

Cartel Price Announcements: The Vitamins Industry

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Abstract

The primary manufacturers of vitamins admitted to participating in international cartels for several years during the 1990s. They announced their price increases in leading trade journals. We show that price announcements, and the leads times before these prices took effect, during the admitted cartel period were fundamentally different in character from the announcements prior to 1985, when explicit collusion was less likely. These differences are consistent with our model of price announcements. Logit estimates show that after 1985 the likelihood of a price announcement is largely driven by the length of time between announcements, rather than cost or demand factors. The importance of inter-announcement time intervals suggests that the price announcements after 1985 stem from cartel meetings, which occurred at regular intervals. The evidence is consistent with explicit collusion, at least among a subset of firms, for a period of time that starts up to five years before the period of admitted collusion.

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1 Introduction

Cartels commonly coordinate public price announcements by the member firms. For example, international cartels in the vitamins industry coordinated announcements of price increases, including the designation of which company would lead the price increase.¹ As another example, in the Rubber Chemicals Cartel, one of the components of the conspiracy was “issuing price announcements and price quotations in accordance with the agreements reached.”² Similar charges have been made against firms in sorbates,³ monochloroacetic acid and organic peroxides,⁴ polyester staple,⁵ high pressure laminates,⁶ and graphite electrodes.⁷ In this paper, we explore the role of public price announcements in supporting collusive behavior and examine the data on public price announcements in the vitamins industry.

The primary manufacturers of vitamins, which admitted to participating in explicit international cartels for several years during the 1990s,⁸ publicly announced their price increases in leading trade journals.⁹ The public price announcements during the admitted cartel period are fundamentally different in character from the price announcements prior to 1985, when explicit collusion was less likely. First, there are far more price announcements after 1985 than before 1985. Second, for the feed grade vitamins considered in this paper, all but one of the announcements prior to 1985 are made by a single firm, but the majority of announcements made after 1985 are led by one firm and then matched by at least one other firm within ninety days (we refer to these as joint announcements). Third, prior to 1985, firms other than the market leader, Hoffmann-LaRoche Ltd. (Roche),¹⁰ never led joint an-

¹United States v. F. Hoffmann-La Roche Ltd, Crim. No. 3:99-CR-184-R, May 20, 1999, Transcript of Plea of Guilty and Sentencing at 10–11.

²U.S. Department of Justice Press Release, “Crompton Corporation Agrees to Plead Guilty for Participating in Rubber Chemicals Cartel,” March 15, 2004. Available at: http://www.usdoj.gov/opa/pr/2004/March/04_at_160.htm

³U.S. Department of Justice Press Release, “Top Japanese Executives Indicted in Price-Fixing Conspiracy,” July 25, 2000. Available at: <http://www.usdoj.gov/opa/pr/2000/July/423at.htm>.

⁴U.S. Department of Justice Press Release, “International Chemical Corp. Agrees to Plead Guilty, Pay Fines for Participating in Multiple Criminal Antitrust Conspiracies,” March 14, 2002. Available at: http://www.usdoj.gov/atr/public/press_releases/2002/10835.wpd.

⁵See *Hollinee LLC vs. Nan Ya Plastics Corp., et al.*, U.S. District Court, Western District of North Carolina, Charlotte Division, October 2002.

⁶“*In Re: High Pressure Laminates Antitrust Litigation*,” Master File No.:00 MD 1368 (CLB), U.S. District Court for the Southern District of New York, June 18, 2003.

⁷U.S. Department of Justice Press Release, “German Company and Chief Executive Officer Each Agree to Pay Record Fines for International Conspiracy,” May 4, 1999. Available at: http://www.usdoj.gov/atr/public/press_releases/1999/2411.htm.

⁸An “explicit” cartel in this paper refers to one in which a subset of firms in the industry directly communicate with one another with the agreed intent to take actions that will increase profits above levels that would have been achievable in the absence of such communication.

⁹Although the Vitamins Cartel was international in breadth, our empirical analysis relies only on public price announcement data for the U.S.

¹⁰According to Connor (2001, Table 10.2), in 1995 no firm had a larger global market share than Roche

nouncements, but after 1985, firms other than Roche frequently led joint announcements.¹¹ Fourth, after 1985 public price announcements often had long lead times before the new price became effective. Fifth, after 1985 price announcements occur in somewhat regular intervals and increase at a steady rate. An explanation for these observed phenomena is offered in this paper.

To the best of our knowledge, there is no other study that analyzes price announcements during a period of admitted explicit collusion.¹² In all other empirical studies of which we are aware, it is unknown whether the firms in the industry were acting non-collusively (tacitly colluding) or functioning as an explicit cartel. Thus, this paper provides a unique window into how explicit cartels use price announcements, which are an important aspect of cartel behavior because they are observable, in real time, by both customers and law enforcement.

In Section 4, we develop a model of price leadership (without explicit collusion) for an industry with homogeneous products and capacity constraints similar to those in the vitamins industry by adapting the duopoly model of Deneckere and Kovenock (1992) to allow firms to have positive sales even if they do not publicly announce a price. We show that in the absence of explicit collusion, (i) there are equilibria in which no firm makes a price announcement, (ii) there are equilibria in which the larger firm makes a singleton announcement or leads a joint announcement, and (iii) there are no equilibria in which the smaller firm makes a singleton announcement or leads a joint announcement. This model provides a way for us to understand the behavior in the vitamins industry prior to 1985, but is inconsistent with the observed behavior after 1985.

To understand public price announcements during the period of admitted explicit collusion, we look at the buyer side of the market. Industrial buyers do not passively accept list or posted prices. In fact, buyers will receive negative performance evaluations if they are perceived as doing so. In the absence of comparative information, and with no way to verify supplier assertions regarding cost and/or demand shocks as the cause of price increases, buyers may exert unusual effort in pursuit of lower prices. Such efforts are contrary to the interests of the cartel. Thus, a cartel seeks to provide ways for buyers to justify higher prices, such as having numerous cartel firms publicly announce the same price, and raising prices at a moderate rate. These steps ease the burden of a buyer in providing evidence to superiors

in any of the vitamins considered in this paper.

¹¹“The parties normally agreed that one producer should first ‘announce’ the increase, either in a trade journal or in direct communication with major customers. Once the price was announced by one cartel member, the others would generally follow suit.” ECD 203. “In this way the concerted price increases could be passed off, if challenged, as the result of price leadership in an oligopolistic market.” ECD 204.

¹²Stigler (1947) provides a brief comparison of the number of price changes during periods with and without explicit collusion for several industries. Wilcox (1940) provides descriptions of price leadership in a number of industries, some of which are known or believed to have been engaged in explicit collusion.

that a price increase could not be resisted, at least not in a cost-effective way.

To analyze whether the price announcements we observe might be related to market phenomena (and not necessarily collusion by firms), we estimate a logit model for the probability that firms announce a price change in a given month as a function of the time elapsed from the previous announced price change, as well as potential cost and demand triggers for a price change. We find that prior to 1985, the time elapsed from the previous announced price change is not a significant driver of new price announcements; however, after 1985, the probability of a new price announcement is positively related to the amount of time elapsed from the previous announced price change. We interpret these results as implying that the timing of price announcements after 1985 is driven by explicit communication between firms and is tied to the timing of cartel meetings.

Although firms did not plead guilty to price fixing prior to the late 1980s or 1990, depending on the vitamin, the characteristics of price announcements between 1985 and the beginning of the period for which firms pled guilty is essentially indistinguishable from the characteristics of price announcements during the period when the firms admitted to explicit collusion. Thus, it seems reasonable to conclude from the price announcement data that explicit collusion in the vitamins industry began as early as 1985, at least among a subset of firms, many years prior to the periods for which the Department of Justice (DoJ) obtained guilty pleas and the European Commission issued findings.

This paper provides insight into how one might structure an empirical investigation to determine the existence of explicit collusion. Of course, as with any investigation of collusion or cartel behavior by firms in an industry, the analysis is tailored to a specific industry. Nevertheless, it is reasonable to extend this analysis to industries with the same general characteristics as the vitamins industry: high concentration, high entry barriers, homogeneous products, and highly inelastic demand.

In terms of public policy, it is noteworthy that the cartel chooses substantial lead times for making newly announced prices effective. Implementation of a higher price often requires interaction between managers of different firms who are orchestrating the conspiracy, especially since their sales staffs do not have explicit knowledge of the conspiracy and thus certain interventions may be required by conspiring managers to avert customer shifts that disrupt market share allocation targets. But substantial lead times for the effective dates of newly announced prices is a facilitating practice that is observable and can be enjoined by enforcement authorities.

The paper is organized as follows. Section 2 contains a description of the vitamins industry, including the cartel behavior of the 1990s. Section 3 reviews the relevant economic literature. Section 4 presents a model of price announcements. Section 5 describes the price

announcement data and contains our empirical analysis. Section 6 provides a discussion.

2 The Vitamins Industry

2.1 Overview

Vitamins are purchased for both human and animal consumption. Each vitamin has a specific set of beneficial effects. Table A.1 in Appendix A provides a list of known and potential benefits of the six vitamins that are the focus of this paper.¹³ The rapid advances in meat and poultry production in the past 40 years have largely come from a better understanding of the role of vitamins and amino acids in facilitating the growth of animals. For example, in 1925 it took 112 days for a broiler chicken to reach maturity for slaughter while in 2000 the same weight bird could be produced in 46 days.¹⁴

The text following Table A.1 in Appendix A provides a more detailed discussion of the vitamins industry, but the salient features of the industry are as follows: 1. Vitamins are largely produced through processes of chemical synthesis, with petroleum as a primary factor input, although fermentation technologies can be used for some vitamins. 2. The vitamins industry is highly concentrated. 3. The large capital investments and production experience required for the manufacture of vitamins are a barrier to entry. 4. When considering the cost of producing animal feed or human food, the incremental cost of vitamin additives is small. 5. A given vitamin product made by one firm is chemically identical to the same product made by another firm. 6. With the possible exception of the Chinese, most sizable producers of vitamins were involved in explicit collusion throughout much of the 1990s.

2.2 The Vitamins Cartel

In the late 1990s, the DoJ obtained guilty pleas from several major vitamin manufacturers for participating in an international price fixing cartel that extended back to at least January 1990.¹⁵ In this report, we refer to the interval of the plea dates as the “plea period.” Detailed descriptions of the vitamins conspiracy can be found in the European Commission’s (2003)

¹³Vitamins are sometimes referred to by both a chemical name and an alphanumeric sequence. For example, “Calpan” is Vitamin B5. See Table A.1 in the Appendix.

¹⁴Delmarva Poultry Industry, Inc.:

<http://www.dpicken.org/download/U.S.%20Broiler%20Performance.doc>

¹⁵In addition, the European Community and Canada found that several of the vitamin producers had violated antitrust laws within their jurisdictions. Table A.3 in Appendix A identifies the firms and plea dates for each of the vitamins. Table A.4 in Appendix A provides the criminal penalties levied against each firm by the DoJ for their participation in the conspiracies.

decision, hereafter ECD. The following excerpt from the DoJ’s Sentencing Statement of Roche also provides important characterizations of the cartel’s organization and behavior.

On a quarterly basis, regional and world marketing managers from the conspirator companies would meet to exchange pricing and sales information in order to have an accurate picture of the overall global demand and price for the vitamins. Once a year, the global marketing directors for each of the conspirator companies, in concert with the various product managers for the companies, would conduct a “budget” meeting. During this meeting, the overall global sales volume for the vitamins would be determined for the current year, and ... the global sales volume for the coming year would be determined. Next, each company would be allocated a percentage of this projected global market demand.... Finally, vitamin pricing would be reviewed and, if price increases were needed to either account for currency discrepancies or to raise profit levels, new pricing would be agreed upon, to include the timing of the price increases and designation of which company would lead the price increase.¹⁶

An explanation for this complex apparatus is provided by Stigler in his seminal 1964 paper. Stigler notes in his paper that the central problem of a cartel is to thwart the incentive to secretly cut prices. A secret price cut by a cartel member benefits the member in the short run but undermines the overall profitability of the cartel in the long run. Stigler characterized a solution that a cartel might employ as follows:

1. Allocate fixed market shares to each cartel participant.¹⁷
2. Monitor output of each cartel participant.
3. Reallocate resources within the cartel to adjust for issues that may arise.¹⁸

Stigler (1964) does not mention the need for public price announcements by the colluding firms, but the discussion in the introduction of cartels that explicitly coordinated public price announcements suggests they have value to a cartel. These announcements are the focus of this paper.

