Post-Cartel Pricing during Litigation*

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Abstract

Standard methods in the U.S. for calculating antitrust damages in price-fixing cases are shown to create a strategic incentive for firms to price above the non-collusive price after the cartel has dissolved. This results in an overestimate of the but for price and an underestimate of the level of damages. The extent of this upward bias in the but for price is greater, the longer the cartel was in place and the more concentrated is the industry.

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1 Introduction

Consider a cartel that has been caught colluding. According to standard U.S. antitrust practice, the damages associated with firms colluding in period t are calculated to be

$$\left[P^c(t) - P^{bf}(t)\right] D\left(P^c(t)\right) \tag{1}$$

where $P^c(t)$ is the observed (collusive) price, $D(P^c(t))$ is the number of units sold, and $P^{bf}(t)$ is the "but for" price; that is, the price that would have been charged but for collusion. $P^c(t) - P^{bf}(t)$ is referred to as the "overcharge." Two crucial elements to the calculation of damages are identifying the periods during which firms were colluding and estimating the but for price. A standard method for the latter is to use price data outside of the time during which the cartel was active.

> A period of collusive activity can be compared with (1) a competitive period prior to the beginning of such activity; (2) a period within the collusive period [during which collusion broke down]; or (3) a period after the termination of the conspiracy. ... More commonly used is the post conspiracy period, since the ending of the conspiracy is usually a fairly dramatic event. [Finkelstein and Levenbach (1983), pp. 161-2]
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> The correct level of the [but for price] can be calculated in four ways [one of which is] the "before and after" approach (that is, examining price levels immediately before or after the known conspiracy period). [Connor (2000), p. 64]

As noted in Fisher (1980) and Page (1996), a common implementation of this approach is to control for demand and supply conditions by running the following type of reduced-form regression:

$$P(t) = \delta + \beta X(t) + \gamma \nu(t) + \varepsilon(t) \tag{2}$$

where $P(t)$ is the observed price, $X(t)$ is a vector of demand and supply factors (with β being a vector of parameters), and $\nu(t)$ is a dummy variable that equals one in those periods that firms were colluding.[1] For example,

> In *In re Chicken Antitrust Litigation* ... plaintiffs' experts had the prices of substitutes for chicken (beef, pork, and turkey), seasonal dummies, the

[1] Numerous examples of this approach can be found in Finkelstein and Levenbach (1983). A related approach is to estimate a reduced form without the dummy variable,

$$P(t) = \delta + \beta X(t) + \varepsilon(t),$$

based on data during the cartel period. The estimates are then used to project what prices would have been during the post-cartel period if collusion had continued. The difference between those projected prices and the actual prices are then used to estimated the overcharge during the cartel period. This method was deployed by an expert witness for the plaintiffs in the corrugated container industry (Breit and Elzinga, 1986).

consumer price index, consumer disposable income, per capita production of chicken, and a dummy for the conspiracy period. [Page (1996), pp. 174-5]

If $\widehat{\delta}$ and $\widehat{\beta}$ are parameter estimates, the but for price for period t is then determined to be:[2]

$$P^{bf}(t) = \widehat{\delta} + \widehat{\beta} X(t). \tag{3}$$

The point of this paper is to show how the "before and after" approach for calculating damages has implications for the manner in which firms price after the cartel has dissolved. Firms are shown to price above the standard non-collusive level and this results in an overestimate of the but for price and thereby an underestimate of the overcharge and antitrust damages. As motivation for this result, the next section argues that the post-cartel prices in the graphite electrodes industry did indeed anomalously exceed the non-collusive level.

2 Graphite Electrodes Cartel, 1992-1997

A graphite electrode is an input in the manufacturing of steel; its function being to conduct high levels of electricity in an electric arc furnace in order to melt scrap steel. According to the Antitrust Division of the U.S. Department of Justice, "there was a price-fixing conspiracy among the major producers of graphite electrodes as early as July 1992 and continuing until at least June 1997."[3] During 1998-99, UCAR International, SGL Carbon, Showa Denko Carbon, and Tokai Carbon pled guilty while Carbide Graphite cooperated under the Antitrust Division's Corporate Leniency Program.[4] At the time that collusion was initiated, these companies comprised 94% of market sales which totalled US$275 million annually in the U.S.[5] Government fines exceeding US$600 million were assessed by the United States, European Union, and Canada and there were many private damage suits as well.

Examination of the price of graphite electrodes suggests that the cartel was successful in its efforts to raise price. Figure 1 reports the (nominal) price per pound of graphite electrodes from just prior to the conspiracy - at which time the price was $1.00/lb - through 2000 which includes 9-10 quarters after the end of the conspiracy. There are at least two interesting properties. First, the cartel only gradually raised price with it ultimately reaching a high of $1.56/lb just prior to its discovery.[6] During the time of the cartel, price increased more than 50%. Second, and directly to the point of this paper, the discovery of the cartel did not induce a quick return to price

[2] While this process makes it seem rather straightforward, it is, of course, a highly contentious issue. See, for example, the debate over the but for price for lysine in Connor (2001) and White (2001).

