cost

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[48]Prices increased gradually after the signing of the 1885 contract. Inventories were dumped in price wars in September 1886 and October 1888. See Levenstein (1993) for further discussion of the bromine price wars. Prices again increased gradually after the resumption of cooperation. There were no price wars between 1892 and 1902, so inventories steadily increased. P_w reached new heights as well.

[49]See footnote 26.

[50]See Rotemberg and Saloner (1986) for a similar argument. In their model, changes in incentives for defection are driven by changes in fluctuations in aggregate demand. The degree of collusion possible falls as the incentive to defect increases. Here, the contract attempts to mitigate this effect.

per unit of product. This feature of the contract transferred greater rents to manufacturers as their incentive to cheat increased without changing the incentives to the distributors.[51]

Individual manufacturers of different size faced different potential gains from cheating. Increasing the price paid (per pound of elemental liquid bromine) over the duration of the contract made the transfer of rents proportionate to the output of the firm. The compensation received by the manufacturer was proportionate to its output, and thus its potential benefit from defection. Increased capacity increased a manufacturer's incentive to cheat; the pool contracts increased the benefit to cooperation as capacity increased by transferring larger rents to larger manufacturers.

C. Dumping Inventories

The strategic accumulation of inventories helped deter cheating and entry. But large inventories also had the potential to destabilize the cartel if they were dumped despite the absence of cheating. One would expect that, with positive inventory carrying costs, the continued accumulation of these inventories would eventually make the arrangement unprofitable for the distributor. Industry participants attempted to limit the rate of accumulation of inventories in various ways. They considered (and may have implemented between 1897 and 1900) plans to "dead rent" some firms, paying them their expected profit in return for

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[51]There is no reason to believe that production costs were expected to increase. The general price level fell over this period.

their producing no bromine. The contracts with the Midland, and later Dow, Chemical Company explicitly limited the amount Mallinckrodt and P&W were required to purchase each year. Despite these attempts to limit the accumulation of inventories, Mallinckrodt and P&W apparently needed to find other ways to dispose of excessive inventories. This is why Mallinckrodt and P&W agreed to sell to the Germans some of these inventories each year. At least in some years, the German purchases were simply dumped into the ocean. The Germans were willing to pay Mallinckrodt and P&W to prevent uncontrolled exports to Europe, and Mallinckrodt and P&W were willing to accept a low price for inventories that were costly to hold and potentially destabilizing to the pool.

These various methods of limiting inventory accumulation were sufficient to maintain the pool as long as the manufacturers optimal capacity was below some level (say, 100,000 pounds annually) and distributors were able to prevent significant new entry. No inventories were dumped between 1892 and 1905. By 1902 the pool structure had given way in the face of the Dow Chemical Company's enormous output capacity. (Between 1905 and 1908, Dow's output averaged almost a million pounds a year.) By 1905, the cost of holding large inventories had become too high, particularly given the uncertainty over the future price in a more competitive environment. So Rosengarten dumped everything.

V. Distributors better at storing inventories

Strategic inventories were used to enforce cooperation in

the pool. Distributors were in a better position to play the role of cartel enforcer than the manufacturers themselves. The capacity of individual manufacturers was relatively small compared to the size of the market. Their ability to increase production quickly was quite limited. Punishments requiring large quantities of output depended on the existence of inventoried stocks. The accumulation and storage of inventories by distributors was both less expensive and strategically more stable than inventory accumulation by the manufacturers themselves.

There were economies of scale in the storage of bromine. It was cheaper and safer to store bromine as potassium bromide than as liquid bromine. There were economies of scale in the transformation of bromine into potassium bromide salts which did not exist in the manufacture of liquid bromine. It was less expensive for the industry to centralize processing of potassium bromide and store output in that form.

