

# Lessons for Competition Policy from the Vitamins Cartel

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## Abstract

Mergers have the potential for negative social welfare consequences from increased likelihood or effectiveness of future collusion. This raises the question of whether there are meaningful thresholds for the post-merger industry that should trigger significant scrutiny by the Department of Justice or Federal Trade Commission. This paper provides empirical analyses relevant to this question using data from the Vitamins Industry, where explicit collusion was admittedly rampant in the 1990s. In analyzing prices in the post-plea period, which is a period of potential tacit collusion, we find that vitamin products with two conspirators continue as if the explicit conspiracy never stopped, while products with three or four conspirators return to pre-conspiracy pricing, or lower, quite quickly. Although it is difficult to extrapolate to other industries, the evidence suggests that, by itself, a proposed reduction in the number of firms manufacturing a given product from four to three via a merger is not problematic in terms of the efficacy of tacit collusion. The danger of a three firm industry is that it is close to duopoly, and the benefits of explicit collusion in a duopoly appear to be sustainable via tacit methods well past intervention by enforcement authorities.

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# 1 Introduction

A major social welfare concern regarding a potential merger is the impact of increased concentration on the future suppression of interfirm rivalry within the industry. The Horizontal Merger Guidelines of the Department of Justice (DoJ) and Federal Trade Commission (FTC)<sup>1</sup> implicitly mandate an analysis of the increased chances of future coordination as well as the increased payoffs from any incremental coordination among firms in an industry.<sup>2</sup> Incremental coordination can be explicit collusion or tacit collusion. Although the latter is not illegal, the Guidelines are clear in expressing concern about approving mergers where tacit collusion may become easier and more effective, and thus lead to diminished social welfare.<sup>3</sup>

Any empirical study of an industry that tries to assess the impact of explicit or tacit collusion will confront basic issues. First, prices can vary for a large number of reasons related to demand and cost conditions that are largely unrelated to the nature of interfirm rivalry in the industry. Second, even if controls exist for many of these factors, it can be difficult to separate tacit from explicit collusion. Yet, these are important to disentangle. Suppose that explicit collusion can be profitably sustained with relatively large number of market participants, but the profitability of tacit collusion is highly sensitive to the number of market participants. Specifically, suppose that a duopoly can sustain prices with tacit collusion that are not different from those attainable by an explicit cartel, but a four-firm oligopoly can only sustain tacitly collusive prices that are half of what was possible with explicit collusion. Then

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<sup>1</sup>Available at [http://www.usdoj.gov/atr/public/guidelines/horiz\\_book/hmg1.html](http://www.usdoj.gov/atr/public/guidelines/horiz_book/hmg1.html).

<sup>2</sup>Arguments regarding the change in coordinated effects from a merger have historically consisted of four components. First, if there are a substantial number of firms remaining after the merger, then adverse effects are viewed as relatively unlikely. Second, if the Herfindahl index rises substantially, then the merger is viewed as being worthy of further investigation for adverse social effects through coordinated effects. Third, the Guidelines make special note of “Maverick” firms—if a Maverick is part of a merger, then the merger is viewed as having potentially adverse social effects, but if a Maverick exists in the industry and is not involved with the merger, then the merger is viewed with less concern. Fourth, arguments are made, rooted in the Folk Theorem and economics literature on tacit collusion, about how firms’ abilities to monitor each other and punish deviant behavior might change as a result of the merger.

<sup>3</sup>According to the Horizontal Merger Guidelines (at Section 2.1): “A merger may diminish competition by enabling the firms selling in the relevant market more likely, more successfully, or more completely to engage in coordinated interaction that harms consumers. Coordinated interaction is comprised of actions by a group of firms that are profitable for each of them only as a result of the accommodating reactions of the others. This behavior includes tacit or express collusion, and may or may not be lawful in and of itself.”

it would be sensible for the FTC to devote considerably more resources to challenging “three-to-two” mergers than “five-to-four” mergers.

We argue that there exist some natural experiments in this regard that are commonplace and for which data should be readily available, especially to enforcement agencies.<sup>4</sup> Specifically, when the DoJ discovers explicit collusion, there is typically a plea period, with the conspirators admitting to collusion during that period. In the abstract, the end of the plea period marks the end of the conduct (although there can be substantial lingering effects on price from explicit collusion). Although the explicit collusion has ended, the nature of the agreements that existed between the firms for organizing their illegal conduct, the processes by which they monitored one another, and the mechanisms used to threaten punishment are not forgotten by the former conspirators. How they organized their conduct to achieve high prices remains well known among them. Thus, these firms should be able to use these lessons, at least in part, to sustain tacit collusion after the end of the plea period.

If data show that after the end of explicit collusion, firms cannot sustain prices close to plea-period levels, this suggests that highly profitable tacit collusion is not easy to sustain in this industry. If data show that prices after the end of explicit collusion are inversely related to the size of the plea-period cartel, this suggests that the number of firms in an industry may affect the potential for profitable and effective tacit collusion as a coordinated effect. Thus, merger policy potentially can be guided based on empirical analyses such as those presented here.

Since the mid-1990s, the DoJ and the FTC ordinarily sued to block horizontal mergers that would have reduced the number of market participants to three or fewer firms. As a rough generalization, over the past decade, antitrust lawyers confidently have been able to advise the parties to proposed mergers that, based on an examination of the agencies’ decisions to prosecute, the threshold at which the federal authorities would sue to block deals is “four-to-three.”<sup>5</sup> As Table 1 below indicates,

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<sup>4</sup>Enforcement agencies should mandate as a condition of merger approval that certain information be made available to them post-merger on an ongoing basis, and they should devote staff resources to the analysis of this data.

<sup>5</sup>There have been exceptions to this general proposition. FTC’s complaint in its unsuccessful challenge in 2004 to the acquisition by Arch Coal of Triton alleged that the number of firms in one relevant market following the merger would have fallen from five to four. *Federal Trade Commission v. Arch Coal Co.*, 329 F. Supp. 2d 109 (D.D.C. 2004). It is also possible to identify some horizontal transactions (particularly in the aerospace and defense sectors) over the past decade for which the federal antitrust agencies took no action even though the number of surviving firms fell to less than three. Kovacic (2003, 444-47).

this litigation threshold has shifted significantly over the past half-century.

Table 1: DoJ/FTC Merger Policy: Litigation Threshold  
for Horizontal Mergers 1960-2005

| Decade | Threshold of Likely Litigation Challenge                |
|--------|---|
| 1960s  | Merger reduces number of survivors to 12 or fewer firms |
| 1970s  | Merger reduces number of survivors to 8 or fewer firms  |
| 1980s  | Merger reduces number of survivors to 5 or fewer firms  |
| 1990s  | Merger reduces number of survivors to 3 or fewer firms  |
| 2000s  | Merger reduces number of survivors to 3 or fewer firms  |

These adjustments have been the result of two interrelated developments: DoJ and FTC self-assessments driven by changes in the state of research and scholarly commentary, and judicial decisions that retreated from the strong presumptions of illegality adopted by courts in the 1960s and imposed more demanding burdens upon the federal agencies when seeking to block horizontal mergers.<sup>6</sup>

The existing economics literature does not clearly address whether a merger that reduces the number of firms from five to four or from four to three should be viewed as problematic. (For a review of the literature, see Section 2.) Thus, empirical studies that can address these numbers could provide a useful guide for enforcement agencies as to where to invest scarce resources in challenging mergers on the basis of coordinated effects.

In this paper, we analyze price data for thirty vitamin products for which we have observations that span three periods of time: prior to a period of admitted explicit collusion, during a period of admitted explicit collusion, and after a period of admitted explicit collusion. The period of admitted explicit collusion spans much of the 1990's, when many of the manufacturers of vitamins admitted their guilt regarding participation in a worldwide price-fixing conspiracy.<sup>7</sup> Even though we examine data for markets characterized by explicit collusion rather than mergers, we are able to draw implications for merger policy. Note that an explicit cartel can be viewed as an illegal, and possibly temporary, merger of the colluding firms.

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<sup>6</sup>On the promulgation and revision of merger guidelines by the federal agencies since the 1960, see Greene (2005); Symposium (2003). On the influence of judicial decisions and the change in merger jurisprudence since 1960, see Gavil et al. (2002, 418–558); Leary (2002).

<sup>7</sup>Explicit collusion may have existed prior to the beginning of the period of admitted guilt. In fact, recent work (Marshall, Marx, and Raiff, 2005) suggests that the collusion may have started in the mid-80's.

There are many different vitamins, and an even greater number of vitamin products. The number and identities of firms that can produce each vitamin product differ across the products, as did the number of cartel participants. Yet, there is no significant heterogeneity in the factor inputs used to produce different vitamin products, and demand fluctuations tend to affect vitamin products in similar ways. Thus, we are able to attribute much of the difference in pricing behavior to the number of firms producing the different vitamin products.

We analyze the price path for these vitamin products after the end of the plea-period. This allows us to examine whether, after the termination of explicit collusion, firms can maintain prices at cartel levels, or whether there is erosion in prices relative to their explicitly collusive levels. We examine whether the price paths following the plea periods for the different vitamin products depend on the number of firms engaged in the previous explicit collusion, controlling for the effects of fringe producers. This analysis allows us to obtain a partial understanding of how market concentration impacts the efficacy of tacit collusion. This understanding can be used to inform merger analysis with respect to concerns about coordinated effects.

Our primary finding is that after the end of explicit conduct, duopolies continue as if the explicit conspiracy never stopped, while markets with three or four cartel firms return to pre-conspiracy pricing, or lower, quite quickly.