[3] United States of America v. Robert J. Hart, 10/19/99. For a review of the graphite electrodes cartel, see Levenstein and Suslow (2001).

[4] There were other defendants including some smaller companies and Mitsubishi which owns 50% of UCAR but does not manufacture graphite electrodes.

[5] United States of America v. Robert J. Hart, 10/19/99.

[6] A model which generates such pricing dynamics can be found in Harrington (2002, 2003).

levels in place prior to the cartel's formation. Using the average price from UCAR Annual Reports (as it is a series that spans both the cartel and post-cartel phases), the price was $1.44 in 1996 and about the same in 1997 at $1.42 (though note that the cartel was only active during the first half of the year). In 1998, price had fallen less than 5% to $1.37. Two years after the cartel's demise, price was down appreciably to $1.21 but was still more than 20% above its pre-cartel level. The post-cartel price series does not reveal a big drop upon the collapse of the cartel but instead a gradual decline over several years.

As these observations are for the nominal price series, it is possible that changes in the cost of production can rationalize both the post-cartel price pattern and the discrepancy between pre- and post-cartel prices. Two of the essential raw materials in the production of graphite electrodes are premium petroleum needle coke and coal tar pitch.[7] After these and other elements are ground, mixed, and extruded, the product is baked (which requires natural gas to fire the ovens) and machined (which uses electricity). Graphite electrodes can weigh as much as two metric tons and are transported by truck from the factory. The PPI for these other key inputs plus that for wages are shown in Figure 2 though coal tar pitch prices are unavailable.[8] The price series are normalized so that they equal 100 at the start of the cartel. Changes in input prices cannot explain why the post-cartel price exceeds the pre-cartel price nor why price gradually fell during the post-cartel regime. The price of electricity is largely unchanged over 1992-2000, trucking is only about 5% higher, and natural gas in 1998-99 is less than 10% higher than that for 1992. The price of petroleum coke has fallen drastically since the pre-cartel period.[9] Wages are the only cost factor that has risen commensurately with the rise in graphite electrode prices. Compared to May 1992, the cost of labor in December 1998 (1999) was 16% (25%) higher. However, this factor by itself is insufficient to counterbalance the lower prices for other inputs, especially for a technology which is likely to be capital-intensive.

In sum, graphite electrode manufacturers, after having cartelized and raised price by more than 50%, were still pricing 20% above the pre-cartel level two years after the cartel's demise. It does not appear that input prices can explain the discrepancy between the pre- and post-cartel prices. Assuming the pre-cartel price is the non-collusive price, why has price not returned to its non-collusive level? One possible explanation is that these continued high prices were due to residual collusion. Though firms may no longer be meeting, explicit collusion might have been replaced with tacit collusion. Another possibility is that competition was abnormally intense prior to the formation of the cartel so that the pre-cartel price was actually below the average

[7] This discussion is based on Jones, Bowman, and Lefrank (1998) and `www.ucar.com/ge/make.html`.

[8] For wages, we chose to use Weekly Earnings of Production Workers in Primary Metals Industries though Wages and Salaries for Manufacturing yield comparable numbers; for example, a 24% increase over 1992-99.

[9] The production of graphite electrodes uses a high-end petroleum coke product which is distinct from the products whose prices go into the petroleum coke PPI. However, since we are not estimating unit cost, all that is important is that the price of this high-end product is strongly correlated with the petroleum coke PPI which seems reasonable.

non-collusive price. This paper provides an alternative explanation as to why, in the aftermath of a cartel's discovery, prices may remain abnormally high. In contrast to these other theories, it does not predict that prices will permanently be high but rather only during the time of litigation. A natural extrapolation of the theory also suggests that the price would fall as litigation is gradually settled.

3 Model

Consider a standard oligopoly model with n firms offering symmetrically differentiated products. Let $\pi(P_i, P_{-i})$ denote firm i's profit when it prices at P_i and the other $n-1$ firms price at the common level of P_{-i}. Assume $\pi : \Re_+^2 \rightarrow \Re_+$ is twice continuously differentiable and strictly concave in P_i so that a firm's best reply function, $\psi : \Re_+ \rightarrow \Re_+$, exists and is unique. Also make the standard assumption of $\partial^2 \pi(P_i, P_{-i}) / \partial P_i^2 + \partial^2 \pi(P_i, P_{-i}) / \partial P_i \partial P_{-i} < 0$ so that the own price effect dominates (Vives, 1999). There is then a unique symmetric Nash equilibrium, denoted by $\widehat{P}$. Define $D(P)$ to be a firm's demand when all n firms charge a price of P and assume it is continuously differentiable and decreasing in P. Finally, assume $D\left(\widehat{P}\right) > 0$ so that the equilibrium has firms being active.