Centralized inventories avoided the creation of tensions among manufacturers because of the uneven accumulation of inventories.[52]

Most importantly, the distributors seem to have been in a better position to commit <u>not</u> to dump inventories unless they believed cheating to have occurred. This was at least in part

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[52]Rotemberg and Saloner (1989) makes this point. It seems reasonable, but I have no direct evidence of a concern regarding uneven accumulation of bromine inventories, even between the two distributors.

because the distributors were larger and more diversified, and therefore less risk averse, than the manufacturers.[53] This helps to explain the greater success of pools which relied on independent distributors rather than captured joint sales agencies. Captured agencies were frequently a creation of the pool itself, and only distributed the products of pool members. Fluctuations in the price of output had a proportionately much greater impact on the balance sheet of a firm whose principal asset was inventories of that output than was the case for multi-product distributors like those in the bromine industry. It was the loss of that (relative) risk neutrality on the part of one bromine distributor that led to the final demise of cooperation in 1905. Having just purchased Powers & Weightman, and its large stock of bromides, Rosengarten's firm was in a more precarious position financially than previously had been the case. Rosengarten's fear that the price of bromide would continue to fall, further cutting the value of his recent investment, explains his decision to put P&W's entire stock of bromides on the market at once. When the risk preferences of the distributor changed, the market's ability to sustain a collusive outcome disappeared.

VI. Conclusion

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[53]Risk neutrality on the part of the distributor is also required in Bernheim and Whinston (1985 and 1986), though for a different reason than I emphasize here. In the bromine industry, the distributor is not only assuming all the risk of fluctuations in demand, which is what Bernheim and Whinston require, but also assumes additional risk by accumulating large inventories.

Manufacturers and distributors in the bromine industry successfully colluded to increases prices and profits from 1885 to 1902. Distributors were crucial to the success of collusion because they were in a better position both to monitor and to enforce the collusive agreement. They accumulated large stocks of inventories and explicitly threatened to use them to punish wayward industry participants or any new entrant. In return, distributors received a large portion of the rents accruing to collusion. With the accumulation of inventories and experience, bromine prices, and distributors' profits, increased. Manufacturers in turn demanded a share of the increasing rents, and, in 1892, a new contract gave them that increasing share while carefully balancing the incentives for continued good behavior with the rising incentives for cheating.

The pool came to its demise because of the entry of a new firm using mass production technology. Producing at levels orders of magnitude greater than the older manufacturers, the Dow Chemical Company had the incentive to invest in the vertically integrated entry that would allow it to bypass the pool.

This study of the bromine industry suggests that further study of the role of distributors in facilitating collusion is in order. Bernheim and Whinston (1985 and 1986) provide a possible explanation of the role of distributors in industries where entry is effectively blocked, but the intuition of their model is not borne out in this industry, where distributors receive cartel rents in part because they increase the barriers to entry. The

bromine industry also provides a very concrete example of the strategic use of inventories hypothesized by Rotemberg and Saloner (1989). It also demonstrates that firms are very capable of designing contracts that allow for fluctuations in a firm's incentive to cheat. The bromine pool contracts simply created parallel incentives for continued cooperation.

Like most American industries in the third quarter of the nineteenth century, the bromine industry was made up of a number of small manufacturers using craft production methods. Unlike firms in the earlier part of the century, however, the transportation revolution meant that they increasingly competed in national, and even international markets. As in many other industries, they cooperated with distributors who were accustomed to operating in larger markets in order to control the intensity of competition in the new economic environment. This arrangement worked for a period, creating profitable opportunities for both local manufacturers and national distributors. The very technological and economic factors which gave rise to the transportation revolution eventually undermined these collusive arrangements by giving rise to a new economic institution - the large, vertically integrated, mass production corporation.

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Bibliographical Note

The Herbert and Grace Dow Collection is housed in the Post Street Archives, Midland, Michigan. Brandt and Brennan (1990) provides a guide to the collection.

The Oil, Paint and Drug Reporter was first published in 1871. Volumes preceding the First World War are housed in the Baker Library (Harvard University), the Boston Public Library, the New England Depository Library, and the Rackham Library (University of Michigan). It has been superseded by the Chemical Marketing Reporter.