## 2 Literature

The early literature in industrial organization discusses how, in industries with small numbers of firms, firms might be expected to recognize their mutual interdependence and that one might expect relatively more collusive outcomes in industries with relatively fewer firms (see Chamberlin, 1933; Bain, 1951; and Stigler, 1964). Later work provides experimental and theoretical support for the idea that the competitiveness of an industry with a small number of firm can be expected to be increasing in the number of firms.<sup>8</sup> Selten's (1973) paper argues that "4 are few and 6 are many" (p.199), so that six firms are sufficiently many that collusive outcomes are unlikely. The empirical work of Kwoka (1979) leads him to conclude that "three-firm

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<sup>8</sup>Dolbear, et al. (1968) provide experimental results, and Selten (1973) provides theoretical results. Also, Werden and Baumann (1986) provide theoretical results in which competitiveness is nonmonotonic in the number of firms. In their model, damages increase more slowly than the benefits of collusion as the number of firms increases.

coordination problems are so severe as to make a large third firm more likely a rival.” (p.108) Thus, his results suggest that in many cases three firms are sufficiently many to prevent collusive outcomes. The empirical work of Bresnahan and Reiss (1991) lead them to conclude that once there are three to five firms in an industry, a new entrant has little effect on the competitiveness of the industry, suggesting that three to five firms are sufficient to prevent collusive outcomes. Recent experimental work by Huck, Normann, and Oechssler (2004) suggests competitiveness is monotonic in the number of firms and that four or five firms is sufficient to prevent collusive outcomes.

### 3 Coordinated Effects Analysis

Concern about post-merger coordinated effects has supplied the main conceptual basis for antitrust scrutiny of horizontal transactions since the Celler-Kefauver Amendment to the Clayton Act’s merger control provision in 1950.<sup>9</sup> The views of scholars, enforcement agencies, and courts about the appropriate application of coordinated effects analysis have undergone considerable change over the past half-century. Through the 1960s, merger doctrine and enforcement policy reflected acute apprehension about the oligopoly gap—the zone in which firms in moderately or highly concentrated industries could realize supranormal returns by accounting for their interdependence in ways that did not transgress the Sherman Act’s prohibitions on express collusion and abusive single-firm behavior.<sup>10</sup>

In the 1950s and 1960s, many economists and lawyers endorsed measures to address the oligopoly gap directly by deconcentrating industries with oligopoly market structures.<sup>11</sup> Although many observers regarded deconcentration was the preferred

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<sup>9</sup>The 1950 amendments established the basic substantive framework of today’s merger control regime. See Gellhorn et al. (2004, 418–21) (describing rationale for and history of the 1950 amendments to Section 7 of the Clayton Act).

<sup>10</sup>For a representative synthesis of this view, see Kaysen and Turner (1959, 110) (observing that “[t]he principal defect of present antitrust law is its inability to cope with market power created by jointly acting oligopolists). See also Kovacic & Shapiro (2000, 51–52).

<sup>11</sup>See Kovacic (1989, 1136–39) (recounting proposals by economists and lawyers to deconcentrate oligopoly sectors). Congress declined to enact the deconcentration legislation, and efforts by the federal antitrust agencies to use the existing antitrust laws to restructure oligopolies – for example, through the prosecution of “shared monopoly” cases by the FTC – were entirely unsuccessful. See Kellogg Co., 99 F.T.C. 8, 269 (1982) (dismissing shared monopolization complaint against leading U.S. producers of breakfast cereal); Exxon Corp., 98 F.T.C. 453, 461 (1981) (dismissing shared monopolization complaint against leading refiners of petroleum products).

solution, merger policy had a key role to play in ensuring that horizontal combinations did not create new oligopolies or increase the effectiveness of tacit coordination in already concentrated industries. As suggested above, U.S. merger policy in the 1960s and early 1970s aggressively policed horizontal mergers, and Supreme Court decisions establishing powerful (and typically decisive) presumptions of illegality for transactions that resulted in post-acquisition market shares of less than ten percent.<sup>12</sup>

The reliance of merger doctrine and enforcement policy upon structural presumptions fell under heavy scholarly attack. Much of the criticism raised doubts about how effectively oligopolists could coordinate their behavior by tacit means—that is, without resorting to an overt or covert exchange of assurances.<sup>13</sup> From at least the late 1970s to the present, this perspective has influenced courts and enforcement agencies in two basic ways. First, it has dramatically shifted the structural threshold of concern in horizontal merger cases. Decisions of the courts have weakened the power of the structural presumption in coordinated effects cases except at the highest levels of concentration.<sup>14</sup> Second, as reflected in judicial decisions such as *Arch Coal* in the United States and *AirTours* in the European Union, the enforcement agencies have been pressed in coordinated effects cases to explain more fully and convincingly how coordination among the surviving firms will take place in the post-merger period.<sup>15</sup>

In light of these developments, a major challenge for enforcement agencies in future coordinated effects cases is to improve the basis for predicting the competitive consequences of individual cases and, in litigated disputes, to provide a more confident basis for courts to infer that specific consolidations will have anticompetitive effects. One means to this end is for the enforcement community to take steps to strengthen the empirical foundations of merger analysis. In recent years the U.S. agencies have invested additional resources in “competition policy research and development” (Kovacic 2005). These investments have included ex post assessments of

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<sup>12</sup>See, e.g., *United States v. Pabst Brewing Co.*, 384 U.S. 546 (1966) (prohibiting merger that yielded a post-acquisition market share of 4.49 percent).

<sup>13</sup>See Baker (1993) (describing evolution of economic thinking about oligopoly and the feasibility and frequency of effective coordination). An important stimulus for this line of inquiry was George Stigler’s work (1964) on the difficulties that firms face in achieving effective coordination when they seek to orchestrate their behavior through express, rather than tacit, means.

<sup>14</sup>See, e.g., *FTC v. H.J. Heinz Co.*, 246 F.3d 708 (D.C. Cir. 2001) (condemning acquisition that reduced the number of firms in the relevant market from three to two); see also Baker (2004) (discussing application of structural presumption in *Heinz* case).

<sup>15</sup>See *FTC v. Arch Coal Co.*, 329 F. Supp. 2d 109 (D.D.C. 2004); *AirTours plc v. Commission*, Case T-342/99, [2002]ECR II-2585.

the competitive effects of completed mergers (Muris & Pitofsky 2005, 827-28) and the review of past merger reviews to identify evidence that most strongly influenced the decision whether to challenge transactions (FTC 2004).

A promising additional frontier for empirically-oriented research relevant coordinated effects analysis is for competition agencies to study their experience with the enforcement of antitrust laws against cartels.<sup>16</sup> Government competition authorities have accumulated considerable experience in anti-cartel enforcement programs, and the examination of individual enforcement episodes can yield valuable insights about industry conditions in which tacit coordination is most likely to be effective. The examination of the Vitamins Cartel in the sections that follow illuminate the possibilities of such a research program.

## 4 Data from the Vitamins Industry

### 4.1 Overview

In this section we provide a brief overview of the Vitamins Industry and collusive behavior by firms in the industry. For more details on the Vitamins Industry, see Bernheim (2002), European Commission (2003), and Marshall, Marx, and Raiff (2005).

Vitamins are produced and purchased for both human and animal consumption. Each vitamin has a specific set of beneficial effects. When considering the cost of producing animal feed or human food, the incremental cost of the vitamin additives typically is small. 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, in this section, we consider four different Vitamin A products: A Acetate 500 USP, A Palmitate 250 USP, A Palmitate 500 USP, and A Acetate 650 Feed Grade.

Vitamins are largely produced through processes of chemical synthesis, although there have been recent advances in fermentation technologies for the production of some vitamins. The industry is highly concentrated, and the large capital invest-

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<sup>16</sup>Some of these possibilities are suggested in Kolasky (2002).

ments, and especially the production experience, required for the manufacture of vitamins are a barrier to entry. 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. A given vitamin product made by one firm is chemically identical to the same product made by another firm.

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.<sup>17</sup> In addition, the European Community and Canada found that several of the vitamin producers had violated antitrust laws within their jurisdictions. In this report, we refer to the interval of the DoJ plea dates as the “plea period.”

Detailed descriptions of the vitamins conspiracy can be found in the European Commission’s (2003) decision. In general, the cartel fixed the market shares of the colluding firms, referring to these shares as “budget targets,” and monitored the output of the cartel members. The cartel used interfirm output transactions as a mechanism for rectifying any internal issues that arose, whether these were adherence to budgeted market share allocations or other matters regarding the enhancement of cartel profits. 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.”

The cartels in the different vitamin products operated over approximately the same period of time in the 1990s, and possibly prior to 1990. The different vitamins have similar factor inputs and demand for the different vitamins is subject to similar shocks, although on the demand side, there may be some differences between vitamins intended for human use and those intended for use in animals. Because of this, we analyze human and feed vitamins separately. Among human vitamins and among feed grade vitamins, similarities in the environments in which the cartels operated, including the time periods and the supply and demand factors, allow us to make comparisons across vitamins.

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<sup>17</sup>On the abuse by Hoffmann-La Roche of its dominant position in the industry in the 1970s, see Case 85/76, *Hoffmann-La Roche v. Commission (Vitamins)*, 1979 ECR 461, 539-40 (C.J.).

## 4.2 Data

Price data on a set of vitamin products is available from the Expert Report of B. Douglas Bernheim, M.D.L. No. 1285, In Re: Vitamins Antitrust Litigation, Misc. No. 99-0197 (TFH), May 24, 2002.<sup>18</sup> Section 12 of Bernheim (2002) provides data for 37 vitamin products, including the monthly weighted average unit price in dollars per kilogram from 1980 to 2002 (shorter time period for some vitamin products), the dates of the plea-period, the identities of the cartel firms, and the identities or locations (e.g., Eastern Europe) of non-cartel firms. In addition, Section 10 of Bernheim (2002) provides data for 2 additional vitamin products, Ascorbic Acid 100% USP and E 50% Adsorbate Feed Grade. For these two vitamin products, prices are broken out by producer, so we used the worldwide production shares for Vitamins C and E, given in Figures 8-1 and 8-7 of Bernheim (2002), to construct a weighted average price.<sup>19</sup>

As an example of the data that is available for each vitamin product in the Bernheim (2002) report, Figure 1 shows the data available for Vitamin A Acetate 650 Feed Grade. The information includes a weighted average price for the vitamin product, the plea-era sales value, and a list of the manufacturers, both cartel and non-cartel. As described in the caption of the figure, the price graphs in Bernheim (2002) show the 7-month centered moving average for U.S. “tel quel” price from Roche ROVIS data.<sup>20</sup> The qualifier “tel quel” means that these are prices for vitamin sold in their straight form rather than as part of premix, which is a premixed collection of different vitamin products. Feed vitamins use feed prices, and human vitamins use food, pharma, and cosmetic prices.