To simplify the analysis, suppose there are three well-defined regimes - pre-cartel, cartel, and post-cartel - and that demand and cost conditions are constant across these regimes and price is constant within each regime. The post-cartel phase is the period between the presumed dissolution of the cartel (for example, the public announcement of an investigation into price-fixing) and the conclusion of litigation. Assuming stationary cost and demand conditions simplifies the analysis as then it is reasonable to assume the but for price is a weighted average of price (averaged across firms) during the pre-cartel and post-cartel regimes.[10] Some examples of this method are:

> [In *Ohio Valley Electric Corp v. General Electric Co.*, plaintiffs] proposed to measure damages by the difference between the average 11% discount [off of list price] during the conspiracy period and the average 25.33% discount that prevailed after the conspiracy had been terminated. [Finkelstein and Levenbach (1983), p. 145][11]
>
> [For the lysine cartel one] might look to the last six months of 1995, after the highly publicized FBI raid of June 1995, as an indication of what prices the non-conspiring oligopolists might have charged. [White (2001, p. 28)]

Let P^c denote the price set during the cartel regime and assume $P^c > \widehat{P}$. If $\underline{\mu}$ and $\overline{\mu}$ is the average pre-cartel and post-cartel price, respectively, the but for price is

[10] Alternatively, cost and demand conditions could be allowed to vary over time in which case all ensuing statements are relevant after controlling for cost and demand conditions.

[11] Also see Sultan (1974).

determined according to the formula:

$$P^{bf} = \alpha(\overline{\mu})\overline{\mu} + (1-\alpha(\overline{\mu}))\underline{\mu} \tag{4}$$

where $\alpha : \Re_+ \rightarrow [0,1]$ is the weight given to post-cartel price data.[12] Assume $\alpha(\overline{\mu}) > 0$ if $\overline{\mu} < P^c$, $\alpha(\overline{\mu}) = 0$ if $\overline{\mu} \geq P^c$, and α is twice continuously differentiable and increasing for $\overline{\mu} \leq P^c$. The motivation for $\alpha(\overline{\mu}) = 0$ when $\overline{\mu} \geq P^c$ is that if firms are pricing higher since the supposed demise of the cartel, the post-cartel data loses credibility as being relevant for estimating the but for price (recall that we have controlled for cost and demand conditions between the cartel and post-cartel regimes). At a minimum, the plaintiffs would exert considerable effort to persuasively argue this point. When $\overline{\mu} > P^c$, it then seems reasonable to assume $\alpha(\overline{\mu})$ is small and it simplifies the analysis to suppose it equals zero.

Given this method for estimating the but for price, the usual formula for damage calculation implies that each firm pays penalties equal to:

$$\theta D(P^c)\left[P^c - \alpha(\overline{\mu})\overline{\mu} - (1-\alpha(\overline{\mu}))\underline{\mu}\right] \tag{5}$$

where $\theta > 0$ and is a multiplier applied to damages. Note that if these regimes have been properly identified then $\underline{\mu} = \widehat{P}$.

The game is one in which the n firms make simultaneous price decisions in the post-cartel phase. Firm i's payoff function is

$$V(P_i, P_{-i}) \equiv \pi(P_i, P_{-i}) - \theta D(P^c)\left[P^c - \alpha(\overline{\mu})\overline{\mu} - (1-\alpha(\overline{\mu}))\underline{\mu}\right] \tag{6}$$

where[13]

$$\overline{\mu} = (1/n)\left[P_i + (n-1)P_{-i}\right]. \tag{7}$$

Among its various roles, θ captures the relative lengths of the cartel phase and the post-cartel phase. If the latter is longer then current profit is given more weight relative to antitrust penalties by setting a lower value for θ. Assume payoff functions are strictly concave:

$$\frac{\partial V^2(P_i, P_{-i})}{\partial P_i^2} = \frac{\partial^2 \pi(P_i, P_{-i})}{\partial P_i^2} + \theta D(P^c)\left(1/n^2\right)\left[\alpha''(\overline{\mu})\left(\overline{\mu} - \underline{\mu}\right) + 2\alpha'(\overline{\mu})\right] < 0. \tag{8}$$

Since $\partial^2 \pi(P_i, P)/\partial P_i^2 < 0$ and $\alpha'(\overline{\mu}) \leq 0$, a sufficient condition is that $\alpha''(\overline{\mu})$ is not too large.

The analysis of this paper is intended to pertain to when guilt of price-fixing has been ascertained but the calculation of damages is in process. However, one could assume that guilt has not yet been resolved and all results would go through as long

[12] $\underline{\mu}$ could also be based on price data from a source other than the market in question. For example, it could be from a similar product market for which firms did not collude.