¹⁶U.S. v. F. Hoffmann-La Roche Ltd, Crim. No. 3:99-CR-184-R, May 20, 1999, Transcript of Plea of Guilty and Sentencing at 10–11.

¹⁷These shares would be fixed within the cartel, not fixed with respect to the industry as a whole.

¹⁸Although not explicitly described in the Sentencing Statement, the ECD indicates that the cartel used interfirm transactions as a mechanism for rectifying any internal issues that arose. (ECD at 225, 590). For example, “Any company that sold more than its allotted share was required in the following year to purchase the excess from another conspirator that had not reached its volume allocation target (U.S. Department of Justice (2000), “International Competition Policy Advisory Committee to the Attorney General and Assistant Attorney General for Antitrust Final Report,” Chapter 4, p.172 (<http://www.usdoj.gov/atr/icpac/chapter4.htm>)).

3 Literature Review

The early literature on price leadership, particularly Stigler (1947), Markham (1951), and Bain (1960), attempts to create a taxonomy within which to view price announcements.¹⁹ It identifies several types of price leadership, including dominant firm price leadership, competitive barometric price leadership, and collusive price leadership (also called monopolistic barometric price leadership). However, this work does not explicitly distinguish between public price announcements and all other ways of notifying buyers of a price increase.²⁰ Our work is unique in this regard.

In dominant firm price leadership, one large producer sets prices, and competitive fringe firms act as price takers.²¹ In competitive barometric price leadership, changes in prices merely reflect changes in market conditions.²² In collusive price leadership, as described by Markham (1951), there need not be an explicit agreement among firms, but the process of price announcements itself serves to coordinate firms' prices at the collusive level. Distinguishing among the various types of price leadership requires an analysis of the industry and of the price announcement behavior.

Rotemberg and Saloner (1990) provide a theoretical model of collusive price leadership in which firms have private information and in which price announcements allow firms to maintain prices above the competitive level without an explicit collusive agreement (although prices are lower than with explicit collusion). In another theoretical model of collusive price leadership, Deneckere and Kovenock (1992) consider a capacity-constrained duopoly with one large firm and one small firm and show that the large firm emerges as the price leader.²³ The intuition for their result is that when the large firm acts as a price leader, it provides a price umbrella, allowing the small firm to undercut and sell all of its capacity. However, when the small firm, which loses more from being undercut, leads, it acts aggressively to discourage matching or undercutting. Thus, the small firm prefers to follow; and in the equilibrium of a timing game, the large firm acts as the price leader and the small firm

¹⁹The literature also contains a number of industry studies that examine the role of price announcements. For a summary of many of these, see Scherer (1980).

²⁰A firm could notify only its incumbent customers of a price increase. Or a firm could offer no formal notification at a point in time and just let its new pricing become clear as it "does deals."

²¹See also D'Aspremont et al. (1983) for price leadership with a dominant cartel and competitive fringe.

²²For example, one firm that has become better informed than the others about new market conditions might announce a change in price, and the others follow rather than engaging in costly information acquisition themselves (see Cooper (1997)).

²³Holt and Scheffman (1987) also provide a model of price announcements, focusing on the role of best-price guarantees and most-favored-customer clauses. Kovenock and Widdows (1998) provide a dynamic model of duopoly price adjustments in response to demand shocks and show behavior may differ depending on which shocks are positive or negative.

follows.²⁴

The aforementioned models of price leadership are non-collusive (including models of “collusive price leadership”) in the sense that they can be sustained as a non-cooperative equilibrium in a game with repeated interaction among firms. We are not aware of prior theoretical model of price leadership in an environment with explicit collusion.

Empirical studies of price leadership have been conducted for a number of industries, including cigarettes, steel, automobiles, ready-to-eat cereals, turbogenerators, gasoline, newsprint, and cheese.²⁵ For each of these industries, for the period in which the price leadership behavior is studied, there is no claim that the firms were explicitly colluding.²⁶

4 Modeling Price Announcements

In this section, we first consider a model of non-collusive price announcements and derive empirical implications, which will potentially allow us to reject the hypothesis of non-collusive behavior in the vitamins industry for time periods other than the plea period. Then, in Section 4.2, we discuss the role of public price announcements in an explicit cartel.

4.1 Non-Collusive Price Announcements

We consider a model with two firms, 1 and 2, that produce homogeneous products and have identical variable costs, where firm 1 has greater capacity. Letting k_i denote the capacity of firm i , we assume $k_1 > k_2$. We consider a price-setting game similar to that considered in Deneckere and Kovenock (1992), hereafter DK. In contrast to the model of DK, to account for the features of the vitamins industry, we allow the possibility that firms can have positive sales even if they do not make a public price announcement. We retain the DK assumption of efficient rationing and the assumptions that there exists a choke price for demand,²⁷ and that demand, $d(p)$, is twice continuously differentiable, decreasing, and concave. As in DK, if the firms simultaneously announce the same price, then demand is allocated proportionally to capacity, and if the firms sequentially announce the same price, then the follower sells to capacity first.

²⁴Similar results hold in a model without capacity constraints, but with customer loyalty (see Deneckere, Kovenock, and Lee (1992)) and in a model in which products are imperfect substitutes (see Furth and Kovenock (1993)).

²⁵See the references in Scherer (1980, pp.176–184); Booth et al. (1991); and Mueller et al. (1997).

²⁶Bain (1959, p.277) and Markham (1951, p.904) suggest that explicit agreements among firms may enhance the effectiveness of price leadership.

²⁷Formally, assume that there exists a $p_0 > 0$ such that for all $p \geq p_0$, $d(p) = 0$ and for all $p < p_0$, $d(p) > 0$.

Firm i 's payoff in the static simultaneous-move game given the realized prices and capacities is:

$$\pi_i^S(p_i, p_{-i}) \equiv \begin{cases} p_i \min \{k_i, d(p_i)\}, & \text{if } p_i < p_{-i} \\ p_i \min \{k_i, k_i d(p_i)/(k_1 + k_2)\}, & \text{if } p_i = p_{-i} \\ p_i \min \{k_i, \max \{0, d(p_i) - k_{-i}\}\}, & \text{if } p_i > p_j. \end{cases}$$

In this environment, DK show that if total capacity is large relative to demand, but neither firm has sufficient capacity to serve the whole market,²⁸ which we assume to be the case, then the unique equilibrium of the simultaneous-move price-setting game is in mixed strategies.

If one firm leads and the other follows, then firm i 's payoff given the realized prices and capacities is:

$$\pi_i^{LF}(p_i, p_{-i} | I_\ell^i) \equiv \begin{cases} p_i \min \{k_i, d(p_i)\}, & \text{if } p_i < p_{-i} \\ p_i \min \{k_i, \max \{0, d(p_i) - I_\ell^i k_{-i}\}\}, & \text{if } p_i = p_{-i} \\ p_i \min \{k_i, \max \{0, d(p_i) - k_{-i}\}\}, & \text{if } p_i > p_j, \end{cases}$$

where I_ℓ^i is an indicator that is one if i is a leader and 0 if i is a follower.

We let π_i^S denote firm i 's payoff in the equilibrium of the simultaneous-move game. We let π_i^L and π_i^F denote firm i 's payoff in the subgame-perfect equilibrium when it is the leader or follower, respectively. DK show that for the larger firm, $\pi_1^L = \pi_1^F = \pi_1^S$, but for the smaller firm, $\pi_2^L = \pi_2^S < \pi_2^F$. As mentioned in the previous section, the intuition for this result is that when the larger firm acts as the price leader, it provides a price umbrella, allowing the smaller firm to undercut it slightly and sell all of its capacity. Because the smaller firm loses more from being undercut, when the smaller firm acts as the leader, it prices aggressively. Thus, the smaller firm prefers to act as a follower. The larger firm is indifferent between acting as leader or follower or announcing prices simultaneously.

We consider the following price announcement game. There are three periods. In the first two periods, firms can make price announcements. In the first period, firms simultaneously make announcement decisions (whether to make an announcement, and, if so, at what price). In the second period, any firm that did not announce in the first period can make an announcement (as in the first period, announcement decisions are simultaneous). This allows the possibility that either firm can be the price leader or that firms can make simultaneous announcements. If neither firm announces a price, then firms simultaneously choose prices in the third period, and then payoffs are realized.

²⁸Specifically, it must be that the price that maximizes $p_2 \min \{k_2, \max \{0, d(p_2) - k_1\}\}$, denoted $p_2^H(k_1, k_2)$, satisfies $p_2^H(k_1, k_2) > d^{-1}(k_1 + k_2)$. The price $p_2^H(k_1, k_2)$ is unique given our assumptions and can be interpreted as a capacity-constrained monopoly price on the residual demand curve $d(p) - k_1$.

Given firms' prices, payoffs are as in DK, with the exception that any firm not announcing its price in one of the first two periods incurs an additional payoff $x \geq 0$. A strictly positive value of x reflects additional value to a firm when it is not constrained by an announced price. For example, in the absence of an announced price, a firm may have greater flexibility to set different prices to different customers.

We can now characterize the subgame perfect equilibria (SPE) of this game. For example, if $x = 0$, there is a SPE in which firm 1 announces a price in the first period and firm 2 announces a price in the second period—a joint price announcement led by firm 1. To support this equilibrium, specify that if no firm announces in the first period, then firm 1 announces its leader price in the second period and firm 2 does not announce a price. There is also an equilibrium in which firm 1 announces a price in the first period and firm 2 does not announce a price—a singleton price announcement by firm 1. Finally, there is an equilibrium in which neither firm announces a price. In this case, firms simultaneously choose prices in the third period. Despite the multiplicity of equilibria, it is noteworthy that there is no SPE in which firm 2 makes a singleton price announcement or leads a joint price announcement. There is also no equilibrium in which firms simultaneously announce prices.

We begin with the following lemma.

Lemma 1 *If $x > 0$, the unique SPE of the subgame after no firm announces a price in the first period is for no firm to announce a price in the second period.*

Proof. See Appendix B.

Using Lemma 1, we can prove the following result.

Proposition 1 *There is no SPE in which the small firm makes a singleton announcement or leads a joint price announcement, and there is no SPE in which firms simultaneously announce prices.*

Proof. See Appendix B.

Using Proposition 1, in the absence of explicit collusion, we would not expect to see the smaller firm leading a joint price announcement. When we do see public price announcements, we should expect to see singleton price announcements by the larger firm or joint price announcements led by the larger firm. We summarize these results in the following corollary.

Corollary 1 *In any non-cooperative SPE, either (i) there are no price announcements, (ii) the large firm makes a singleton price announcement, or (iii) the large firm leads a joint price announcement.*

The empirical implications of this result for the vitamins industry are that in a period without explicit collusion, we should expect to see no announcements, singleton announcements by Roche, or joint announcements led by Roche. We would not expect the identity of the firm leading joint announcements to change.

Proposition 1 and Corollary 1 provide us with predictions on price announcement behavior in a period without explicit collusion. But what role do price announcements play during a period of explicit collusion? This is the subject of Section 4.2.

4.2 Collusive Price Announcements

We can provide several reasons why joint public price announcements led by different cartel firms might be valuable to the cartel members. First, in the absence of public price announcements, the presence of multiple firms charging identical prices might raise suspicion among antitrust authorities. But if one firm leads by announcing a price, and then the other firms “follow” by announcing the same price increase shortly thereafter, then the cartel creates an explanation for identical prices other than illegal interfirm communication regarding prices. Second, if joint price announcements are always led by a single firm, for example the market leader, then that firm risks being identified as the “cartel leader” should the cartel face prosecution by antitrust authorities. Thus, members of a cartel may rotate which firm is designated to lead the joint price announcements. Third, joint price announcements by the members of the cartel can facilitate collusion by increasing the likelihood that a cartel price increase is “accepted” by buyers. It is this last benefit of public price announcements that we now consider in more detail.