According to Bernheim (2002), the price data are derived from the Roche ROVIS database (except Choline Chloride (B4), which we do not include in our data).<sup>21</sup>

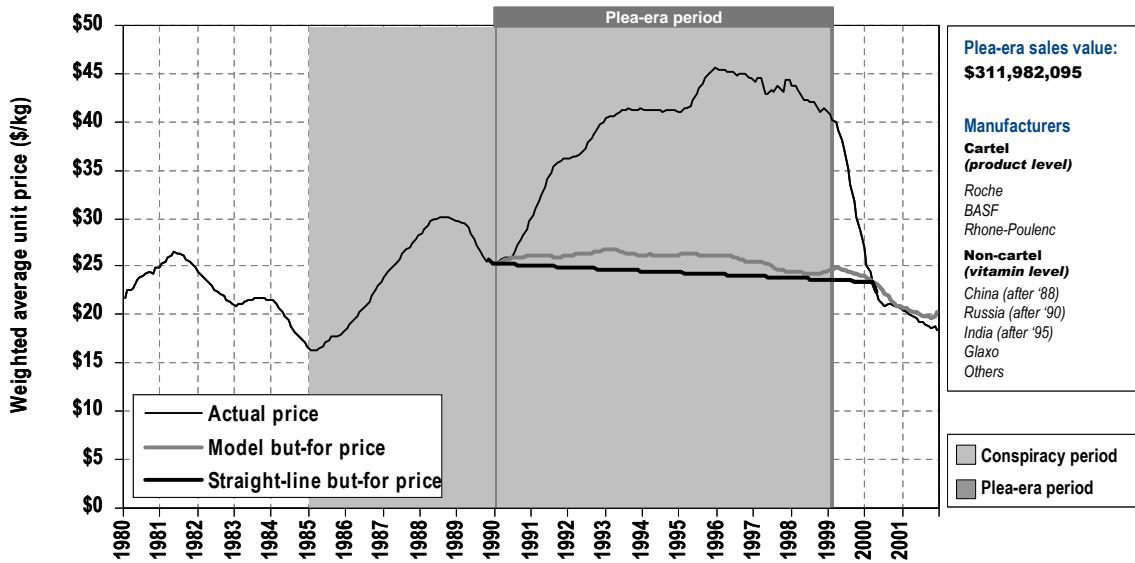
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<sup>18</sup>Bernheim (2002) was submitted as exhibit number 243 in In re: Vitamins Antitrust Litigation, case No. 99-0197 (TFH) filed in the District Court of the District of Columbia. We obtained the document through a request to the law clerk to Chief Judge Thomas F. Hogan. The document was made available based on D.C. Local Civil Rule 79.2 and the United States District Court for the District of Columbia’s policy of not retaining exhibits that are admitted into evidence at trial in civil cases. The price data used in this paper were reverse engineered from the graphs in the document.

<sup>19</sup>Weights are given by year and are not available after 1998, so for years after 1998, the weights are assumed to be the same as in 1998. Figure 8-7 does not explicitly state BASF’s Vitamin C production share for four years. Based on the figure, we judge those shares to be 1980: 2%; 1981: 2%; 1989: 4%; and 1996: 4%.

<sup>20</sup>For Ascorbic Acid 100% USP and Vitamin E 50% Adsorbate Feed Grade the source is listed as “defendant transaction data.”

<sup>21</sup>According to Bernheim (2002, p.23), the ROVIS data were “reviewed and verified” as described in an appendix to the report. Bernheim had access to “documents produced through discovery,



Source: 7-month centered moving average for U.S. “tel quel” feed price from Roche ROVIS data

Figure 1: Data on Vitamin A Acetate 650 Feed Grade as shown in Figure 12-6 of Bernheim (2002, p.207)

The vitamin products in Section 12 of Bernheim (2002) are those that satisfy two requirements: the data must be consistently reported throughout the 1980 to 2001 time period (with a few exceptions) and the product must account for at least 1.5 percent of Roche’s U.S. sales within the relevant vitamin family between 1980 and 2001 and account for at least \$10 million in Roche’s sales volume over the same period.

To improve comparability across vitamin products, we focus on vitamin products that are produced by Roche. This eliminates seven vitamin products, including two Choline Chloride products, four Niacin products,<sup>22</sup> and Vitamin B12 Crystals. In addition, we drop the two Biotin products because they are outliers in a number of ways: they are the only two vitamin products with five firms in the cartel (the other Roche vitamins have four or fewer in the cartel); they are small in terms of the

litigation-related information including testimony and affidavits, and publicly available documents and data.” (p.24) He also “reviewed testimony, affidavits, written discovery responses, and other litigation-related information.” (p.25)

<sup>22</sup>Although Bernheim’s (2002) Figure 12-27 shows Roche as a manufacturer of one Niacin product, Niacinamide (B3) 33 1/3% USP, Figure 8-18 shows that Roche does not produce Niacin, so we do not include this vitamin product in our data.

dollar amount of sales during the plea period (they have less than \$9 million in plea sales, whereas the average plea sales of the other Roche vitamins is over \$97 million); and the identities of the cartel firms, although Roche is one, are not consistent with those of the other Roche vitamin products (the Biotin products are the only Roche products that are also produced by Tanabe and Lonza). That leaves us with the thirty vitamin products shown in Table 2.

Table 2: Description of the Vitamin Products Included in the Analysis

|    | Vitamin Type  | Vitamin Product                                | Start of Plea Period | End of Plea Period | Number in Cartel | Non-Cartel Production Share Prior to Plea | Non-Cartel Production Share at End of Plea |
|----|---------------|--|----------------------|--------------------|------------------|---|--|
| 1  | A             | Vitamin A Acetate 500 USP                      | 1/1/1990             | 2/1/1999           | 2                | 1   | 9  |
| 2  | A             | Vitamin A Acetate 650 Feed Grade               | 1/1/1990             | 2/1/1999           | 3                | 1   | 9  |
| 3  | A             | Vitamin A Palmitate 250 USP                    | 1/1/1990             | 2/1/1999           | 2                | 1   | 9  |
| 4  | A             | Vitamin A Palmitate 500 USP                    | 1/1/1990             | 2/1/1999           | 2                | 1   | 9  |
| 5  | B1            | Thiamine (B1) Hydrochloride USP                | 1/1/1991             | 6/1/1994           | 3                | 15  | 40   |
| 6  | B1            | Thiamine (B1) Mononitrate USP                  | 1/1/1991             | 6/1/1994           | 3                | 15  | 40   |
| 7  | B2            | Riboflavin (B2) 33 1/3% USP                    | 1/1/1991             | 9/1/1995           | 1                | 10  | 12   |
| 8  | B2            | Riboflavin (B2) 80%/50% Spray-Dried Feed Grade | 1/1/1991             | 9/1/1995           | 4                | 10  | 12   |
| 9  | B2            | Riboflavin (B2) USP                            | 1/1/1991             | 9/1/1995           | 4                | 10  | 12   |
| 10 | B5            | Calpan (B5) Spray-Dried Feed Grade             | 1/1/1991             | 12/1/1998          | 3                | 14  | 17   |
| 11 | B5            | Calpan (B5) USP                                | 1/1/1991             | 12/1/1998          | 3                | 14  | 17   |
| 12 | B6            | Pyridoxine (B6) Hydrochloride USP              | 1/1/1991             | 6/1/1994           | 3                | 10  | 46   |
| 13 | Beta Carotene | Beta Carotene 10% Cold Water Soluble USP       | 1/1/1991             | 12/1/1998          | 2                | 0   | 0  |
| 14 | Beta Carotene | Beta Carotene 22% HSS USP                      | 1/1/1991             | 12/1/1998          | 2                | 0   | 0  |
| 15 | Beta Carotene | Beta Carotene 30% Fluid Soluble USP            | 1/1/1991             | 12/1/1998          | 2                | 0   | 0  |
| 16 | C             | Ascorbic Acid 100% USP                         | 1/1/1991             | 11/1/1995          | 4                | 13  | 38   |
| 17 | C             | Ascorbic Acid Coated Feed Grade                | 1/1/1991             | 11/1/1995          | 4                | 13  | 38   |
| 18 | C             | Ascorbic Acid Coated USP                       | 1/1/1991             | 11/1/1995          | 4                | 13  | 38   |
| 19 | C             | Ascorbic Acid Compressible 90% USP             | 1/1/1991             | 11/1/1995          | 3                | 13  | 38   |
| 20 | C             | Sodium Ascorbate USP                           | 1/1/1991             | 11/1/1995          | 4                | 13  | 38   |
| 21 | Carotenoids   | Apocarotenal 20% USP                           | 5/1/1993             | 12/1/1998          | 2                | 0   | 0  |
| 22 | Carotenoids   | Canthaxanthin 10% Feed Grade                   | 5/1/1993             | 12/1/1998          | 2                | 0   | 0  |
| 23 | Carotenoids   | Canthaxanthin 10% USP                          | 5/1/1993             | 12/1/1998          | 2                | 0   | 0  |
| 24 | D             | Vitamin D3 100 USP                             | 1/1/1994             | 6/1/1998           | 3                | 0   | 0  |
| 25 | D             | Vitamin D3 500 Feed                            | 1/1/1994             | 6/1/1998           | 3                | 0   | 0  |
| 26 | E             | Vitamin E 50% Adsorbate Feed Grade             | 1/1/1990             | 2/1/1999           | 4                | 0   | 13   |
| 27 | E             | Vitamin E Acetate 50% Spray-Dried Feed Grade   | 1/1/1990             | 2/1/1999           | 3                | 0   | 13   |
| 28 | E             | Vitamin E Acetate 50% Spray-Dried USP          | 1/1/1990             | 2/1/1999           | 2                | 0   | 13   |
| 29 | E             | Vitamin E Acetate Oil USP                      | 1/1/1990             | 2/1/1999           | 3                | 0   | 13   |
| 30 | Folic Acid    | Folic Acid (B9)                                | 1/1/1991             | 6/1/1994           | 4                | 4   | 41   |

To define the plea period for each vitamin product, we use the U.S. plea period for that product's vitamin type if there is one, and otherwise we use the EC or Canadian plea period as given in Bernheim (2002, Table 6). For vitamin products with both EC and Canadian plea periods, but no U.S. plea period, we use the EC plea period.