[13] An alternative specification for $\overline{\mu}$ is to have it be the average transaction price so that a firm's price is weighted by its market share. I do not believe any results would change and it would only serve to complicate some expressions. I could also assume there is some noise in the price data to motivate using as much as data as is available.

as the probability of paying damages is positive and that probability is independent of how firms price after the cartel was detected. A lower probability would be captured in our model by a lower value for θ. If, however, post-cartel pricing influences the likelihood of being found guilty of collusion then that introduces a force which is not currently present in this model.

4 Results

A symmetric Nash equilibrium price, denoted P^*, is defined by the first-order condition:

$$\phi(P^*) \equiv \frac{\partial V(P^*, P^*)}{\partial P_i} = \frac{\partial \pi(P^*, P^*)}{\partial P_i} + \theta D(P^c)(1/n)\left[\alpha'(P^*)\left(P^* - \underline{\mu}\right) + \alpha(P^*)\right] = 0. \tag{9}$$

Equilibrium is unique if

$$\phi'(P) = \frac{\partial^2 \pi(P, P)}{\partial P_i^2} + \frac{\partial \pi(P, P)}{\partial P_i \partial P_{-i}} + \theta D(P^c)(1/n)\left[\alpha''(P)\left(P - \underline{\mu}\right) + 2\alpha'(P)\right] < 0, \tag{10}$$

which holds by our previous assumptions.

In stating our main result, the dependence of P^* on θ is made explicit. Theorem 1 shows that, in response to the dissolution of the cartel, price is set below the cartel price but above the standard non-collusive price. Furthermore, the post-cartel price is higher when firms assign more weight to damages.

Theorem 1 *If* $\theta' > \theta'' > 0$ *then* $P^c > P^*\left(\theta'\right) > P^*\left(\theta''\right) > \widehat{P}$.

Proof: To establish that $P^c > P^*$, first note that $\phi(P^c) < 0$ since $\partial \pi(P^c, P^c)/\partial P_i < 0$, $\alpha(P^c) = 0$, and $\alpha'(P^c) \leq 0$. Given $\phi'(P) < 0$ then $P^c > P^*$.

As $P^*(0) = \widehat{P}$, if $P^*(\theta)$ is shown to be strictly increasing in θ then it immediately follows that that $P^*(\theta) \geq \widehat{P}\ \forall \theta$. Since $\partial^2 V(P^*, P^*)/\partial P_i^2 < 0$ then, by the usual arguments, if $\partial^2 V(P^*, P^*)/\partial P_i \partial \theta > 0$ then $\partial P^*/\partial \theta > 0$.

$$\frac{\partial^2 V(P^*, P^*)}{\partial P_i \partial \theta} = D(P^c)(1/n)\left[\alpha'(P^*)\left(P^* - \underline{\mu}\right) + \alpha(P^*)\right] \tag{11}$$

and, from the first-order condition,

$$\theta D(P^c)(1/n)\left[\alpha'(P^*)\left(P^* - \underline{\mu}\right) + \alpha(P^*)\right] = -\frac{\partial \pi(P^*, P^*)}{\partial P_i} > 0. \tag{12}$$

Hence, $\partial^2 V(P^*, P^*)/\partial P_i \partial \theta > 0$. ♦

The logic is clear. A firm's price during the post-cartel regime forms part of the data set that is used to estimate the but for price. By pricing above that which maximizes profit, a firm raises the estimated but for price which serves to lower the amount of damages that it can expect to pay. This method for estimating the but for price then results in an overestimate of the price that would have occurred in the absence of a cartel having ever been formed. To see why the post-cartel equilibrium price is strictly less than the cartel price, consider all firms pricing at P^c during the litigation phase. By marginally lowering its price, a firm raises its current profit - since $\psi(P^c) < P^c$ - *and* lowers its damages by raising the estimated but for price since now more weight is attached to the higher post-cartel price, $\alpha'(P^c) \leq 0$. There is a potentially negative effect from lowering price since, holding the weight on post-cartel data fixed, the estimated but for price is decreasing in the post-cartel price. However, since $\alpha(P^c) = 0$ then this effect is zero when a firm considers pricing marginally below P^c though becomes relevant when it considers yet lower prices.

There are a number of intuitive comparative statics associated with Theorem 1. For example, a higher value for θ can measure a longer cartel regime, so that there are more units upon which damages are assessed (where I am interpreting $D(P^c)$ as the demand per period during the cartel regime). Hence, upon dissolution of the cartel, price is predicted to fall less if firms have been colluding for a longer time.

Result 2 The longer is cartel duration, the higher is the post-cartel price.

The prediction of price exceeding the standard non-collusive level is consistent with the post-cartel prices for graphite electrodes. Furthermore, an extrapolation of this logic to a dynamic setting can also explain the gradual decline in post-cartel prices (see Figure 1). If there is a sequence of antitrust cases associated with a price-fixing episode, firms will place less weight on damages as these cases are settled. As this means a falling value for θ over time, Theorem 1 implies that the post-cartel price would gradually decline. Both the circumstances and the observed behavior describe the graphite electrodes case well. For example, UCAR settled with the antitrust authorities of the U.S. in 1998, Canada in 1999, and the E.U. in 2001. Though lacking a public record, there were many private damage suits that were settled out-of-court during these years.