Consider an oligopoly in which the firms are explicitly colluding, including entering into a market share agreement, agreeing to provide verifiable information to one another regarding output and sales, and committing to engage in redistributions should there be deviations from the agreed upon market shares. With these agreements in place, the firms can now address the issue of increasing profits through price increases.

Clearly the cartel members need to coordinate their prices; otherwise, they would invariably find themselves bidding different prices or notifying customers of different prices. The consequence would be a shift by customers to the firm offering the lowest price. Realized market shares would tend to be different from agreement and frequent redistributions would be required.

Given that many buyers conduct competitive procurements,²⁹ it seems that it would be sufficient for the colluding suppliers to rig bids. But if bids are rigged, what is the role of public price announcements? Industrial buyers are evaluated on a number of criteria. If prices ascend in sequential procurements and there is no public indication of increasing prices, then the buyers' performance will be questioned by supervisors. Thus, buyers faced with ascending prices who have no public indication that prices should be rising and who have no information about the prices paid by buyers at other firms will aggressively challenge the price. This may be done in a number of ways. They may seek third party suppliers, such as product brokers, to see what supplies they have available. They may investigate foreign supplies that they had previously ignored. They may actively involve the engineering department at their firm in determining the feasibility of substitute products or, alternatively, reductions in the use of the product in question. All of these efforts are contrary to the interests of the cartel. The cartel wants the buyers to "accept" the price increases. To avoid these efforts to challenge price increases, the members of a cartel publicly announce their price increases.³⁰

There are additional beneficial features of a public price announcement for a cartel. If each firm publicly announces the same price with the same effective date then firm A has told firm B's customers, and firm B has told firm A's customers that there is no gain to challenging the price increase by soliciting a bid or price quote from a non-incumbent supplier. Furthermore, public price announcements alleviate any challenge by antitrust authorities regarding knowledge of a competitor's pricing intentions. Also, a market share agreement is easier to enforce when the firms have stable customer relations, which naturally occur with identical public price announcements. In fact, a sudden shift in incentives for a sales force away from pursuit of market share and towards implementation of price increases could be an indication of the formation of a cartel.

Announcing substantial lead times for the effective date of a newly announced price may be an important part of implementation of the new price by a market share cartel. The sales force of a cartel firm will typically have no direct knowledge of the conspiracy. It is natural for a sales force to seek new customer accounts or retain existing ones, and one way to do that is to offer price concessions. If an aggressive sales force views a newly announced price increase as an opportunity to pursue new accounts through secret price concessions, then a market share cartel will find itself undergoing excessive year-end interfirm redistributions to

²⁹In industrial buying, buyers are motivated primarily by profits. Competitive procurements are common, although some contracts are extended without competition, at least for some incremental time period. Split awards are frequent.

³⁰One can also view a public price announcement as providing a "reference price" as described in Thaler (1985).

“true-up” market shares per the cartel agreement. In addition, having market shares move dramatically out of line during the course of a year may be destabilizing to a cartel because firms whose market shares are below their allocations may become concerned about whether or not year-end redistribution will occur.

There are several reasons why a cartel would not increase prices dramatically in one step upon its inception. First, cartel members do not initially know the reliability of their co-conspirators. Incremental steps in price reduce incentives for cheating and give the cartel time to gain confidence in the quality of its monitoring and its members’ willingness to engage in redistributions when realized shares differ from agreed shares. Second, buyers are more likely to resist a large price increase. Third, large price increases may generate attention from antitrust authorities.

Overall, a market share cartel could function without public price announcements, but the cost of enforcing the cartel agreement would be higher, the threat of instability and breakdowns would be higher, and the chance of drawing the attention of enforcement authorities would be higher.

5 Data

In the United States, vitamins manufacturers typically announce price increases in two weekly trade journals—*Feedstuffs* and the *Chemical Marketing Reporter*. Our data come from an exhaustive review of these journals from 1970 to 2001. We believe we have been able to construct a complete set of the public price announcements used by the vitamins manufacturers in the United States during this time period.

There are many vitamin products for which price announcements exist other than those reported in this paper. We selected those products in which both Roche and BASF were major manufacturers during the entirety of the respective plea periods.^{31,32} Although both Roche and BASF produced Thiamine (B1), Carotenoids (other than Beta Carotene), and Vitamin D3 (see Table A.2), we exclude these vitamins because BASF exited production of Thiamine in 1989, BASF did not enter the production of Carotenoids until 1995, and Vitamin D3 generates relatively small amounts of annual revenue. Within the remaining vitamins, we exclude smaller individual vitamin products. This leaves us with the following

³¹As can be seen in Table A.3, approximately 80% of the criminal fines for the vitamins conspiracy in the U.S., Canada, and Europe were levied against Roche and BASF. Thus, it is reasonable to view Roche and BASF as the two major players in the conspiracy.

³²“The main common denominator of the different vitamin cartels is the presence of Roche and BASF, the two leading producers of vitamins worldwide, in all vitamin cartels to eliminate all effective competition between them in the Community and EEA across almost the whole range of important vitamins.” ECD 75.

vitamin products (any product with the qualifier “USP” is a human product):

- Vitamin A Acetate 650 Feed Grade
- Vitamin A Acetate 500 USP
- Vitamin E Acetate 50% Spray Dried Feed Grade
- Vitamin E Acetate Oil USP
- Vitamin C Ascorbic Acid 100% USP
- Beta Carotene FS 30%³³
- Riboflavin (B2) 96% Feed Grade
- Riboflavin (B2) USP
- Calpan (B5) Feed Grade
- Calpan (B5) USP

5.1 Description of the Data

The following graphs depict for each vitamin product the dates and amounts of price announcements, the identity of the price leader (first firm to announce a given price), whether other firms announced the same price within ninety days of the leader’s announcement, and the number of days that the announcement preceded the effective date of the price change. The date of the leader’s announcement is given on the horizontal axis, and the amount of the announced price, in 1982 U.S. dollars per kilogram,³⁴ is given on the left vertical axis. The number of days that the announcement date preceded the effective date is given on the right vertical axis (negative values indicate that the announcement was published in the trade journal after the effective date of the price change). The relevant plea period, as defined in Table A.3, is shaded in each graph.

The shape of a symbol marking a price announcement indicates the identity of the price leader. A symbol (e.g., a square or triangle) that is filled-in indicates a *joint announcement*, where that at least one other firm announces the same price within ninety days of the leader’s announcement. In our data, it is never the case that multiple firms announce the same price in the same issue of a trade journal, and so we are always able to identify the price leader. A symbol that is not filled-in indicates a *singleton announcement*, where no other firm announces the same price within ninety days.

³³Beta Carotene is a human product.

³⁴We deflate the prices using series the U.S. Department of Labor, Bureau of Labor Statistics, PPI for “Chemicals and Allied Products,” which is series WPU06 available at <http://data.bls.gov/cgi-bin/srgate>.

5.2 Feed Grade Vitamin Products

Some specific comments about each of the figures are warranted.

INSERT FIGURE 1

A650 Feed Grade: The cartel members are Roche, BASF, and Rhone-Poulenc. Referring to Figure 1, in 1992 and 1995 there are singleton announcements that occur within a few days of joint announcements. In early 1992, three firms jointly announce a price of \$40.55, and then Danochemo announces \$40.35. In April 1995, Rhone-Poulenc announces a price of \$48.70, which is matched shortly thereafter by Roche. But in between the announcements of \$48.70 by Rhone-Poulenc and Roche, BASF announces a price of \$48.75.³⁵

INSERT FIGURE 2

E Feed Grade: The cartel members are Roche, BASF, Rhone-Poulenc, and Eisai. Referring to Figure 2, we see singleton announcements in early 1994 in which Rhone-Poulenc, a member of the cartel, undercuts BASF's price announcement by \$0.05.

INSERT FIGURE 3

B2 Feed Grade: The cartel members are Roche, BASF, and Takeda. Referring to Figure 3, the sequence of price increases observed in the plea period starts before the official beginning of the plea period. This also occurs in B5 Feed Grade.

INSERT FIGURE 4

B5 Feed Grade: The cartel members are Roche, BASF, and Daiichi. We have been unable to determine whether or not Thompson Hayward was the dominant producer of B5 Feed Grade in the 1970s. Referring to Figure 4, it is interesting that there is a period of singleton

³⁵Having a cartel firm make a singleton announcement at a price that is slightly higher than the previous joint announcement may allow the cartel to reallocate market shares without using direct interfirm transfers.

announcements from mid-1992 to early 1994. In August 1992, BASF announces a price of \$22.50. Shortly thereafter, Roche and Daiichi jointly announce a price of \$21.60. Then, in February 1993 Roche announces a price of \$23.00, the next month BASF announces a price of \$23.50, and the month after that Daiichi announces a price of \$22.70.

If we view the period prior to 1985 as being one without explicit collusion, then the price announcement data for that period can be understood in terms of the model of Section 4.1. Consistent with the model, we see no joint announcements led by firms other than Roche. Most singleton price announcements are made by Roche. After 1985, price announcements tend to be joint. After 1985, joint price announcements are regularly led by cartel firms other than Roche. (Joint price announcements are never led by firms outside the cartel.) This behavior is inconsistent with Proposition 1, suggesting that the price announcements after 1985 are not consistent with non-collusive behavior. However, the behavior is consistent with the explicitly collusive behavior described in Section 4.2. In particular, there are regular joint announcements led by a variety of cartel firms.

5.3 Human Vitamin Products

For the human vitamin products C Ascorbic Acid USP, B2 USP, and B5 USP, we sometimes observe that two or more firms announce the same price in the same issue of the trade publication. We classify this type of price announcement as a *tie*.

INSERT FIGURE 5

A500 USP: Figure 5 shows singleton announcements in 1992 in which Roche leads and Danochemo undercuts Roche's price by \$0.15 and \$0.25, respectively. Note that Danochemo did not admit to participating in the cartel, but it was purchased by BASF in 1993.

INSERT FIGURE 6

E USP: As shown in Figure 6, in March 1991, Roche and BASF make a joint announcement of \$28.50, and shortly thereafter Eisai makes an announcement of \$28.00.³⁶ In mid-1986,

³⁶Roche announced a price of \$28.50 on March 4, 1991. BASF announced a price of \$28 on March 11, 1991, but then the *Chemical Marketing Reporter* published a correction on March 18, 1991, saying BASF's price was actually \$28.50. Eisai then announced a price of \$28.00 on March 25, 1991.

BASF and Roche jointly announce a price of \$20.50. In October 1986, Eisai also announces a price of \$20.50; but because Eisai's announcement is not within ninety days of BASF's announcement, it is reported on the graph as a singleton announcement by Eisai.

INSERT FIGURE 7

C Ascorbic Acid USP: Referring to Figure 7, prior to 1985 there is frequent "undercutting." For example, in September 1978, Takeda and Merck jointly announce a price of \$10.00, and shortly thereafter Roche and Pfizer jointly announce a price of \$9.90. In March 1980, Roche and Merck jointly announce a price of \$11.00, and Takeda follows with an announcement in May 1980 of \$10.90. In April 1981, Roche announces a price of \$12.00, and in June 1981, Merck announces a price of \$11.90. In contrast, we do not observe this type of undercutting in C USP after 1985.

INSERT FIGURE 8

Beta Carotene: As shown in Figure 8, as well as the graphs for the other human products, it is notable that human vitamin products seem to avoid the price downturn that affects animal feed products from mid-1988 to early 1990.

INSERT FIGURE 9

B2 USP: Referring to Figure 9, it is notable that prior to 1985, the majority of the announcements are joint announcements or ties (multiple firms announcing the same price increase on the same day). This contrasts with most other vitamin products, where announcements prior to 1985 tend to be singleton announcements.