To define the non-cartel production shares prior to the plea and at the end of the plea, we use the figures of Section 8 of Bernheim (2002), which show annual world production shares by firm at the vitamin level (not the vitamin product level). We use the shares in the year prior to the beginning of the plea period and in the final year of the plea period.<sup>23</sup>

<sup>23</sup>Share data is not available for Apocarotenal, so we use the share data for Canthaxanthin for all of the Carotenoids.

Note that Table 2 shows one vitamin product, Riboflavin (B2) 33 1/3% USP, that had only one firm involved in the conspiracy. For this vitamin product, Roche was the only manufacturer charged with illegal activity. The data for this vitamin product gives us some idea of how a monopolist manufacturer would behave. All other vitamin products had a two, three, or four-firm cartel.

For each vitamin product listed in Table 2, we constructed a monthly dataset of prices based on the price graphs in Bernheim (2002).<sup>24</sup> For all but four vitamin products, data are available from January 1980 until December 2001. The exceptions are that the data for Vitamin D3 500 Feed starts in January 1983, the data for Vitamin D3 100 USP starts in January 1985, the data for Ascorbic Acid 100% USP is continuous starting from December 1985, and the data for Vitamin E 50% Adsorbate Feed Grade is continuous starting from January 1986.

Although the plea periods vary for the different vitamin products, data are available for all the vitamin products in our sample for 48 months prior to the beginning of their plea periods and for 31 months after the end of their plea periods.

The data are not useful for examining firms' propensity to engage in explicit collusion. However, the data for the period after the end of the plea period, when it is reasonable to assume that explicit collusion has ended, is useful for examining the efficacy of tacit collusion. Afterall, the lessons of explicit collusion are fresh in the post-plea period. This has implications for merger policy. If prices remain high after the plea period, there is a reasonable chance that firms may have transferred key components of the profitable conduct of explicit collusion to tacit collusion. And, if there are differences in post-plea prices based on the number of firms in the cartel, this may indicate differences in the ability of firms to sustain tacit collusion after the termination of explicit collusion depending on the number of firms involved.

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<sup>24</sup>The underlying data used to construct the figures in Bernheim (2002) is not in the public domain, so we scanned and digitized the figures using Engauge Digitizer software and then used the software to constructly monthly data by collecting two data points off the graph for each month and then taking the average. Complete details on the procedure used are available from the authors.

## 5 Analysis

### 5.1 Graphical Analysis

To begin our analysis, we consider the percentage change in price relative to the plea-period maximum for the different vitamin products broken out by the number of firms in the cartel.

Figures 2–5 provide information on the prices of the different vitamin products included in the analysis. Figure 2 shows the product produced by only one conspirator. Figure 3 shows the products with a two-firm cartel. Figure 4 shows the products with a three-firm cartel. And Figure 4 shows the products with a four-firm cartel. On the horizontal axis, we show the number of months prior to the start of the plea period (negative numbers) and the number of months after the end of the plea period (positive numbers), and on the vertical axis the percentage change in price relative to the maximum price achieved during the plea period.<sup>25</sup> Note that we are not claiming that the behavior in the Vitamins Industry prior to the plea period was non-collusive. To the contrary, Bernheim (2002) assumes the conspiracy began in January of 1985, an assumption that is supported by the analysis of the vitamin manufacturers’ public price announcements in Marshall, Marx, and Raiff (2005). We address this more formally in Section 5.2.

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<sup>25</sup>Note that the prices in Bernheim (2002) are seven-month centered moving averages, so our “maximum plea-period price” is the maximum of these seven-month centered moving averages.

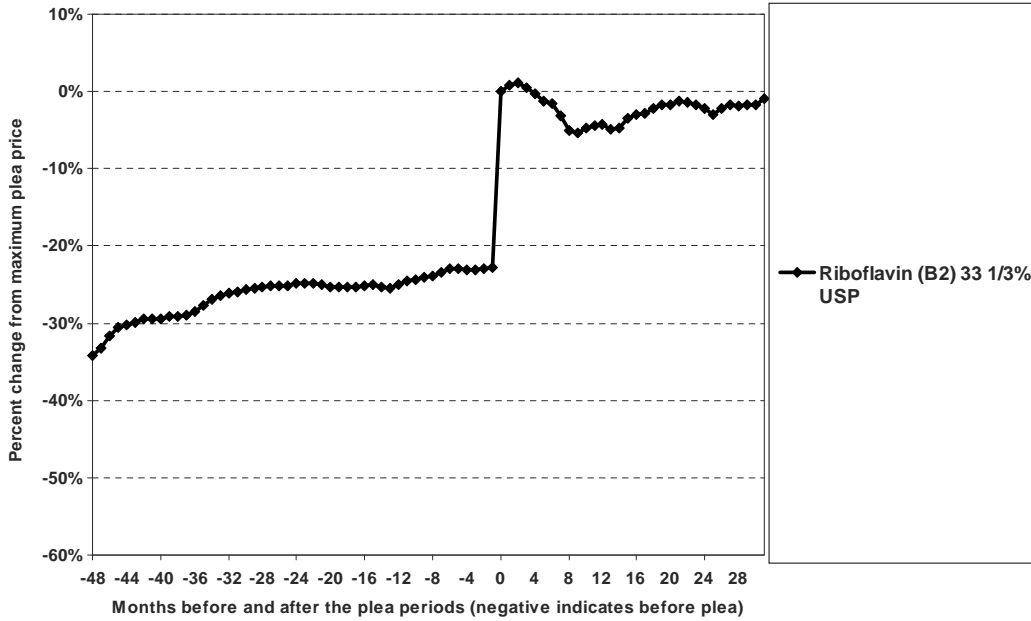


Figure 2: Percentage change in price relative to plea-period maximum for the product produced by only one conspirator

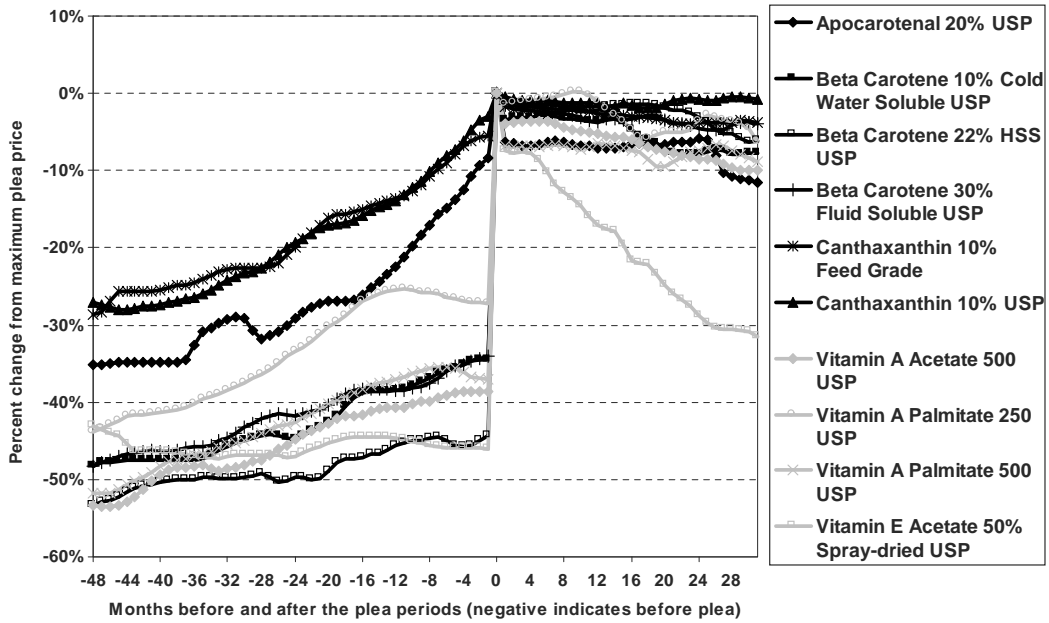


Figure 3: Percentage change in price relative to plea-period maximum by product for products with a two-firm cartel

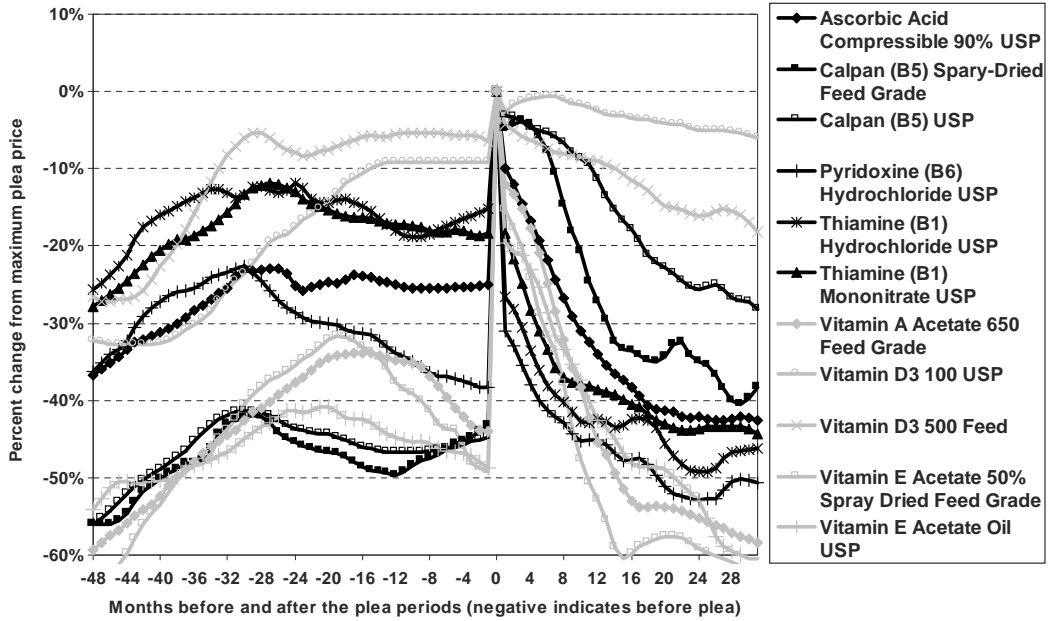


Figure 4: Percentage change in price relative to plea-period maximum by product for products with a three-firm cartel