By strategically pricing during the litigation period, firms result in an overestimate of the but for price as measured by:

$$Bias = \frac{P^* - \widehat{P}}{\widehat{P}}. \tag{13}$$

To what extent is this bias greater for more concentrated industries? In addressing that question, one must take account of how n influences both P^* and $\widehat{P}$ but also recognize that P^* depends on P^c which may also depend on n. To do this requires imposing additional structure on the problem.

Assume a differentiated products price game using the demand system from Vives

(1999, p. 146). In that case, firm i's demand function is[14]

$$D(P_i, P_{-i}) = \frac{a}{b+(n-1)e} - \left(\frac{b+(n-2)e}{(b+(n-1)e)(b-e)}\right)P_i + \left(\frac{e(n-1)}{(b+(n-1)e)(b-e)}\right)P_{-i} \quad (14)$$

where $b > e > 0$. Products are more homogeneous when e is closer to b and products are fully independent when $e = 0$. Note that if all firms charge a common price then each firm's demand is

$$D(P) = \frac{a-P}{b+(n-1)e}. \quad (15)$$

The firm cost function is linear and common across firms, $C(q) = cq$. Assume $a > c \geq 0$ so that the resulting equilibrium is interior.

From the firm's profit function (excluding damage payments), one can derive its best response function:

$$\psi(P_{-i}) = \frac{(a+c)(b-e)+(n-1)ec}{2(b+(n-2)e)} + \left(\frac{(n-1)e}{2(b+(n-2)e)}\right)P_{-i}. \quad (16)$$

The symmetric Nash equilibrium price is

$$\widehat{P} = \frac{(a+c)(b-e)+(n-1)ec}{2(b+(n-2)e)-(n-1)e}. \quad (17)$$

Finally, the joint profit-maximizing price is $P^m = (a+c)/2$.

In deriving the post-cartel equilibrium price, it is assumed that the weight given to post-cartel data is a constant, $\alpha \in (0,1)$, and thereby independent of firms' post-cartel prices. Letting P^* denote the symmetric equilibrium post-cartel price, it is defined as the following fixed point:

$$P^* \in \arg\max\,(P_i - c)\,D(P_i, P^*) - \theta D(P^c)\left[P^* - \alpha\left(((n-1)/n)P^* + (1/n)P_i\right) - (1-\alpha)\widehat{P}\right] \quad (18)$$

where $\theta > 0$. It is straightforward to show that[15]

$$P^* = \frac{(a+c)(b-e)+(n-1)ec+(\alpha\theta/n)(b-e)(a-P^c)}{2(b+(n-2)e)-(n-1)e} = \widehat{P} + \frac{(\alpha\theta/n)(b-e)(a-P^c)}{2(b+(n-2)e)-(n-1)e}. \quad (19)$$

[14] This demand system comes from the following specification of a consumer's utility function:

$$U(q_1,\ldots,q_n) = a\sum_{i=1}^{n} q_i - \left(\frac{1}{2}\right)\left[b\sum_{i=1}^{n} q_i^2 + 2e\sum_{j\neq i}^{n} q_i q_j\right].$$

[15] If $\alpha\theta$ is sufficiently low then $P^* < P^c$ since $\lim_{\alpha\theta\to 0} P^* = \widehat{P} < P^c$.

The resulting bias between the estimated but for price and the true but for price is then

$$\frac{P^* - \widehat{P}}{\widehat{P}} = \frac{\alpha\theta\,(b-e)\,(a-P^c)}{n\left[(a+c)\,(b-e)+(n-1)\,ec\right]}. \tag{20}$$

Initially, suppose that P^c is independent of n. In the context of an infinitely repeated game, this occurs when firms' discount factors are sufficiently close to one so that P^m can be supported for the range of values of n under consideration. Given $P^c = (a+c)/2$ then

$$\frac{P^* - \widehat{P}}{\widehat{P}} = \frac{\alpha\theta\,(b-e)\,(a-c)}{2n\left[(a+c)\,(b-e)+(n-1)\,ec\right]}. \tag{21}$$

Hence, the bias is decreasing in n so that the overestimate of the but for price is more severe in more concentrated markets. There are two effects at work. First, both P^* and $\widehat{P}$ decline with n for the usual reason of increased competition. However, there are two additional forces causing P^* to fall. As n rises, the number of units upon which damages are assessed for a firm, $(a-P^c)/(b+(n-1)\,e)$, is smaller as each firm has a smaller market share during the cartel period. Keeping price up so as to reduce the estimated but for price then becomes less significant in a firm's pricing decision when there are more firms. Second, more firms imply that an individual firm's price during the litigation phase has less of an effect on the estimated but for price since it depends on the *average* post-cartel price. In other words, the pricing data collected from one firm is less influential in the estimation of the but for price and this weakens the incentive for a firm to price above that which maximizes post-cartel profit.[16] In sum, when the cartel price is independent of (or sufficiently insensitive to) the number firms, the extent of the bias in estimating the but for price is greater when the market is more concentrated.