INSERT FIGURE 10

B5 USP: Figure 10 shows that, in contrast to the five singleton announcements during the plea period in B5 Feed Grade, in B5 USP there is only one singleton announcement during that period. This is notable because the cartels for B5 Feed Grade and B5 USP have the same membership.

5.4 Observations on Leaders and Followers

It is illuminating to consider some simple calculations about the frequency with which price announcements are followed. For example, consider the vitamin products that are made by both Roche and BASF. During the plea period (as defined in Table A.3) when both firms had production capacity, for 73% of price announcements (52 out of 71 announcements), both Roche and BASF announce the same price within ninety days of each other. During the period after 1985, but prior to the plea period, when a price announcement is made by either firm, the other firm announces the same price within ninety days 79% of the time (48 out of 61 announcements). Prior to 1985, there are 15 price announcements made in vitamin products during time periods when both Roche and BASF have production capacity. For these 15 pre-1985 announcements, Roche and BASF never announce the same price within a ninety-day interval. Thus, the plea period and the period between 1985 and the plea period exhibit similar levels of coordination of price announcements by Roche and BASF, while the period prior to 1985 shows no leader/follower behavior by these two producers.

5.5 Logit Estimates

Our description of the role of price announcements in explicit collusion in Section 4 suggests that joint price announcements by cartel members are desirable any time contracts are up for renewal. Furthermore, since joint price announcements are coordinated by the cartel in our model of explicit collusion, the timing of announcements might also be expected to be related to the timing of cartel meetings.

An alternative explanation for the timing of joint price announcements is that they are responses to changes in underlying cost or demand factors, as in the models of barometric price leadership described in the literature (see, e.g., Stigler (1947), Markham (1951), Bain (1960), and Cooper (1997)). To distinguish between these explanations, in this section we consider what factors cause a firm to issue a price announcement. As described below, our results suggest that the primary drivers for price announcements are not cost or demand factors, but rather the length of time since the previous announcement.

During a period of explicit collusion, one would expect cartel firms that meet regularly to make regular price announcements, pushing the price up until the desired price is reached. In particular, one would expect the likelihood of a new price announcement to be an increasing function of how much time has passed since the previous price change. In contrast, in the absence of explicit collusion, one would not expect price announcements to be tied to the calendar or to the length of time since the previous announcement in any systematic way. To address this hypothesis, we estimate a logit model for the probability that a new price

is announced in a given month conditional on the amount of time that has passed since the previous price change, with variables to control for potential cost and demand triggers for a price change.

To construct our dependent variable, we define a *new price announcement* to be any singleton price announcement or any lead announcement in a joint announcement (i.e., we exclude follower price announcements in a joint announcement). Then, for all months in our sample, we create a variable *newprice* that is equal to 1 if there is a new price announcement in that month, and 0 otherwise.

To control for potential cost and demand triggers for a price change, we use the price of oil, the Deutsche Mark/U.S. dollar (DM/USD) exchange rate, and a weighted average of the number of hogs slaughtered (weighted 20 percent) and the number of chickens slaughtered (weighted 80 percent).³⁷ Because oil is a primary element in the manufacture of all vitamins, the price of oil provides a measure of costs. The DM/USD exchange rate is potentially relevant because the primary vitamin manufacturers were located in Germany, while the price announcement data are for the U.S. market. The numbers of hogs and chickens slaughtered provide a measure of demand, with hogs being a smaller share of the feed market than chickens.

We code these independent variables as dummy variables because we are interested in determining whether a price announcement is triggered by a given change in a right-hand-side variable. We arbitrarily select a 10% threshold for these changes.³⁸ The variable *oildum10* is a dummy variable that is 1 if the price of oil increased by 10% or more since the previous new price announcement, and 0 otherwise; *markdum10* is a dummy variable that is 1 if the DM/USD exchange rate decreased by 10% or more since the previous new price announcement, and 0 otherwise;³⁹ and *demanddum10* is a dummy variable that is 1 if demand factors increased by 10% or more since the previous new price announcement, and 0 otherwise.⁴⁰

Finally, we include the independent variables to capture the amount of time that has passed since the previous price change. The variable *delay* is the number of months since the previous new price announcement and *delay*² is the square of *delay*.⁴¹

We consider four approximately five-year periods, three before and one after the beginning

³⁷If price increases were tied to cost and/or demand factors, this would not preclude the possibility of explicit collusion; but it would make the task of disentangling the component attributions of a given price increase more challenging.

³⁸We also considered thresholds of 5% and 20% and found no substantial changes in the results.

³⁹Similar results obtain using other related specifications of the *oildum10* and *markdum10*.

⁴⁰As in the previous section, the demand index is calculated as the weighted sum of the number of hogs slaughtered (20 percent) and chickens slaughtered (80 percent). Results are robust to other weighted averages.

⁴¹Because our independent variables are not defined for months prior to the first price announcement, the number of observations in the different time periods will differ.

of the period of admitted collusion. We use the data from the graphs in Section 5, rather than the admitted period of collusion, to define the *start of the plea-period price increase*. For example, for B2 Feed Grade, the legal plea period begins January 1991. Yet it is clear from Figure 3 that the price ascent associated with the DoJ’s plea period begins well before January 1991. In fact, the price run clearly begins with the BASF-led joint price announcement of late 1989. Thus, we define the start of the plea-period price increase for B2 Feed Grade to be late 1989. Comparable adjustments are made for the other vitamin products. For A650 Feed Grade, we use the Roche-led price announcement of 1989. For B5 Feed Grade, we use the Daiichi-led price announcement of early 1990, and for E Feed Grade we use the start of the legal plea period. The approximately five-year periods we consider are: 1/1972–12/1976, 1/1977–12/1981, 1/1985 to the start of the plea-period price increase, and from the start of the plea-period price increase to 12/1994.

Using these approximately five-year time periods, we get the results of Table 4. The results for five-year periods prior to 1985, particularly prior to 1977, should be interpreted with caution because they are based on a small number of price announcements.

Table 1: Logit Estimates for Periods Before and After the Start of Explicit Collusion⁴²

	1/1972–12/1976	1/1977–12/1981	1/1985 to start of the plea-period price increase	Start of the plea-period price increase to 12/1994
<i>delay</i>	0.0818	-0.1809	0.6493*	0.4083*
	0.34	-1.70	3.15	2.95
<i>delay</i> ²	0.0008	0.0031	-0.0452*	-0.0213*
	0.10	1.18	-2.83	-2.65
<i>markdum</i> 10	2.2150	0.5444	1.6097*	0.7429
	1.77	0.68	4.16	1.54
<i>oildum</i> 10	-1.4051	1.0950*	0.6803	-0.3855
	-1.41	2.02	1.87	-1.21
<i>demanddum</i> 10	3.0517	-0.9319	0.5996	-0.7210
	1.85	-1.20	0.72	-1.54
<i>constant</i>	-4.2085*	-2.0104*	-4.3820*	-3.3026*
	-2.95	-4.73	-8.09	-6.71
N obs	166	408	515	540
Wald Chi ²	15.37	12.20	57.52	19.02
Wald Chi ² Prob	0.0089	0.0322	0.0000	0.0019
Pseudo R ²	0.1764	0.0431	0.1858	0.0548
<i>Note:</i> We estimate a logit model for the log odds ratio for the probability of a new price announcement in a given month. The z-statistics (ratio of the estimated coefficient to the robust standard error) are reported under the coefficients. Coefficients that are significant at the 5 percent level are indicated with an asterisk.				

⁴²The pseudo R^2 is calculated as $1 - \ln(L)/\ln(L_0)$, where L is the likelihood and L_0 is the likelihood when

Note that the coefficients for *delay* and *delay*² are not statistically significant in the periods prior to 1985, but they are statistically significant for the periods after 1985.⁴³ Furthermore, the coefficient estimates indicate that for the periods after 1985, the log odds ratio increases rapidly with time in the first six months after a new price announcement; but for the periods prior to 1985, the log odds ratio either decreases or increases much more gradually (see Figure 5). Other notable features of Table 4 are that the coefficient on *oildum10* is significant in period 2 (the late 1970s), as one might expect, and that the coefficient on *markdum10* is significant in the period between 1985 and the start of the plea-period price increase.

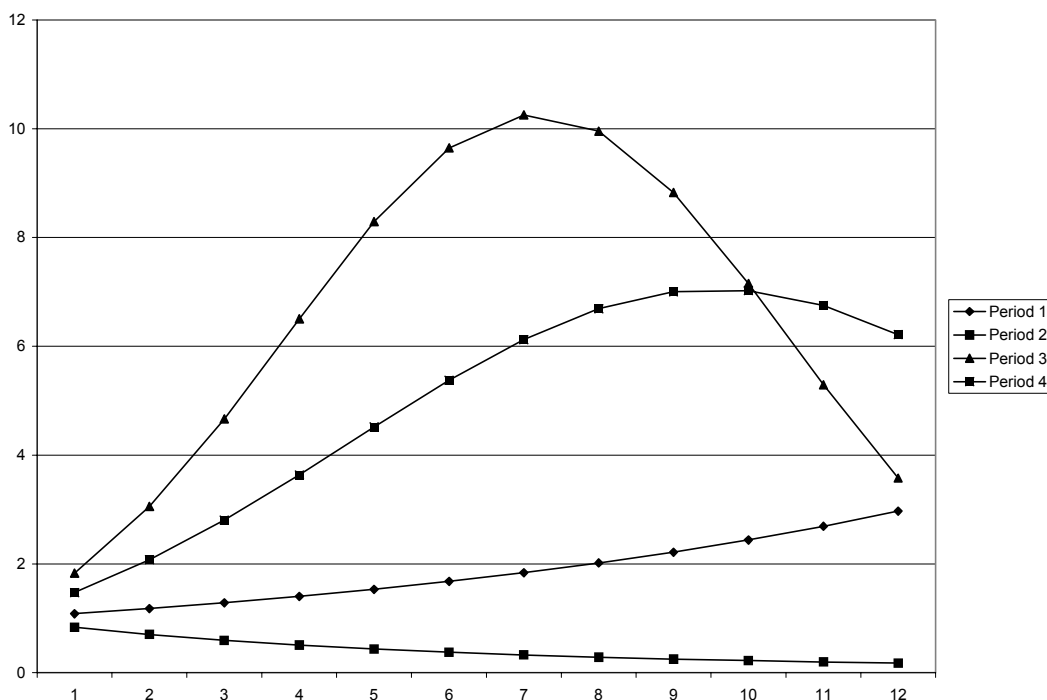


Figure 11: Estimated Effect of *delay* and *delay*² on the Odds Ratio for the Approximately Five-Year Periods of Table 4

Period 1 is 1/1972–12/1976; period 2 is 1/1977–12/1981; period 3 is from 1/1985 until the start of the plea-period price increase; and period 4 is from the start of the plea-period price increase until 12/1994. The horizontal axis shows the delay since the previous announcement in months.

Referring to Figure 5, we see that the effect of *delay* on the odds ratio for a new price announcement is similar in the two periods after 1985, but remarkably less pronounced in

only a constant is included on the right-hand side.

⁴³The only notable change when we use a probit model is that the coefficient on *delay* in the period 1/1977 to 12/1981 has a z-statistic of 2.04.

the two periods prior to 1985. The positive, significant coefficient on *delay* and the negative, significant coefficient on *delay*² for the two time periods after 1985 are robust to a variety of specifications of the explanatory variables and are robust to whether we estimate a logit or probit model.

It appears that in both periods after 1985, the fact that a certain amount of time had elapsed since the previous price announcement is a significant driver in inducing firms to make new price announcements. We know from the Sentencing Statement that the cartel controlled new price announcements during the plea period. Given that the cartel met regularly to discuss cartel business, it is not particularly surprising to see results in Figure 5 that suggest new price announcements for period 4 (early 1990s) on a schedule of approximately every six to twelve months.⁴⁴ In fact, our results suggest that the length of time between price announcements may provide a critical indicator of cartel meetings and explicitly collusive behavior. The results in Figure 5 for period 3 (late 1980s), especially when compared with those for period 4 (early 1990s), suggest explicit collusive behavior well before the beginning of the plea periods described in Table A.3.