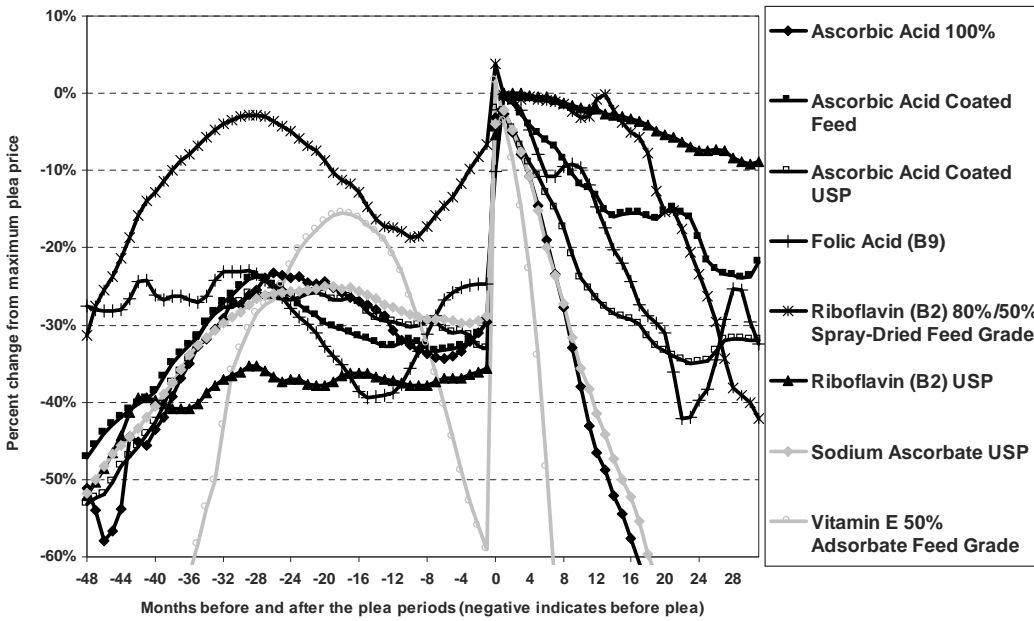


Figure 5: Percentage change in price relative to plea-period maximum by product for products with a four-firm cartel

We see from Figure 2 that for the vitamin product manufactured by only one conspirator, prices remained high after the plea period relative to their pre-plea levels.

From Figure 3 we see that for all but one of the vitamin products with a two-firm cartel, prices remain close to their plea-period maxima. The price of Vitamin E Acetate 50% Spray-Dried USP falls after the end of the plea period, but after more than two years, remains well above its pre-plea levels. Referring to Figure 4, for the cartels involving three firms, the evidence is somewhat mixed.<sup>26</sup> Prices for some products remain above their pre-plea levels, but others drop sharply after the end of the plea period. Finally, referring to Figure 5, for four-firm cartels, in all cases, the price eventually ends up below pre-plea nominal levels (for Ascorbic Acid Coated Feed, the price does not drop below pre-plea levels until mid 1999, 41 months after the end of the plea period). The rate of descent varies for these vitamin products, with the prices in coated Vitamin C products descending less rapidly than for many of the other vitamin products.

We now combine the graphs described above, averaging across vitamin products, to obtain the average price changes relative to the plea-period maximum for vitamin products with different numbers of cartel members.

Figure 6 shows a dramatic difference between the post-plea prices of products with one conspirator or a two-firm cartel versus products with three or four-firm cartels. When there is one dominant producer or there is a two-firm cartel, firms are able to maintain prices significantly above pre-plea levels. This is despite the fact that for most vitamin products in our sample, there are competing non-cartel producers. The prices for three and four-firm cartels remain elevated above their pre-plea levels for approximately one year after the end of the plea period.

Figure 6 also shows that pre-plea prices are 23% to 31% less than the plea-period maxima. It may be surprising that there is any increase at all for a product with only one conspirator, but it may be that the explicit collusion involved agreements among the larger set of conspiring firms not to enter this market, and that the removal of the threat of entry induced firms to increase prices. It may also be that other vitamin products, although not perfect substitutes, did have some substitutability with the product with only one conspirator, and so the increases in the prices of the other vitamin products due to conspiratorial behavior in those products may have allowed an increase in prices in the product produced by only one conspirator.

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<sup>26</sup>Bernheim (2002, p.176) states, “In the case of Riboflavin (B2), the evidence suggests that Roche attempted to re-cartelize the market with Rhone-Poulenc after the end of the conspiracy period. This may have prolonged the effects of the original conspiracy and delayed the onset of non-conspiratorial price dynamics.”

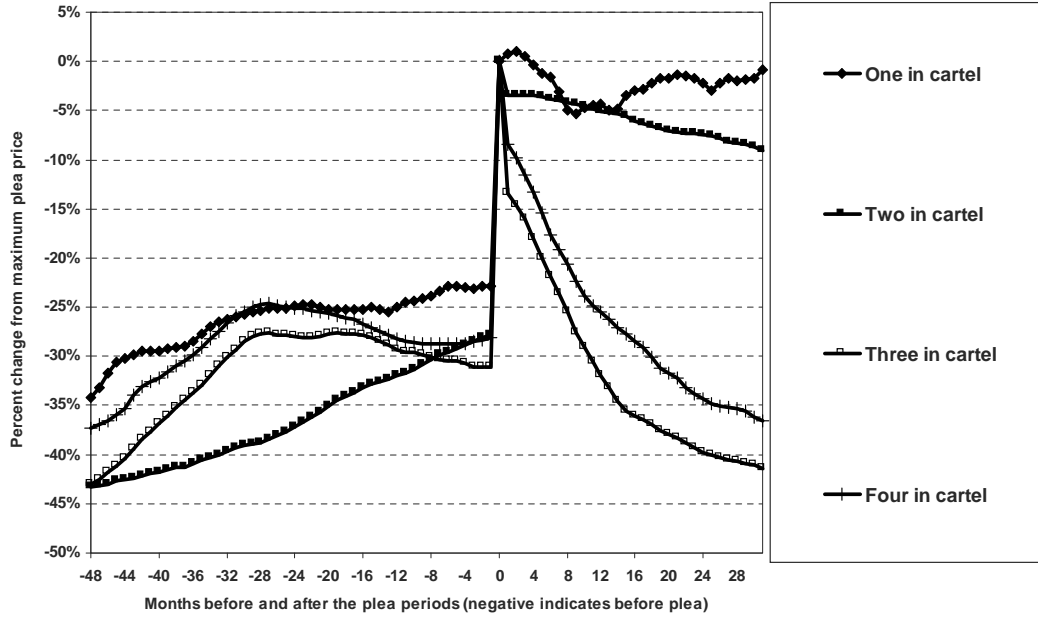


Figure 6: Average percentage change in price relative to the plea-period maxima by number in cartel

To provide an additional way to view the data, we also consider the percentage price change relative to the price one month prior to the beginning of the plea period. This data is shown in Figure 7.<sup>27</sup> Note that we only have data for all vitamin products for 31 months after the end of the plea period. Beyond 31 months after the end of the plea period, some vitamin products drop out of our data, resulting in jumps in the price series shown in Figure 7.

Figure 7 shows that prices for two, three, and four-firm cartels increase between 48% and 64% during the plea period relative to one month prior to the plea period. For products with only one firm involved in the conspiracy, the price increases about 30%. In the months after the plea periods, for products with one or two conspiring firms, prices remain well above their pre-plea levels. For products with one conspirator, prices remain close to their plea-period maxima long after the end of the plea period and show no signs of decay. For two-firm cartels there is slight decay, but prices remain more than 20% above their pre-plea levels over three years after the

<sup>27</sup>The price change shown at date zero in Figure 7 is the for maximum price during the plea period.

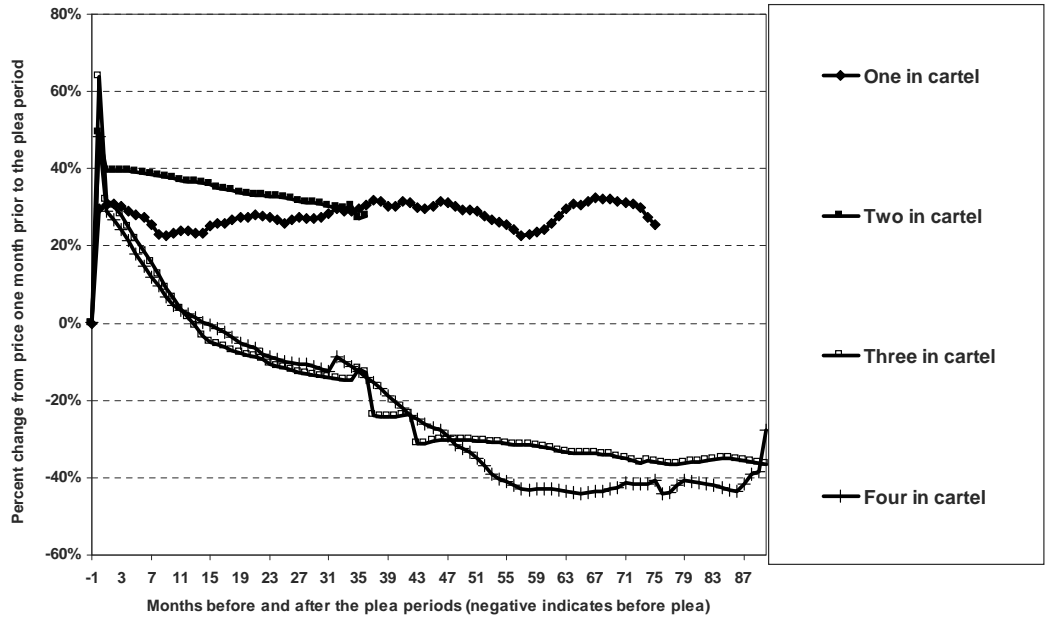


Figure 7: Average percentage change in price relative to one month prior to the beginning of the plea period by number in the cartel

end of the plea period. For three and four-firm cartels, prices fall to their pre-plea levels within fifteen months after the end of the plea period. It is interesting that prices for three and four-firm cartels fall to about 40% below their pre-plea levels within five years after the end of the plea period. This may be due to competition from new entrants whose entry was induced by the high prices during the plea period.