To consider the case when the cartel price is sensitive to market structure, I deploy the standard repeated game framework and assume that the cartel sets the most profitable price supportable by grim trigger strategies. The condition for a collusive price P to be sustainable is then

$$(P-c)\,D(P) \geq (1-\delta)\,(\psi(P)-c)\,D(\psi(P),P)+\delta\widehat{\pi}, \tag{22}$$

where $\widehat{\pi} \equiv \left(\widehat{P}-c\right)D\left(\widehat{P}\right)$ and $\delta \in (0,1)$ is the common discount factor. If

$$(P^m-c)\,D(P^m) \geq (1-\delta)\,(\psi(P^m)-c)\,D(\psi(P^m),P^m)+\delta\widehat{\pi} \tag{23}$$

then $P^c = P^m$. If

$$(P^m-c)\,D(P^m) < (1-\delta)\,(\psi(P^m)-c)\,D(\psi(P^m),P^m)+\delta\widehat{\pi} \tag{24}$$

then P^c is the upper root to

$$(P^c-c)\,D(P^c)-(1-\delta)\,(\psi(P^c)-c)\,D(\psi(P^c),P^c)-\delta\widehat{\pi}=0. \tag{25}$$

[16] Even if a distinct but for price is calculated for each firm using only that firm's pre- and post-cartel price data, the first effect is still operative so that Theorem 1 is still true.

As the case when $P^c = P^m$ was explored above, our focus is on when $P^c < P^m$ so that the equilibrium condition is binding. It is difficult to solve this algebraically since P^c is the solution to the quadratic equation in (25) and then that solution has to be placed in the formula in (20). Numerical analysis is then used. Assume $a = 100$, $c = 10$, $(b, e) \in \{(10, 5), (10, 9)\}$, $\alpha\theta \in \{1, 3, 6\}$, and $\delta = .57$.[17] Results are in Tables 1 and 2 and they show that the bias is decreasing in n.[18] For example, consider the case of fairly similar products, $(b, e) = (10, 9)$, and damages are moderately significant, $\alpha\theta = 3$.[19] The estimated but for price exceeds the true but for price by 45% when there are two firms and this falls to 15% when n is doubled to four and to 4% when it is doubled again to eight firms.

Result 3 The more concentrated is the industry, the greater is the upward bias in the estimated but for price.

In concluding, one could in principle test this theory by collecting data on product prices and demand and cost shifters and constructing a timeline on litigation resolution. In response to such events as government sentencing and the settling of private damage suits - through either an out-of-court settlement or a court decision - one should observe a price decline, controlling for other factors. Indeed, I considered performing exactly this analysis for the graphite electrodes case. However, the problem was in constructing the litigation time series. While a timeline can be created for government sentencing, almost all (if not all) of the private damage suits brought by the plaintiffs (who are steel mini-mills running electric arc furnaces) were settled out of court and the date of their completion is not in the public record. The ideal case for testing this theory would be for a cartel case in which the private damage suits are settled by a judicial decision.

5 Policy Analysis

In light of the previous analysis, the "before and after" approach in estimating the but for price is biased because the post-cartel data is tainted by the machinations of the price-fixing defendants during the litigation phase. The objective of this section is to put this critique in the context of a more general assessment of various data sources for estimating the but for price.

Since post-cartel data may be problematic because the damages that a firm ultimately has to pay depends on the prices it sets during litigation, a general solution is to use data excluding those prices. One option is to estimate for each firm a but for price that uses the post-cartel prices of the other firms in that market as well

[17] The discount factor is set sufficiently low so that the equilibrium condition binds and $P^c < P^m$.

[18] The results are limited to those parameter values for which $P^* < P^c$. This is why, for Table 1, $n = 2$ is absent for $\alpha\theta = 3$ and $n \in \{2, 3\}$ is absent for $\alpha\theta = 6$.

[19] For example, $\alpha\theta = 3$ when post-cartel data is given equal weight with pre-cartel data ($\alpha = 1/2$), the cartel regime is six times as long as the litigation regime, and single damages are assessed. Though damages are trebled in a court case, single damages are not uncommon in an out-of-court settlement.

as pre-cartel data.[20] As an individual firm's post-cartel prices do not influence the damages it pays, it has no incentive to strategically raise price. Related to this suggestion, there are instances in which only some firms in an industry are part of the cartel which would suggest that their prices during the cartel regime may be a source of data. However, those prices will be higher by virtue of their (colluding) rivals' prices being higher. So, such data cannot be used without controlling for that effect. When firms are similar, this general avenue of using other firms' prices is a viable option. When firms are not, this method is fraught with problems associated with controlling for differences across firms.