In period 1 (1/1972–12/1976), the coefficients on *delay* and *delay*² are not statistically significant, although the coefficients do indicate that a new price announcement is more likely the greater is the number of months that have passed since the previous new price announcement. This may reflect the collusive activity alleged in the early 1970s by Adams (1984). However, period 2 (1/1977–12/1981), shows no tendency for new price announcements to be more likely after more time has passed since the previous new price announcement. In fact, the results for period 2 indicate that new price announcements should be less likely if more time has passed since the previous announcement. These results are robust to various specifications of the explanatory variables and to whether we estimate a logit or probit model.

In conclusion, the analysis of the data on the probability of new price announcements provides a potentially valuable tool for identifying explicit collusive behavior. In particular, one would test for organized price announcements coordinated at regular cartel meetings by looking for an increasing probability of a new price announcement with the passage of time, especially at intervals related to the interval contract renewals and cartel meetings.

⁴⁴Perhaps the cartel required a certain (regular) amount of time to agree upon the next price announcement, or perhaps they decided on an interval that they felt would not generate consumer outrage or arouse antitrust suspicion.

5.6 Announcement and Effective Dates

As depicted in Figures 1–10, it was not uncommon for the vitamin manufacturer making a singleton announcement or leading a joint announcement to announce the price increases prior to the effective date of the increase. There are also cases in which the announcement of a price increase in the trade press does not occur until after the effective date of the price increase, but these are rare and, except for one case with a delay of 20 days, they involve a delay in the announcement of seven or fewer days (the trade journals are weekly publications).

Figure 12 below shows histograms for the number of days that the effective date follows the announcement date for singleton announcements and the lead announcement of joint announcements for the vitamins in our sample. The figure shows the histograms for the same four time periods described in Section 5.5, and also for the combined period 1/1972–12/1984.

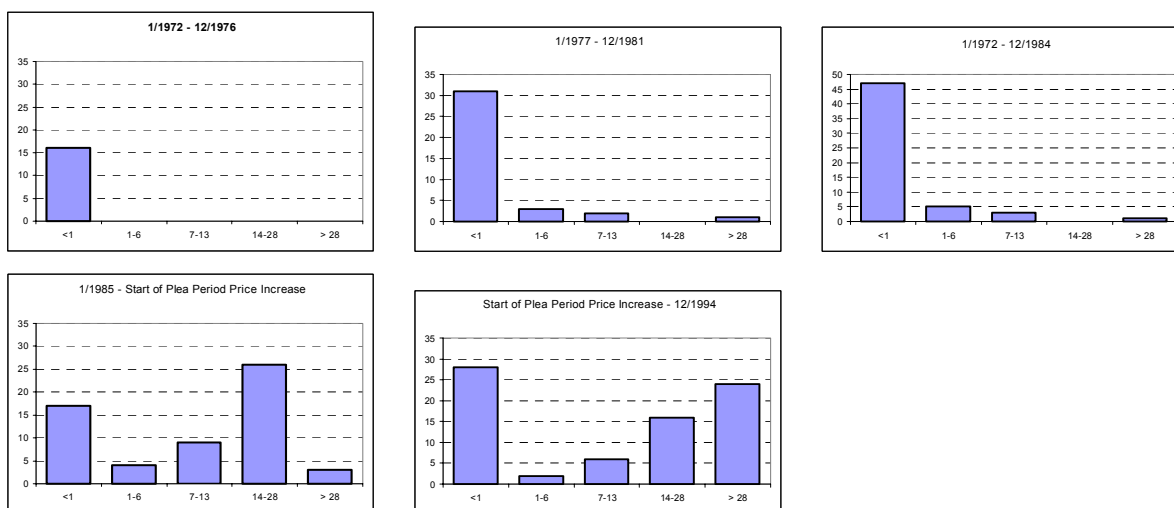


Figure 12: Histograms of Days of Delay until the Effective Date

One can see from Figure 12 that prior to 1985 it was rare to see price announcements far in advance of the effective date; however, after 1985 this was relatively more common.

Days of Delay	1/1972–12/1984	1/1985–Plea Price Inc.	Plea Price Inc.–12/1994
6 or fewer	93%	36%	39%
7 or more	7%	64%	61%
# of obs.	56	59	76

Calculating a simple Z -test for the equality between two proportions,⁴⁵ we get the following values:

Sample 1	Sample 2	Z statistic	p value
1/1972–12/1984	1/1985–Plea Price Inc.	−6.37	0.0000
1/1972–12/1984	Plea Price Inc.–12/1994	−6.25	0.0000
1/1985–Plea Price Inc.	Plea Price Inc.–12/1994	0.46	0.6446

Table 3 shows that we can reject the hypothesis that the proportion of long delays, defined as delays of 7 days or more, is the same in the period before 1/1985 as it is in either of the periods after 1/1985. And, we fail to reject the hypothesis that the proportion of long delays is the same in the two periods after 1/1985.

6 Discussion

The public price announcements of firms in the vitamins industry in the period prior to 1985 are consistent with our model of non-collusive price leadership, with Roche playing the role of the dominant firm. The period after 1985 exhibits a fundamentally different set of characteristics. The price announcements after 1985 are not consistent with our model of non-collusive behavior, but they are consistent with a model in which public price announcements increase the willingness of buyers to accept price increases. Furthermore, the period between 1985 and the plea period is nearly identical to the plea period in terms of the price announcement behavior of the firms. Since the plea period is known to be a period of explicit collusion, it seems reasonable to conjecture, based upon the characteristics of the price announcements, that explicit collusion extended back to 1985 for many vitamins.

The Vitamins Cartel discussed price announcements at its regular meetings.⁴⁶ Thus, it seems reasonable to expect regularity in the cartel’s price announcements, both in terms of timing and magnitude. This regularity shows up in our logit estimates for the probability of a new price announcement for the periods after 1985, but is absent for the periods prior to 1985.

⁴⁵This test is approximate and assumes that the number of observations in the two samples are sufficiently large to justify the normal approximation to the binomial. The test statistic is $\frac{p_1 - p_2}{\sqrt{\frac{p_1 n_1 + p_2 n_2}{n_1 + n_2} \left(1 - \frac{p_1 n_1 + p_2 n_2}{n_1 + n_2}\right) \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$, which is approximately distributed as a standard normal under the null hypothesis that $\pi_1 = \pi_2$. (See Kanji, 1993.)

⁴⁶“The decisions on whether, when, and by how much to increase prices were taken by the heads of vitamin marketing in their periodic meetings.” (ECD p.201).

As noted in Clark (1983), “Under some conditions, a systematic and parallel pattern of public announcements of prices or other terms of trade can provide important evidence that a group of firms has agreed to coordinate pricing and output strategies and therefore can support the finding of agreement that Section 1 of the Sherman Act requires.”⁴⁷ This suggests one possible remedy—a prohibition on the announcement of prices prior to their effective date. Such a prohibition was imposed on an association of sugar refiners in 1934,⁴⁸ but the Supreme Court reversed that portion of the district court order.⁴⁹ More recently, a prohibition on advance price announcements was included in the 1967 consent agreement in *US v. Pennsalt Chem. Corp.*⁵⁰ In addition, in *Ethyl Corp.*,⁵¹ the Federal Trade Commission found advance announcement of price changes to have an anticompetitive effect. This suggests that the prohibition of advance price announcements may be a feasible and useful remedy in cases in which public price announcements are used by a cartel.

⁴⁷Clark cites the example of *Wall Products Co. v. National Gypsum Co.* 326 F. Supp. 295, 316 (N.D. Cal. 1971), in which case the colluding firms announced pricing policies that were all to become effective on the same date.

⁴⁸*US v. Sugar Inst.*, 15 F. Supp. 817, 830, 908 (S.D.N.Y. 1934).

⁴⁹*Sugar Inst. v. US*, 297 U.S. 553, 603 (1936).

⁵⁰*US v. Pennsalt Chem. Corp.*, 1967 Trade Cas. (CCH) P71,982, at 83,475 (E.D. Pa. 1967).

⁵¹*In re Ethyl Corp.*, 3 Trade Reg. Rep. (CCH) at 22,546 (F.T.C. Mar. 22, 1983).

A Appendix—Additional materials

Table A.1: Known and Potential Benefits of Vitamins and Product List

Vitamin	Vitamin Product	Benefits
Beta Carotene	BETAVID/BETATAB 20% B-CAROTENE FS 30% BETAVID/BETATAB 10% B-CAROTENE CWS 10% B-CAROTENE CWS 1%	Vitamin A/Beta Carotene are important in the promotion of growth, strong bones, healthy teeth, skin, hair and gums. They also counteract night blindness, weak eyesight, and help build resistance to respiratory infections. Beta Carotene is associated with a protective effect against the development of certain cancers, and a high intake/status of this nutrient has been related to a decreased incidence of certain cancers and cardiovascular events. Findings in laboratory studies show that Beta Carotene acts in synergy with Vitamins E and C.
Calpan (B5)	CALPAN SD USP CALPAN FEED GRADE CALPAN 80 CALPAN 45% FEED GRADE CALPAN 160	Pantothenic acid (Calpan) is vital for the release of energy from food, for healthy growth, and for the production of antibodies. Pantothenic acid requires Vitamin A, Vitamin B6, Vitamin B12, Folic Acid, and biotin in order to function properly.
Riboflavin (B2)	RIBOFLAVIN USP RIBOFLAVIN 95/98 RIBOFLAVIN 80% SD RIBOFLAVIN 96% FEED GRADE RIBOFLAVIN FEED GRADE	Riboflavin is vital for the release of energy from foods and for healthy skin, eyes, and growth. It plays a major role in oxidation and reduction processes in cells. Deficiency is rare, and usually occurs in combination with deficiencies of other water-soluble vitamins. In farm animals, even marginal Vitamin B2 deficiency leads to loss of appetite and impaired growth rate. Riboflavin deficiency also affects the nervous system, gastrointestinal tract, and reproductive organs.
Vitamin A	A ACET 650 FEED GRADE A PALM 1.7 A ACET 500 USP A PALM 250 A DLC 500	Vitamin A/Beta Carotene are important in the promotion of growth, strong bones, healthy teeth, skin, hair, and gums. They also counteract night blindness, weak eyesight, and help build resistance to respiratory infections.
Vitamin C	ASCORBIC ACID (AA) 100% AA COMPRESSIBLE 90% SODIUM ASCORBATE AA COMPRESSIBLE 95% AA COMPRESSIBLE 97.5%	Vitamin C is important for the production of collagen, connective tissue, and protein fibers that give strength to our teeth and gums, muscles, blood vessels, and skin. In the immune system, Vitamin C helps the white blood cells to fight infection. It helps the body to absorb iron. It is believed that the so called "antioxidant" properties of Vitamin C help protect the body from the harmful effects of too many free radicals. These are potentially damaging molecules in our bodies that may harm healthy cells. Together with Vitamin A and Vitamin E it forms the trio of antioxidant vitamins now believed to have a preventive effect on degenerative diseases such as cardiovascular disease and cancer. Vitamin C is also commonly used as a natural antioxidant, i.e., it prevents spoilage of foods and beverages by oxygen in the air.
Vitamin E	E ACETATE OIL USP E 50% ADSORBATE E ACETATE 50% SD E ACETATE OIL FEED GRADE E DLC 40%	Vitamin E plays an important role in protecting the fat molecules in cell membranes and the blood. Without Vitamin E, these polyunsaturated fat molecules could be damaged by the oxygen in aggressive molecules, called free radicals. Oxidized fat molecules can harm body tissues over long periods of time. Owing to its potent antioxidant properties in the body, Vitamin E has a stabilizing effect on Vitamin A, various hormones, and enzymes. It also plays an essential role in protecting cell membranes. Together with Vitamin A and Vitamin C it forms the trio of antioxidant vitamins now believed to have a preventive effect on degenerative diseases such as cardiovascular disease or cancer. In animals, Vitamin E is involved in reproduction, and has an immunomodulatory effect. Furthermore, meat and fish flesh from Vitamin E-supplemented animals are protected against rancid deterioration.