Figure 7 also provides information about the sustainability of cartel prices after the end of explicit collusion. One might expect the vitamin manufacturers to be under heightened scrutiny from antitrust authorities in the period after the end of the plea period, and so one might expect especially competitive behavior in that period. However, as shown in Figure 7, this does not appear to be the case for products with two-firm cartels. The figure shows that prices for products with one or two conspirators remain steady from the end of the plea period out as far as our data allows. In contrast, the prices for three and four-firm cartels decrease rapidly after the end of the plea period.

The analysis of Marshall, Marx, and Raiff (2005) suggests that the collusive period in the Vitamins Industry extended back to 1985. If we use the price on January 1,

1985 as the reference point, we obtain similar results.<sup>28</sup> A general upward trend in prices between month  $-60$  and month zero, and the fact that prices fall below their 1985 levels after the end of the plea period for three and four-firm cartels, provide additional support for a collusive period that predates the beginning of the DoJ plea period.

In the Vitamins Industry, twelve firms paid a total of \$911 million in fines related to U.S. antitrust charges; however, Rhone-Poulenc, who is listed in Bernheim (2002) as a cartel producer of Vitamin A 650 Feed Grade, Vitamin E 50% Adsorbate Feed Grade, Vitamin E 50% Spray-Dried Feed Grade, Riboflavin (B2) USP, and Riboflavin (B2) 80%/50% Spray-Dried Feed Grade, received amnesty and did not pay any U.S. fines.<sup>29</sup> The conditions of amnesty may have affected the behavior of Rhone-Poulenc during the post-plea period, as suggested by Figure 8.

In summary, the figures in this section suggest that there may be differences in post-plea pricing based on the number of firms in the cartel; however, these differences may be due to factors other than the number of firms, such as the ease of entry and the conditions of DoJ amnesty. In addition, it is not clear from the figures whether the differences are statistically significant. In Section 5.2 below, we use regression analysis to control for other factors that may explain the differences and to obtain measures of the statistical significance of the effect of the number of cartel firms.

In the Appendix, we review a simple model based on Cournot competition and linear demand, which shows that when there are two firms in an industry, each firm has higher profit if it colludes than if it does not, but if there are more than two firms in an industry, then given any division of the cartel profits, there will be some firm that prefers to be outside the cartel while the remaining firms collude rather than inside the cartel. This model emphasizes that having more than two firms in an industry can be extremely disruptive to firms' attempts to collude.

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<sup>28</sup>Our data for Ascorbic Acid 100% and Vitamin E 50% Adsorbate Feed Grade does not extend back to January of 1985.

<sup>29</sup>Roche, BASF, Takeda, Eisai, Daiichi, and Merck, which were major manufacturers of the vitamin products in our data, all paid substantial U.S. fines. Besides Rhone-Poulenc, the only cartel firms for vitamin products in our data that did not pay U.S. fines were Solvay (Vitamin D), Kongo (Folic Acid), and Sumika/Sumitomo (Folic Acid).

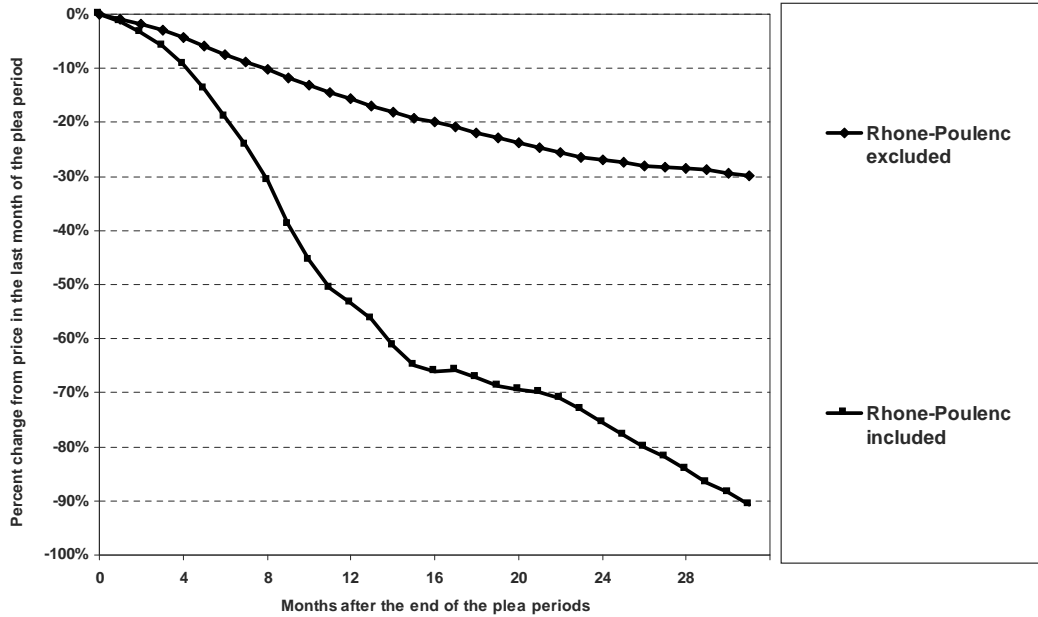


Figure 8: Average percentage change in price relative to the last month of the plea period for vitamin products produced by Rhone-Poulenc and those not produced by Rhone-Poulenc

## 5.2 Regression Analysis

The figures in Section 5.1 suggest that after the end of a period of explicit collusion, prices may remain above their pre-collusion levels for products with one dominant firm or a two-firm cartel, but not for products with three or four-firm cartels. In addition, the figures suggest that a period of explicit collusion may have a similar effect on post-collusion prices when there are three or four firms in the cartel. In this section, we test these hypotheses using regression analysis to control for factors other than the number of firms that may explain the post-plea differences (or similarities) and to obtain measures of the statistical significance of the effect of the number of cartel firms.

We present results for OLS regressions using as the dependent variable the percentage change in price over different periods of time. In regressions 1–3, we use the percentage change in price 12, 24, and 30 months after the end of the plea period relative to the price one month prior to the beginning of the plea period. In regressions 4–6, we use the percentage change in price 12, 24, and 30 months after the end

of the plea period relative to the price during the last month of the plea period. In regressions 7–9, we use the percentage change in price 12, 24, and 30 months after the end of the plea period relative to the price in January of 1985.

As independent variables, we use a dummy that is one if the vitamin product is a feed vitamin, the non-cartel world production share (at the vitamin level) in the last year of the plea, and the change in the non-cartel world production share (at the vitamin level) from the year prior to the plea to the last year of the plea. The size of the non-cartel fringe gives a measure of the competitiveness of a market, and the change in the size of the non-cartel fringe gives a measure of the ease of entry into the vitamin product. To account for any effects of the DoJ’s amnesty program, we include a dummy variable for whether Rhone-Poulenc, who received amnesty, was the manufacturer of a vitamin product. For the regressions in Section 5.3, we include a dummy that is one if China produces the vitamin product. Finally, we include dummies for whether the cartel for the vitamin product was a two-firm, three-firm, or four-firm cartel, using the product with only one conspirator as the omitted category.

Table 3 below gives descriptive statistics for the dependent and independent variables used in our regressions.

Table 3: Descriptive Statistics for Variables Used in Regression Analysis

| Variable   | Mean   | Median | Standard Deviation | Kurtosis | Skewness | Min    | Max    | Count |
|--|--------|--------|--------------------|----------|----------|--------|--------|-------|
| % change in price from -1 to +12                 | 14.24  | 6.60   | 28.17              | -0.67    | 0.44     | -32.01 | 75.79  | 30    |
| % change in price from -1 to +24                 | 5.23   | 1.99   | 29.51              | -0.67    | 0.47     | -40.05 | 74.00  | 30    |
| % change in price from -1 to +30                 | 2.94   | 1.40   | 29.67              | -0.89    | 0.44     | -37.90 | 68.21  | 30    |
| % change in price from last month of plea to +12 | -14.62 | -10.00 | 15.51              | -0.13    | -0.88    | -53.92 | 0.65   | 30    |
| % change in price from last month of plea to +24 | -21.19 | -21.22 | 18.30              | -1.16    | -0.39    | -57.67 | 0.38   | 30    |
| % change in price from last month of plea to +30 | -22.71 | -23.55 | 19.07              | -1.01    | -0.47    | -60.94 | -0.16  | 30    |
| % change in price from 1/1985 to +12             | 57.35  | 50.92  | 52.78              | 5.81     | 1.80     | -7.75  | 251.95 | 28    |
| % change in price from 1/1985 to +24             | 45.84  | 44.77  | 54.08              | 5.38     | 1.69     | -24.29 | 242.59 | 28    |
| % change in price from 1/1985 to +30             | 42.73  | 43.17  | 53.60              | 5.79     | 1.82     | -18.42 | 240.71 | 28    |
| Feed   | 0.27   | 0      | 0.45               | -0.82    | 1.11     | 0      | 1      | 30    |
| Non-Cartel Share                                 | 17.17  | 12.5   | 15.96              | -1.23    | 0.57     | 0      | 46     | 30    |
| Change in Non-Cartel Share                       | 11.47  | 8      | 11.83              | -0.75    | 0.73     | 0      | 37     | 30    |
| Rhone-Poulenc                                    | 0.17   | 0      | 0.38               | 1.66     | 1.88     | 0      | 1      | 30    |
| China  | 0.73   | 1      | 0.45               | -0.82    | -1.11    | 0      | 1      | 30    |
| 2 in cartel                                      | 0.33   | 0      | 0.48               | -1.55    | 0.74     | 0      | 1      | 30    |
| 3 in cartel                                      | 0.37   | 0      | 0.49               | -1.78    | 0.58     | 0      | 1      | 30    |
| 4 in cartel                                      | 0.27   | 0      | 0.45               | -0.82    | 1.11     | 0      | 1      | 30    |