Another option is to exclude altogether the post-cartel data for the market under investigation. There are two alternative sources of data in that case. First, one can rely exclusively on pre-cartel data. While pre-cartel data is not subject to strategic manipulation, it does suffer from at least two weaknesses compared to post-cartel data. First, pre-cartel data is older and thus is less likely to yield accurate estimates of damages in the later years of the cartel. Compounding this problem is that older data is more likely to be incomplete which means less precise estimates. To get a sense about the significance of this weakness, Bryant and Eckard (1991) find that the mean and median duration of 184 (discovered) cartels was 7.27 and 5.80 years, respectively. Furthermore, 22% of the cartels lasted more than ten years. Thus, in some instances, the age of the pre-cartel data can be a serious problem if one is forced to rely exclusively on it. A second problem is that it is more difficult to identify when the cartel started than when it ended. If one presumes that the beginning of an investigation caused collusion to stop then the beginning of the post-cartel period may be relatively easy to identify. However, the end of the pre-cartel period is typically not so straightforward. For suppose that evidence of meetings (memos, testimony, etc.) is used to date the start of the cartel. If there is such evidence in a given year then the firms almost certainly colluded in that year while the absence of such evidence may be due to firms not colluding but could also be due to such evidence being lost or destroyed. There is then a tendency to include some cartel periods as part of the pre-cartel regime and this results in an overestimate of the but for price.

There are some other potential biases that are worth noting. It is interesting that in the case of the citric acid cartels, the formation of the cartel was preceded by a decline in prices. Prices fell from about 80 cents per pound to 60 in the 18 months prior to the beginning of the conspiracy and then increased back up to 80 in the ensuing 18 months (see Figure 1 in Connor, 1998). This pricing pattern raises the possibility that firms cartelized in response to an *abnormally* intense bout of competition. Using pre-cartel price data would then provide an underestimate of the but for price. While it is natural to presume that the absence of a cartel would have led to a continued period of low prices, if these prices were due to abnormally intense competition then one would expect, on average, for competition to subside and return to normal levels. This suggests that the pre-cartel prices might be below average prices for the non-collusive regime.[21] On the other side, post-cartel prices

[20] I thank a referee for this suggestion.

[21] This criticism may also apply to using periodic breakdowns of collusion during the cartel regime,

may be above true but for prices for a reason different than that of reducing estimated damages. There may be some "residual collusion" after the cartel has been detected. Even if firms are no longer directly communicating, it is quite possible that the inherited collusive outcome may still be stable or, given sufficient understanding by virtue of past explicit collusion, firms may be able to replace it with some level of tacit collusion.[22] Just as pre-cartel prices may be more competitive than normal, post-cartel prices may be less competitive than normal.

As an alternative to pre- and post-cartel data, one may be able to estimate a but for price using data from a comparable market over the same period for which firms were not believed to be colluding. If collusion occurred only in some geographic markets, one could use data from other geographic markets for the same product. A nice example of this approach is Porter and Zona (1999) for the case of milk. This approach largely avoids all of the difficulties mentioned above. The problem is that such a comparison market is not always available. Indeed, that is the norm with international cartels such as lysine, graphite electrodes, and vitamins. One is then left to using data for the market that is being investigated and thus back to wrestling with the biases associated with pre- and post-cartel data.

6 Concluding Remarks

Though the analysis is simple, this paper makes a point that is of some relevance to price-fixing cases. Standard methods for calculating the but for price provide former cartel members with an incentive to price higher during the time between when the cartel is dissolved and litigation is concluded. This strategic behavior leads to an overestimate of the but for price and an underestimate of the damages incurred as well as resulting in the usual welfare losses from price being too high. The extent of this upward bias in the but for price is greater, the longer the cartel was in place and the more concentrated is the industry. Having theoretically identified this source of bias, the more challenging issue is to empirically test for it and to find a practical way in which to control for it in actual damage calculations.

which is another source of data for estimating the but for price.

[22] Connor (2001) makes this point to explain post-detection pricing in the lysine case.