Vitamins are largely produced through processes of chemical synthesis, although there

have been recent advances in fermentation technologies for the production of some vitamins. Throughout the study period, petroleum was a primary factor input for the production of each vitamin considered in this study.⁵² For vitamins produced using fermentation technologies, such as C and B2, sugar is an important factor input.⁵³

The vitamins industry is highly concentrated. Table A.2 in Appendix A sets forth the firms that were involved in the production of specific vitamins according to the plea agreements and European Commission findings. The dominant firm in the industry is Roche, which produces almost all vitamins.⁵⁴ Another key firm in the industry is BASF.⁵⁵ Prior to 1982, BASF only produced Vitamins A and E; but in 1982 BASF began production of B5 and purchased Grinsted, a Danish producer, adding four vitamins to its portfolio—C, B1, B2, and B6. During the mid-1980s BASF gradually increased its production of Beta Carotene.

The large capital investments, and especially the production experience, required for the manufacture of vitamins are a barrier to entry in this industry. Although the major producers have similar production technologies, the chemical synthesis processes involve substantial “learning by doing.” Each producer becomes better, through time, at debottlenecking the chemical synthesis process at any given plant.

When considering the cost of producing animal feed or human food, the incremental cost of the vitamin additives typically is small. Nevertheless, sales of vitamins in the U.S. alone during the 1990s were several billion dollars. Due to the significant nutritional impact of vitamin supplements, the demand for vitamins is highly inelastic.

Although it is common to think of vitamins as a single entity—such as Vitamin A or Vitamin E—in fact, specific vitamin products are manufactured within each vitamin type. For example, “A650” is a specific Vitamin A product that is used in the feed sector. Table A.1 in Appendix A lists some of the key vitamin products that are offered by the primary manufacturers.

A given vitamin product made by one firm is chemically identical to the same product made by another firm. For example, Roche’s A650 is identical to BASF’s A650. Purchasers are aware of the fact that vitamin products are homogeneous. As an indicator of the substitutability of the products for end users, in the 1970s, Roche actively tried to inhibit customer switching by using “fidelity contracts,” contracts with large rebates paid at the terminal date

⁵²The price of oil for the relevant time period is shown in Figure A.1 in Appendix A. The importance of oil as a factor input varies between vitamins – more for A, E, and Beta Carotene and less so for C.

⁵³The world price of sugar for the relevant time period is shown in Figure A.2 in Appendix A.

⁵⁴Notable exclusions are Niacin (B3), Choline Chloride (B4), and B12.

⁵⁵During the 1990’s, Roche and BASF jointly had the following percentages of the world vitamin market: A–80 percent, E–65 percent, C–45 percent, B2–75 percent, B5–65 percent, Beta Carotene–100 percent (see European Commission (2003, 123)).

if a customer purchased all of its vitamins from Roche.⁵⁶

The Chinese began production of some vitamins in the 1980s and developed a major market presence by the middle of the 1990s in vitamins such as C and B1. The Chinese developed fermentation technologies (in contrast to chemical synthesis technologies) for the production of some vitamins. Entry barriers are far lower for fermentation processes.

With the possible exception of the Chinese, most sizable producers of vitamins were involved in explicit collusion throughout much of the 1990s.

⁵⁶According to Adams (1984, p.76), in June 1976, the European Commission issued a decision requiring Roche to stop using fidelity contracts and to pay a fine of 1,098,000 DM.

Table A.2: Vitamin Production by Cartel Members During the Plea Period, Generally 1990 through 1998⁵⁷

	Vitamin A	Vitamin E	Vitamin C	Beta Carotene	Calcium (B5)	Riboflavin (B2)	Choline Chloride (B4)	Niacin (B3)	Biotin (H)	Thiamine (B1)	Vitamin B12	Pyridoxine (B6)	Carotenoids	Vitamin D3	Folic Acid (B9)
BASF	X	X	X	X	X	X	X			X			X	X	
Chinook							X								
Daiichi					X							X			
Degussa								X							
DuCoa							X								
Eisai		X													
Hoechst											X				
Kongo															X
Lonza								X	X						
Merck KGaA			X						X						
Nepera								X							
Reilly								X							
Rhone-Poulenc	X	X									X			X	
Roche	X	X	X	X	X	X			X	X		X	X	X	X
Solvay														X	
Sumika															X
Sumitomo									X						
Takeda			X			X				X		X			X
Tanabe									X						

⁵⁷Based on plea agreements, statements of fact, and press releases. Rhone-Poulenc was named in Hoechst's Canadian Agreed Statement of Fact in the Vitamin B12 conspiracy.

Table A.3: Summary of Guilty Pleas and Findings

Vitamin	Supplier	Source	Plea or finding start date	Plea or finding end date
Premix	Roche	U.S. plea	Jan 91	Dec 97
	BASF	U.S. plea	Jan 91	Dec 97
Vitamin E	Roche	U.S. plea	Jan 90	Feb 99
	BASF	U.S. plea	Jan 90	Feb 99
	Rhone-Poulenc	Canadian plea	Jan 90	Feb 99
	Eisai	U.S. plea	Jan 91	Feb 99
Vitamin A	Roche	U.S. plea	Jan 90	Feb 99
	BASF	U.S. plea	Jan 90	Feb 99
	Rhone-Poulenc	Canadian plea	Jan 90	Feb 99
Vitamin C	Roche	U.S. plea	Jan 91	"late Fall" 95
	BASF	U.S. plea	Jan 91	"late Fall" 95
	Takeda	U.S. plea	"early" 91	"Fall" 95
	Merck KGaA ¹	U.S. plea	"early" 91	"Fall" 95
Choline Chloride (B4)	BASF	Canadian plea	Nov 92	Jun 95
	Chinook	U.S. plea	Jan 88	Sep 98
	DuCoa	U.S. plea	Jan 88	Sep 98
Beta Carotene	Roche	U.S. plea	Jan 91	Dec 98
	BASF	U.S. plea	Jan 91	Dec 98
Calpan (B5)	Roche ²	U.S. plea	Jan 91	Dec 98
	BASF ³	U.S. plea	Jan 91	Dec 98
	Daiichi	U.S. plea	Jan 91	Feb 99
Niacin (B3)	Lonza	U.S. plea	Jan 92	Mar 98
	Degussa	U.S. plea	Jan 92	Mar 98
	Reilly	U.S. plea	Sep 94	Mar 98
	Nepera	U.S. plea	Jan 92	Jul 95
Riboflavin (B2)	Roche	U.S. plea	Jan 91	"Fall" 95
	BASF	U.S. plea	Jan 91	"Fall" 95
	Takeda	U.S. plea	"early" 91	"Fall" 95
Biotin (H)	Roche	EC finding	Oct 91	Apr 94
	BASF	EC finding	Oct 91	Apr 94
	Lonza	EC finding	Oct 91	Apr 94
	Merck KGaA	Canadian plea	Oct 91	Sep 95
	Sumitomo	EC finding	Oct 91	Apr 94
	Tanabe	EC finding	Oct 91	Apr 94
Thiamine (B1)	Roche	EC finding	Jan 91	Jun 94
	BASF	EC finding	Jan 91	Jun 94
	Takeda	EC finding	Jan 91	Jun 94
Vitamin B12	Hoechst	Canadian plea	Jan 90	Dec 97

¹ Canadian plea from May 1991 to November 1995: Indictment and Agreed Statement of Facts, Federal Court of Canada, Trial Division, Between Her Majesty the Queen and Merck KGaA, Court File No.: T-304-00 (March 24, 2000).

² EC finding from January 1991 to February 1999: "Commission imposes fines on vitamins cartels," Press Release, European Commission Internet web site (http://europa.eu.int/rapid/start/cgi/guesten.ksh?p_action.gettxt=gt&doc=IP/01/16250|RAPID&lg=EN), November 21, 2001.

³ EC finding from January 1991 to February 1999: "Commission imposes fines on vitamins cartels," Press Release, European Commission Internet web site (http://europa.eu.int/rapid/start/cgi/guesten.ksh?p_action.gettxt=gt&doc=IP/01/16250|RAPID&lg=EN), November 21, 2001.

Defendant	United States (in USD)	Europe (in USD)	Canada (in USD)	Total (in USD)
Roche	\$ 500,000,000	\$ 410,394,600	\$ 32,496,107	\$ 942,890,707
BASF	\$ 225,000,000	\$ 263,078,928	\$ 12,863,042	\$ 500,941,970
RP	amnesty	\$ 4,477,032	\$ 9,478,031	\$ 13,955,063
Takeda	\$ 72,000,000	\$ 32,920,398	\$ 3,559,693	\$ 108,480,091
Eisai	\$ 40,000,000	\$ 11,752,209	\$ 1,354,004	\$ 53,106,213
Daiichi	\$ 25,000,000	\$ 20,786,220	\$ 1,692,506	\$ 47,478,726
Merck	\$ 14,000,000	\$ 8,207,892	\$ 684,556	\$ 22,892,448
Degussa	\$ 13,000,000		\$ 1,584,284	\$ 14,584,284
Lonza	\$ 10,500,000		\$ 697,085	\$ 11,197,085
Nepera	\$ 4,000,000		\$ 152,091	\$ 4,152,091
Reilly	\$ 2,000,000		\$ 22,180	\$ 2,022,180
Bioproducts	amnesty		\$ 429,707	\$ 429,707
Chinook	\$ 5,000,000		\$ 1,523,255	\$ 6,523,255
Ducoa	\$ 500,000			\$ 500,000
Akzo Nobel			\$ 716,178	\$ 716,178
Solvay		\$ 8,083,530		\$ 8,083,530
Hoechst			\$ 250,406	\$ 250,406
Totals	\$ 911,000,000	\$ 759,700,809	\$ 67,503,127	\$ 1,738,203,936

Table A.4: Fines Levied on Cartel Members through 2003



Figure A.5: Oil Prices—Indexed to January 1990

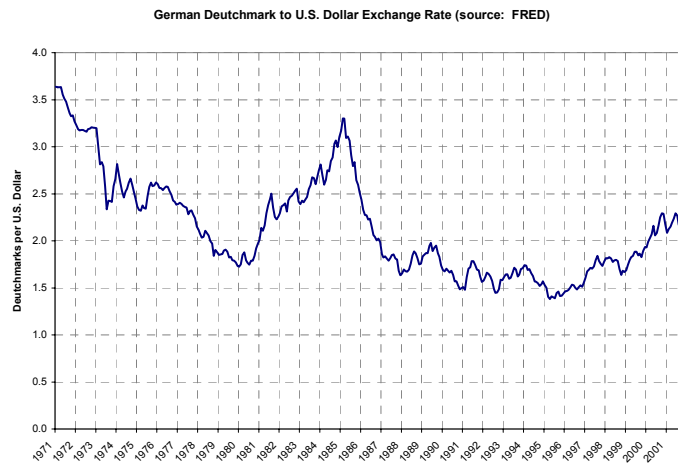


Figure A.6: German Deutsche Marks to One U.S. Dollar⁵⁸

⁵⁸Source: Federal Reserve Bank of St. Louis and Board of Governors of the Federal Reserve System,

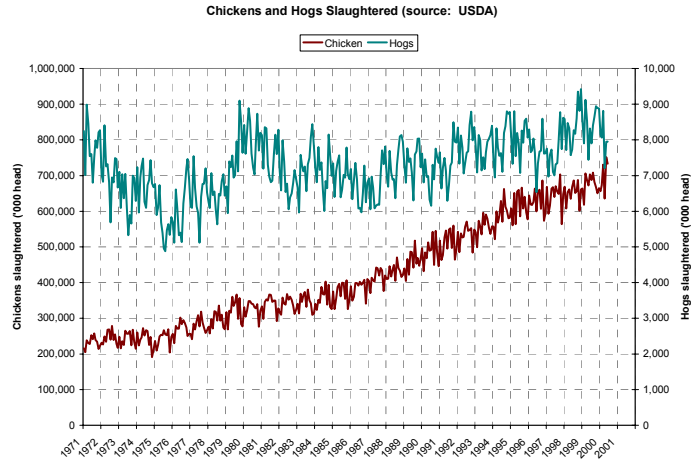


Figure A.7: Chickens and Hogs Slaughtered

B Appendix—Proofs

Proof of Lemma 1. Assume $x > 0$. In any SPE, if no firm announces a price in either the first or second period, then the firms' payoffs in the unique equilibrium of simultaneous announcement game in the third period are $(\pi_1^S + x, \pi_2^S + x)$. Consider the subgame after no firm announces a price in the first period. Note that there is a SPE in which no firm announces a price in the second period, in which case payoffs are $(\pi_1^S + x, \pi_2^S + x)$. To see this, note that if firm 1 does not announce a price, then firm 2's maximum payoff if it announces is $\pi_2^L < \pi_2^S + x$. If firm 2 does not announce a price, then firm 1's maximum payoff if it announces is $\pi_1^L < \pi_1^S + x$. Thus, there is a SPE of the subgame after no firm announces a price in the first period in which no firm announces a price in the second period.