Our general functional form is as follows:<sup>30</sup>

$$\begin{aligned}
\% \text{ change in price} = & \beta_0 + \beta_1 \cdot \text{feed dummy} + \beta_2 \cdot \text{non-cartel share} \\
& + \beta_3 \cdot \text{change in non-cartel share} + \beta_4 \cdot \text{amnesty dummy} \\
& + \beta_5 \cdot \text{two-firm cartel dummy} + \beta_6 \cdot \text{three-firm cartel dummy} \\
& + \beta_7 \cdot \text{four-firm cartel dummy}.
\end{aligned}$$

In regressions 1–3 and 7–9, we focus on price changes relative to dates prior to the beginning of the plea period. The dependent variables used in these regressions provide measures of the lasting impact of explicit collusion on prices. In regressions

<sup>30</sup>We also ran the regressions using dummies for different ranges of the non-cartel share rather than the levels themselves and found this made little difference. And we tried dropping the observation with only one conspirator and running the regressions with “2 in cartel” as the omitted category. Again, the change had little effect on the results, although the resulting coefficients on the “3 in cartel” and “4 in cartel” dummies were generally more negative (larger in absolute value) and had somewhat greater statistical significance. The coefficients on the “3 in cartel” and “4 in cartel” dummies were not statistically significantly different from each other in any of the regressions.

4–6, we focus on price changes relative to the last month of the plea period. This dependent variable allows us to focus on the sustainability of the collusive price increase.

Table 4: Regressions 1–9 for the Percentage Change in Price at Dates after the Plea Period Relative to Dates Prior to the Plea Period and Relative to the Last Month of the Plea Period

| Independent Var.           | Dependent Variable           |                           |                           |  |                          |                           |                                  |                           |                           |
|----------------------------|------------------------------|---------------------------|---------------------------|--|--------------------------|---------------------------|----------------------------------|---------------------------|---------------------------|
|                            | 1                            |                           |                           | 2  |                          |                           | 3                                |                           |                           |
|                            | % change in price from -1 to |                           |                           | % change in price from last month of plea to |                          |                           | % change in price from 1/1985 to |                           |                           |
|                            | +12                          | +24                       | +30                       | +12  | +24                      | +30                       | +12                              | +24                       | +30                       |
| Constant                   | 21.332**<br><i>9.353</i>     | 24.289***<br><i>6.877</i> | 24.852***<br><i>7.504</i> | -5.912<br><i>5.872</i>                       | -3.172<br><i>5.929</i>   | -2.467<br><i>7.525</i>    | 69.229**<br><i>28.498</i>        | 72.888**<br><i>30.064</i> | 73.512**<br><i>31.730</i> |
| Feed                       | -13.914<br><i>12.018</i>     | -12.469<br><i>12.247</i>  | -13.906<br><i>11.569</i>  | -5.373<br><i>5.631</i>                       | -4.679<br><i>7.280</i>   | -5.822<br><i>8.215</i>    | -20.224<br><i>24.940</i>         | -20.981<br><i>25.643</i>  | -23.679<br><i>25.581</i>  |
| Non-Cartel Share           | 0.485<br><i>0.967</i>        | 0.472<br><i>0.709</i>     | 0.458<br><i>0.782</i>     | 0.323<br><i>0.606</i>                        | 0.272<br><i>0.595</i>    | 0.231<br><i>0.752</i>     | -1.871<br><i>2.663</i>           | -1.944<br><i>2.808</i>    | -1.964<br><i>2.973</i>    |
| Change in Non-Cartel Share | -1.594<br><i>1.242</i>       | -1.658*<br><i>0.908</i>   | -1.474<br><i>1.025</i>    | -1.150<br><i>0.753</i>                       | -1.180*<br><i>0.680</i>  | -0.993<br><i>0.830</i>    | -2.233<br><i>1.863</i>           | -2.086<br><i>1.942</i>    | -1.841<br><i>2.104</i>    |
| Rhone-Poulenc              | -5.624<br><i>10.634</i>      | -7.940<br><i>10.841</i>   | -8.851<br><i>11.121</i>   | -15.417*<br><i>8.160</i>                     | -16.885*<br><i>8.842</i> | -17.635<br><i>10.263</i>  | -45.098<br><i>33.204</i>         | -50.446<br><i>33.169</i>  | -52.245<br><i>32.860</i>  |
| 2 in cartel                | 20.755<br><i>13.518</i>      | 13.883<br><i>11.197</i>   | 10.940<br><i>11.535</i>   | 7.544<br><i>6.146</i>                        | 2.557<br><i>5.959</i>    | 0.094<br><i>7.417</i>     | 22.369<br><i>25.308</i>          | 14.165<br><i>25.984</i>   | 10.616<br><i>27.156</i>   |
| 3 in cartel                | -2.233<br><i>13.667</i>      | -16.669*<br><i>9.611</i>  | -21.448**<br><i>9.911</i> | -3.366<br><i>5.269</i>                       | -13.548*<br><i>6.573</i> | -16.830**<br><i>7.668</i> | 74.902**<br><i>31.744</i>        | 54.553<br><i>33.471</i>   | 48.410<br><i>34.604</i>   |
| 4 in cartel                | 5.294<br><i>12.446</i>       | -7.581<br><i>10.774</i>   | -13.017<br><i>11.809</i>  | 6.163<br><i>7.543</i>                        | -3.695<br><i>8.948</i>   | -8.233<br><i>10.352</i>   | 82.217**<br><i>36.019</i>        | 65.002*<br><i>37.576</i>  | 58.153<br><i>38.730</i>   |
| Number of Obs.             | 30                           | 30                        | 30                        | 30   | 30                       | 30                        | 28                               | 28                        | 28                        |
| Adj. R-squared             | 0.306                        | 0.501                     | 0.497                     | 0.532  | 0.638                    | 0.557                     | 0.468                            | 0.475                     | 0.435                     |
| t-stat 2 in = 3 in         | -1.860                       | -3.250                    | -3.340                    | -1.650                                       | -1.830                   | -1.500                    | 0.990                            | 0.720                     | 0.640                     |
| t-stat 3 in = 4 in         | 0.730                        | 0.950                     | 0.840                     | 1.450  | 1.530                    | 1.200                     | 0.630                            | 0.880                     | 0.830                     |

Robust standard errors are in italics. Coefficients that are significant at the 90% level are shown with one asterisk, 95% level with two asterisks, and 99% level with three asterisks.

In all regressions, the feed dummy appears to be of no consequence. We expect the variables related to the non-cartel production share to capture both entry and competitive effects in regressions 1–3 and 7–9. The high price during the explicitly collusive period would be expected to induce entry, possibly causing the post-plea price to fall below its pre-plea levels (the entry effect), and a larger non-cartel share would be expected to increase the rate at which the price declines after the end of explicit collusion (the competition effect). In regressions 4–6, we expect these variables to capture only competitive effects because in these regressions the percentage change is not measured relative to pre-plea levels. When the coefficients on these variables are statistically significant, they are negative.

The coefficient on the Rhone-Poulenc dummy is negative and large in magnitude in all of the regressions. This suggests that the amnesty program may have affected prices in this industry in the post-plea era.

Focusing on regressions 1–3, the coefficients on the three-firm cartel dummy and the four-firm cartel dummy are generally negative, and in two cases we see statistically significant coefficients for the price decreases of three-firm cartels. The coefficients on the two-firm cartel dummy are positive, indicating that for products with two-firm cartels, post-plea prices remain higher relative to their pre-plea levels than if there were only one conspirator. The coefficient for a two-firm cartel is significantly different from that for a three-firm cartel in regressions 2 and 3, but the coefficients for three and four-firm cartels are not significantly different from one another.

Focusing on regressions 4–6, it is interesting that we see negative and statistically significant coefficients on the Rhone-Poulenc dummy in two cases. The coefficient on the three-firm cartel dummy is negative in all cases and statistically significant in two of the cases. Also in these regressions, the coefficients on the three-firm cartel dummy and four-firm cartel dummy are not significantly different from one another.

The large positive coefficients on the two-firm cartel dummy in regressions 1–3 and 7–9 imply that a two-firm cartel achieves a larger increase in price during the plea-period than when there is a monopoly producer. One might interpret this as occurring because products in which there was a monopoly producer were already priced at monopoly levels. The coefficients on the two-firm cartel dummy are smaller but still positive in regressions 4–6, reflecting the fact that prices are equally persistent relative to a monopoly.

The coefficients on the cartel dummies are generally larger in regressions 7–9 than in regressions 1–3, which may reflect collusive behavior prior to the beginning of the plea period as suggested by the results of Marshall, Marx, and Raiff (2005).

Overall, our results suggest that prices do not return to pre-plea levels within thirty months after the end of a period of explicit collusion in products with a two-firm cartel, but they do return to pre-plea levels within this time period for products with three-firm or four-firm cartels. In addition, we find a significant difference in pricing behavior based on whether a product had a two-firm cartel versus a larger cartel, but we do not find a significant difference based on whether a product had a three-firm cartel versus a four-firm cartel.