Suppose there is a SPE in which both firms announce a price in the second period. Then payoffs are (π_1^S, π_2^S) , but firm i can guarantee itself a payoff of at least $\pi_i^S + x$ by not announcing in the second period, a contradiction. Suppose there is a SPE in which firm 1 announces a price in the second period, but firm 2 does not. Then payoffs are $(\pi_1^L, \pi_2^F + x)$, but firm 1 can secure a payoff of $\pi_1^S + x > \pi_1^L$ by not announcing in the second period, a contradiction. Suppose there is a SPE in which firm 2 announces a price in the second period, but firm 1 does not. Then payoffs are $(\pi_1^F + x, \pi_2^L)$, but firm 2 can secure a payoff of $\pi_2^S + x > \pi_2^L$ by not announcing in the second period, a contradiction. Thus, there is no SPE in which either firm makes a pure-strategy price announcement in the second period.

To complete the proof, we must show that there is no SPE in which a firm uses a mixed strategy in the second period. If firm i mixes over its price, but announces with probability one, then the other firm strictly prefers not to announce and then choose a best reply in the third period and receive additional amount x . But if the other firm waits until the third period, then firm i also strictly prefers to wait, so there is no equilibrium in which a firm mixes over its price in the second period. Suppose firm i mixes over its price and whether to announce. Then, if firm i announces, the other firm strictly prefers to wait (so it can choose a best reply and receive x), and if firm 1 does not announce, the other firm strictly prefers to wait because, for $i \in \{1, 2\}$, its maximum leader payoff π_i^L is less than its payoff from waiting $\pi_i^S + x$. As before, if the other firm waits until the third period, firm i also strictly prefers to wait, so there is no equilibrium in which a firm mixes over price and whether to announce. Q.E.D.

Proof of Proposition 1. If no firm announces a price in either the first or second period, then the firms' payoffs in the unique equilibrium of simultaneous announcement game in the third period are $(\pi_1^S + x, \pi_2^S + x)$. Suppose there exists a SPE in which firm 1 does not announce a price and firm 2 announces a price in the second period. Then payoffs are $(\pi_1^F + x, \pi_2^L)$, and firm 2 can profitably deviate by not announcing, in which case its payoff is $\pi_2^S + x > \pi_2^L$, a contradiction.

In the subgame after no firm announces a price in the first period, Lemma 1 shows there is a unique equilibrium if $x > 0$, with payoffs $(\pi_1^S + x, \pi_2^S + x)$. If $x = 0$, there is still an equilibrium in which no firm announces a price, in which case payoffs are (π_1^S, π_2^S) , but there is also an equilibrium in which firm 1 announces a price and firm 2 does not, in which case payoffs are (π_1^L, π_2^F) . There is no equilibrium in which both firms announce a price in the second period, because a firm can profitably deviate by waiting until the third period and

best responding to the other firm's announced price. Using the argument above, there is also no equilibrium in which firm 2 announces a price and firm 1 does not. Thus, SPE payoffs in the subgame after no firm announces a price in the first period are $(\pi_1^S + x, \pi_2^S + x)$ if $x > 0$ and either (π_1^S, π_2^S) or (π_1^L, π_2^F) if $x = 0$.

Suppose there exists a SPE in which firm 2 announces a price in $t = 1$ and firm 1 does not announce a price in $t = 1$. Then firm 2's payoff is π_2^L . By not announcing in $t = 1$, the argument above implies that firm 2's payoff in the continuation game is $\pi_2^S + x$ if $x > 0$ and either π_2^S or π_2^F if $x = 0$. In any case, the deviation is profitable, a contradiction. Thus, there exists no SPE in which firm 2 announces its price before firm 1.

Finally, suppose there is a SPE in which firms simultaneously announce prices. Then, in the period in which the firms announce, the firms use mixed strategies, giving payoffs (π_1^S, π_2^S) . Either firm can profitably deviate by not announcing and then in the next period choosing a best reply to the other firm's observed price, a contradiction. Q.E.D.

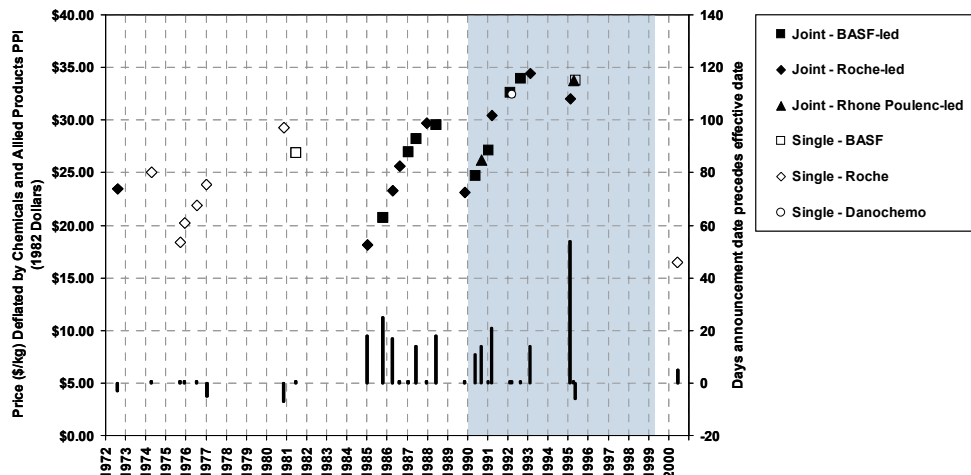


Figure 1: Vitamin A Acetate 650 Feed Grade

Notes regarding Figure 1. The Chemical Marketing Reporter reported a price increase from Danochemo of \$14.70 per kilogram in December 1987. This appears to be a typographical error since \$14.70 per pound equals \$32.41 per kilogram, the same price as BASF and Roche announced during the same period. We have classified this announcement as \$14.70 per pound. Also, BASF’s November 1989 announcement in Feedstuffs is listed as \$122.70 per pound, when a price of \$12.70 per pound maps to \$28 per kilogram, a price announced by others at the time. We have classified this announcement as \$12.70 per pound.

The price announcement by Danochemo on July 20, 1987 did not include an explicit effective date. We assume the effective date is the same as the announcement date.

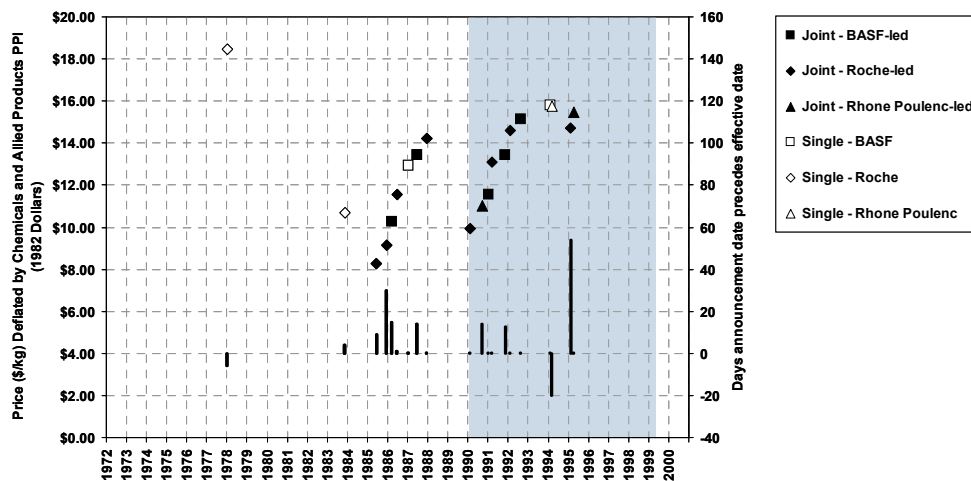


Figure 2: Vitamin E 50% SD Feed Grade

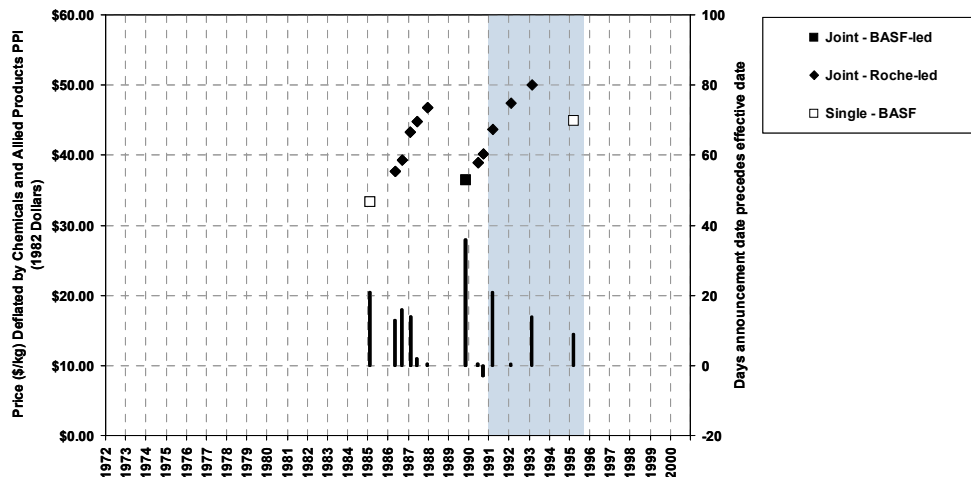


Figure 3: Riboflavin (B2) 96% Feed Grade

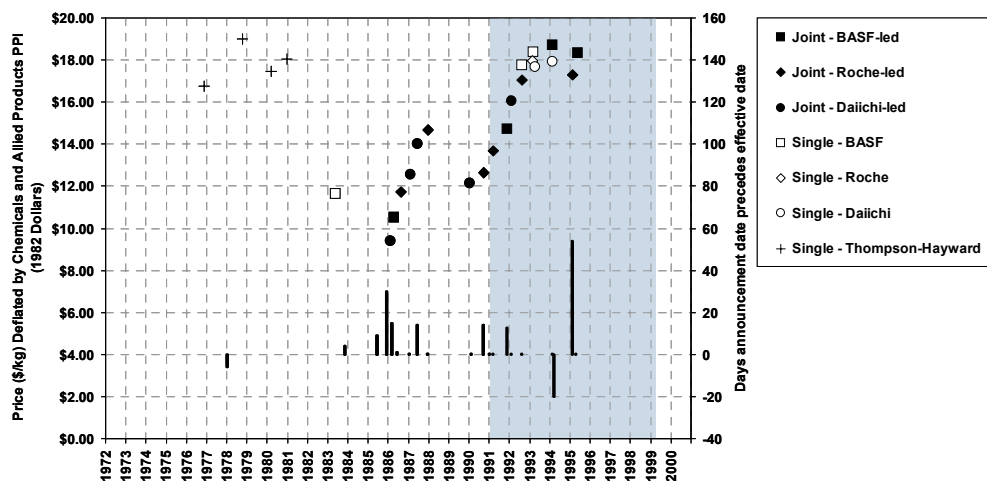


Figure 4: Calpan (B5) Feed Grade

Notes regarding Figure 4. However, entries in the Chemical Marketing Reporter on February 10, 1986 and March 25, 1991 indicate that Duphar was acting as a distributor for Daiichi, so we classify these as announcements by Daiichi.

On May 29, 1995, BASF announced a 7 percent increase in the price of B5 Feed Grade, but did not provide an exact price; however, it seems BASF's intent was to match Roche's announcement of May 8, 1995, so we classify that announcement as a joint announcement led by Roche (Daiichi announced the same price as Roche on May 29, 1995).

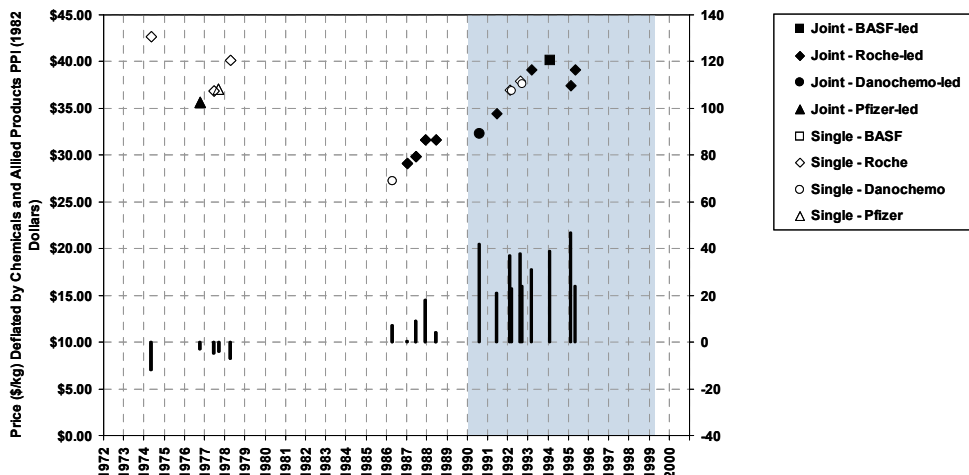


Figure 5: Vitamin A500 USP

Notes regarding Figure 5. On October 8, 1979, Roche announced a 7 percent increase in the price of A500 USP, but did not provide an exact price; this announcement is not included in the graph. On May 29, 1995, BASF announced a 7 percent increase in the price of A500 USP, but did not provide an exact price; however, it seems BASF’s intent was to match Roche’s announcement of May 8, 1995, so we classify that announcement as a joint announcement led by Roche (no other firms announced at that time).

On March 23, 1993, the Chemical Marketing Reporter reported a price increase for Danochemo. As BASF had acquired Danochemo by this time, we classify the announcement as being made by BASF. Although Rhone-Poulenc is listed as a cartel member for Vitamin A in Table A.3, they did not produce human products such as A500 USP (see ECD 95).

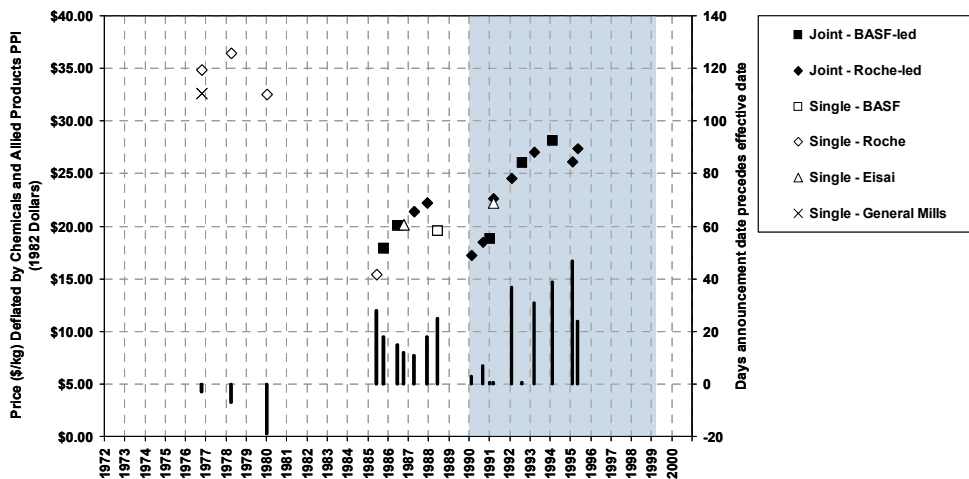


Figure 6: Vitamin E Acetate Oil USP

Note regarding Figure 6. On May 29, 1995, BASF announced a 7 percent increase in the price of E USP, but did not provide an exact price; however, it seems BASF’s intent was to match Roche’s announcement of May 8, 1995, so we classify that announcement as a joint announcement led by Roche (no other firms announced at that time).

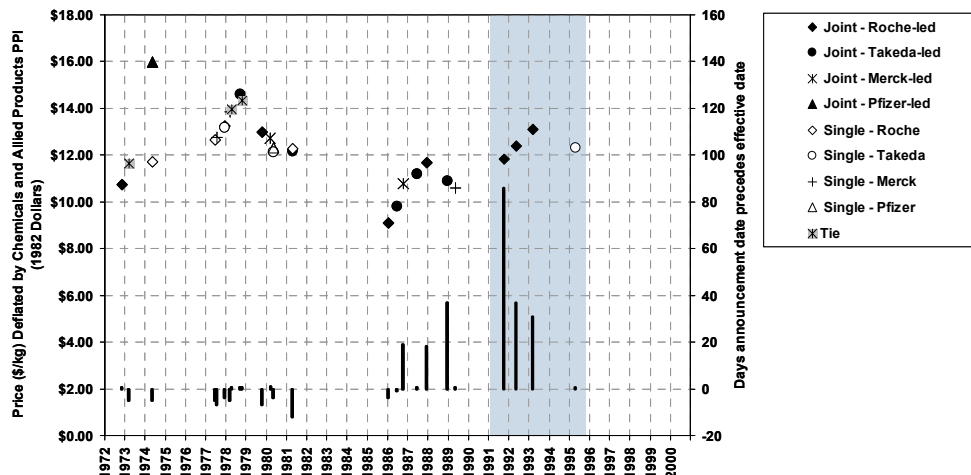


Figure 7: Ascorbic Acid 100% USP

Notes regarding Figure 7. Takeda announced a \$0.40/kg increase on September 6, 1976, but since Takeda made no previous announcement, its previous list price is unknown, so this announcement is not included.

Three price announcements did not include an explicit effective date: Pfizer's announcements on November 13, 1972 and May 13, 1974, and Merck's announcement on June 22, 1981. In these cases, we assume the effective date is the same as the announcement date.

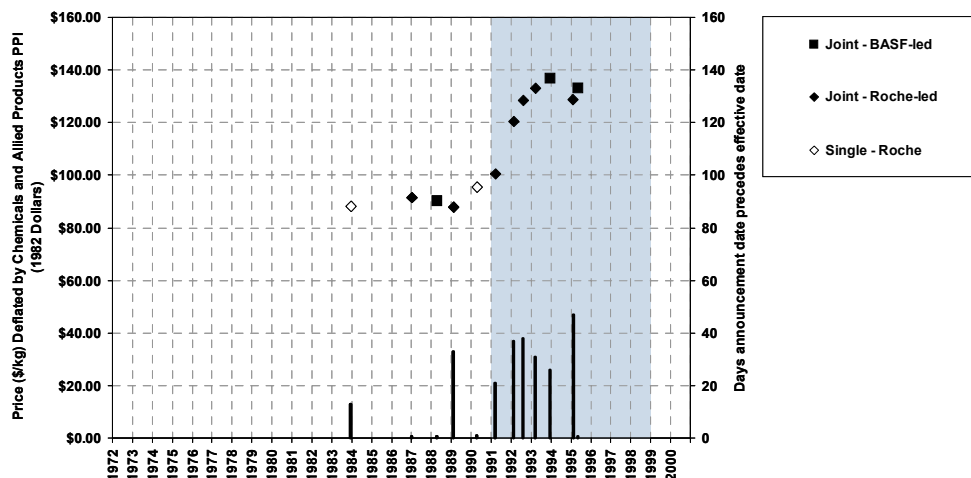


Figure 8: Beta Carotene FS 30% USP

Notes on Figure 8. Roche's announcement on May 9, 1988 did not include an explicit effective date. We assume the effective date is the same as the announcement date.

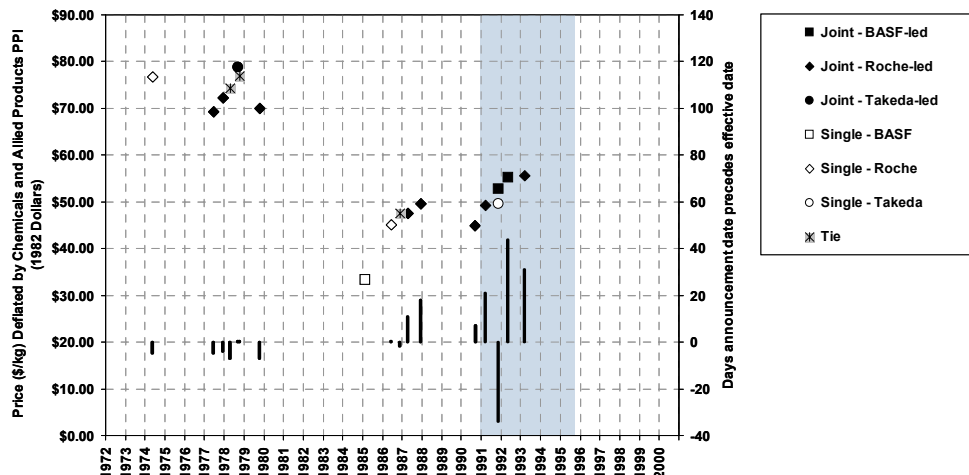


Figure 9: Riboflavin (B2) USP

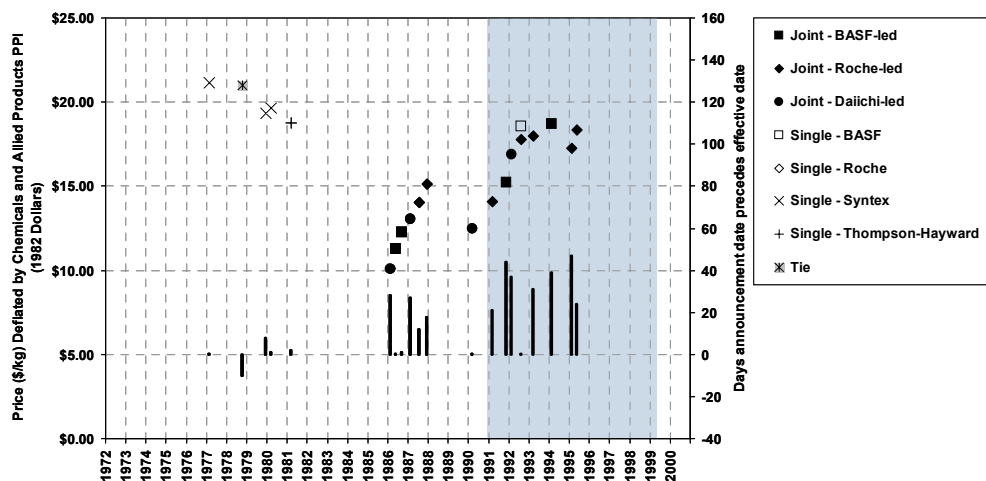


Figure 10: Calpan (B5) USP

Notes regarding Figure 10. Several price announcements issued prior to April 1991 were made by Duphar. However, entries in the Chemical Marketing Reporter on February 10, 1986 and March 25, 1991 indicate that Duphar was acting as a distributor for Daiichi, so we classify these as announcements by Daiichi.

On May 29, 1995, BASF announced a 7 percent increase in the price of B5 USP, but did not provide an exact price; however, it seems BASF's intent was to match Roche's announcement of May 8, 1995, so we classify that announcement as a joint announcement led by Roche (Daiichi announced the same price as Roche on May 29, 1995).

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