### 5.3 Role of a Maverick Firm

As suggested by the Horizontal Merger Guidelines, the presence of certain firms, labeled “mavericks,” in an industry may reduce the ability of the other firms to maintain prices above their competitive levels. In the Vitamins Industry, the conditions of Rhone-Poulenc’s amnesty may have caused Rhone-Poulenc to behave like a maverick firm in this industry during the post-plea period. Consistent with this, we observe large, negative, and sometimes statistically significant coefficients on the Rhone-Poulenc dummy in regressions 1–9. The post-plea behavior of Rhone-Poulenc, which is reasonably conjectured to be induced by the conditions of amnesty, provides a window by analogy to the impact of a maverick firm on pricing behavior in an industry.

One might also consider China to be a maverick in the Vitamins Industry. 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 Vitamin C and Thiamine (B1). According to Bernheim (2002), China produced all of the vitamin products in our data except the three Beta Carotene products, the three Carotenoids, and the two Vitamin D products.

To analyze this conjecture, we run three additional regressions, which are the same as regressions 4–6 described in Section 5.2 except that we add an additional dummy variable for whether China is a producer of the vitamin product. These regressions allow us to analyze how the presence of China affects the percentage change in price twelve months, twenty-four months, and thirty months after the end of the plea period, relative to the last month of the plea period.

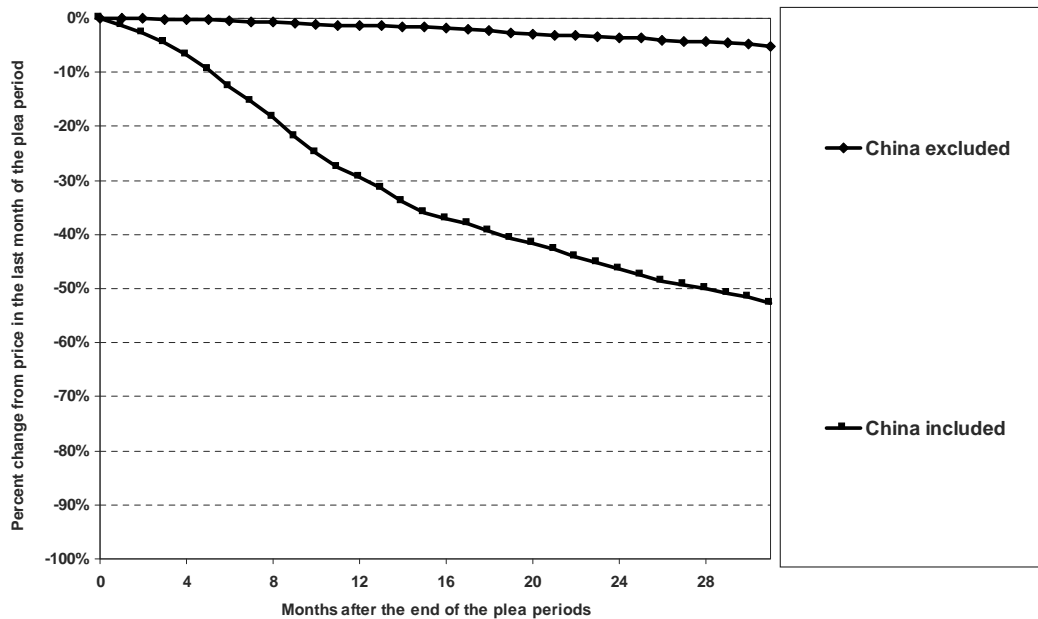


Figure 9: Average percentage change in price relative to the last month of the plea period for vitamin products produced by China and those not produced by China

Table 5: Regressions 10–12 for the Percentage Change in Price at Dates after the Plea Period Relative to Dates Prior to the Plea Period Including a Control for Maverick Behavior by China

| Independent Variable       | Dependent Variable                           |                    |                     |
|----------------------------|--|--------------------|---------------------|
|                            | % change in price from last month of plea to |                    |                     |
|                            | +12  | +24                | +30                 |
| Constant                   | -3.283<br>6.552                              | 2.914<br>6.638     | 6.343<br>7.422      |
| Feed                       | -5.532<br>5.543                              | -5.047<br>6.96     | -6.355<br>7.505     |
| Non-Cartel Share           | 0.441<br>0.612                               | 0.545<br>0.552     | 0.625<br>0.708      |
| Change in Non-Cartel Share | -1.177<br>0.745                              | -1.244*<br>0.609   | -1.085<br>0.73      |
| Rhone-Poulenc              | -12.945<br>8.716                             | -11.162<br>9.268   | -9.35<br>10.859     |
| China                      | -3.985<br>5.027                              | -9.225<br>6.392    | -13.355<br>7.911    |
| 2 in cartel                | 6.157<br>6.502                               | -0.656<br>6.451    | -4.557<br>7.379     |
| 3 in cartel                | -5.24<br>5.58                                | -17.887**<br>6.269 | -23.111***<br>7.447 |
| 4 in cartel                | 3.799<br>8.267                               | -9.168<br>9.044    | -16.156<br>10.515   |
| Number of Observations     | 30   | 30                 | 30                  |
| Adjusted R-squared         | 0.516  | 0.647              | 0.586               |

As shown in Table 5, the coefficient on the China dummy is negative but is not statistically significant. The point estimate in regression 11 shows that the presence of China as a manufacturer results in a 9.2% decrease in price in the two years after the end of the plea period, all else constant. This effect is comparable to the effect of having Rhone-Poulenc as a manufacturer of the vitamin product.

## 6 Conclusion

Although it is difficult to extrapolate to other industries, the evidence from the Vitamins Industry suggests that a proposed reduction in the number of firms manufacturing a given product from four to three via a merger does not alone pose an incremental threat in terms of tacit coordination. But, this should not be interpreted as suggesting the absence of social harm for mergers in which industry size goes from four to three. The data from the Vitamins Industry suggests that the real social danger after a period of explicit collusion is duopoly, and three is much closer to two than four. Coordinated effects analysis would be required of any merger to assess whether the merger will lead the industry toward effective duopoly through tacit (or explicit) collusion.

Beyond its specific technical findings, our examination of the Vitamins Industry suggests the value of retrospective inquiries as guides to the refinement and application of coordinated effects analysis to the review of mergers. Amid continuing debate about how competition authorities should conduct a coordinated effects analysis and about whether the treatment of coordinated effects in the U.S. merger guidelines requires adjustment, there appears to be broad agreement about the value of using retrospective studies to supplement a careful fact-intensive assessment of proposed transactions and the institutional arrangements that govern the operations of the merging parties (FTC/DoJ Joint Workshop 2004, 127–195). Merger policy will be well served if enforcement authorities invest resources in research programs to gather and analyze post-merger data as well as post-plea data. The insignificance of many of the coefficients in our statistical analysis speaks to the need for incremental data.

## Appendix—Review of a Simple Model

In this appendix we remind readers of a simple model based on Cournot competition and linear demand. This model provides some insights that can be used to understand what appear to be differences in the viability of tacit collusion based on the number of firms in the industry. We do not intend to imply that this model captures all of the relevant features of the Vitamins Industry. In particular, we assume a fixed number of symmetric firms; whereas in the Vitamins Industry, products typically have a small number of dominant firms and entry is possible. The results of the simple model presented here suggest that one might see a discrete difference in the sustainability of tacit collusion in markets with only two firms in contrast to markets with more than two firms.

Assume there are  $n$  firms producing a homogenous product with common constant marginal cost  $c$ . Assume industry inverse demand is  $P = a - bQ$ , where  $a > c \geq 0$  and  $b > 0$ . Assuming either Cournot competition or fully collusive behavior, we can calculate the profits for the firms in our model.

Table A1: Firm and Cartel Profits in Various Environments  
Based on a Simple Cournot Model with Linear Demand

|         | Cournot profit             | All-inclusive cartel profit | All-inclusive cartel profit/firm | Profit if other $n - 1$ collude |                      |
|---------|----------------------------|-----------------------------|----------------------------------|---------------------------------|----------------------|
|         |                            |                             |                                  | In cartel                       | Outside cartel       |
| $n$     | $\frac{(a-c)^2}{b(n+1)^2}$ | $\frac{(a-c)^2}{4b}$        | $\frac{(a-c)^2}{4bn}$            | $\frac{(a-c)^2}{(n-1)9b}$       | $\frac{(a-c)^2}{9b}$ |
| $n = 1$ | $\frac{(a-c)^2}{4b}$       | $\frac{(a-c)^2}{4b}$        | $\frac{(a-c)^2}{4b}$             | —                               | —                    |
| $n = 2$ | $\frac{(a-c)^2}{9b}$       | $\frac{(a-c)^2}{4b}$        | $\frac{(a-c)^2}{8b}$             | —                               | —                    |
| $n = 3$ | $\frac{(a-c)^2}{16b}$      | $\frac{(a-c)^2}{4b}$        | $\frac{(a-c)^2}{12b}$            | $\frac{(a-c)^2}{18b}$           | $\frac{(a-c)^2}{9b}$ |
| $n = 4$ | $\frac{(a-c)^2}{25b}$      | $\frac{(a-c)^2}{4b}$        | $\frac{(a-c)^2}{16b}$            | $\frac{(a-c)^2}{27b}$           | $\frac{(a-c)^2}{9b}$ |

Note that when there are two firms in an industry, each firm can increase its profit by colluding. If a firm chooses not to collude, the industry necessarily reverts to non-cooperative play with two firms. However, when there are three firms in an industry, if two firms agree to collude, then the third firm strictly prefers to remain outside the cartel (and play non-cooperatively against the two-firm cartel) rather than join the two firms to form a three-firm cartel. This is apparent from Table A1, which shows that the profit from creating a three-firm cartel is  $\frac{(a-c)^2}{12b}$ , but the profit from remaining outside while a two-firm cartel operates is  $\frac{(a-c)^2}{9b}$ .

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