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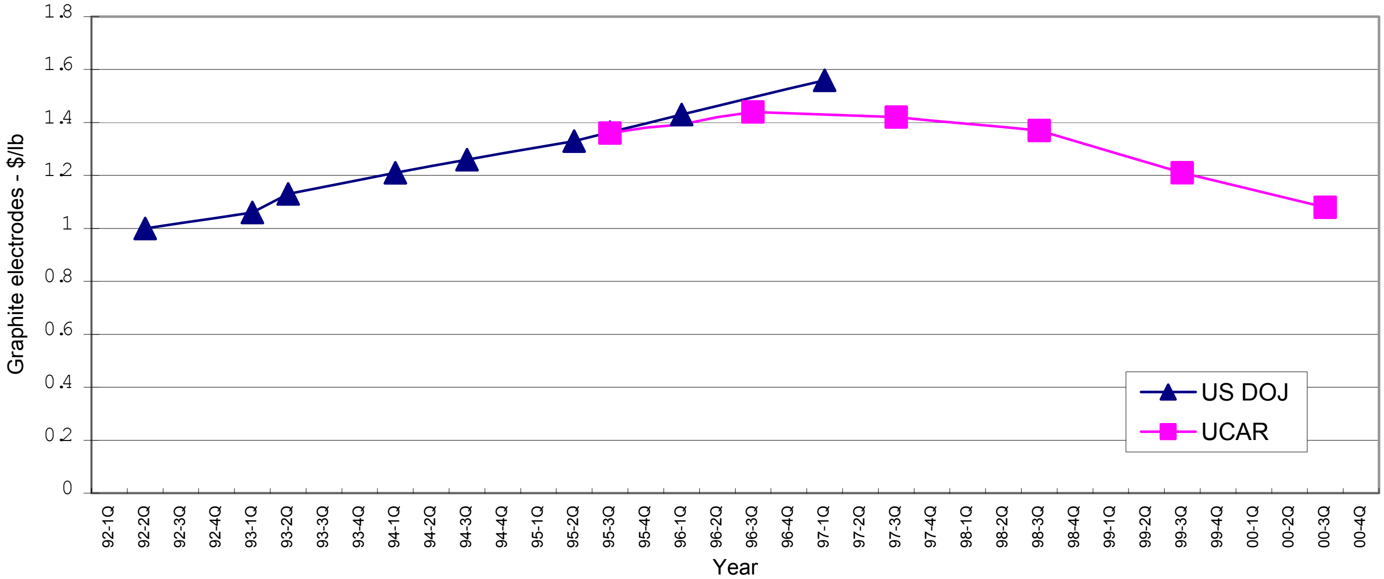
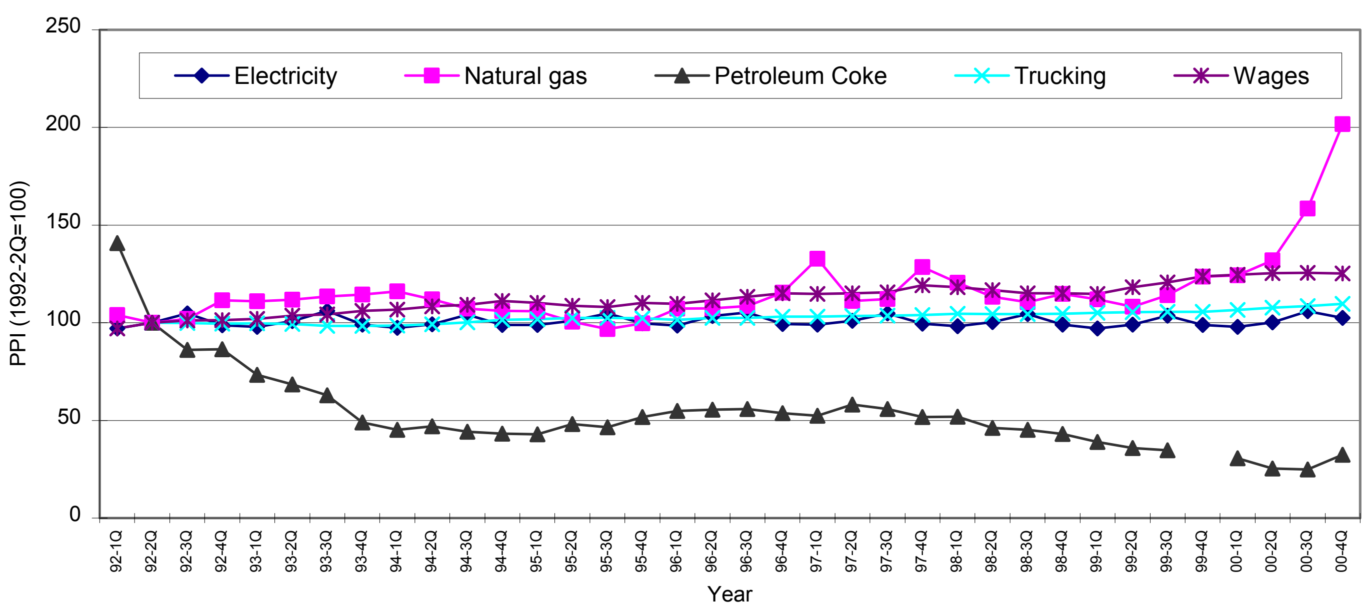
Figure 1 - Graphite Electrodes, Prices, 1992-2000



Source: The US DOJ series is from court documents (United States of America v. Robert J. Hart, 10/19/99) and the UCAR series is from UCAR Annual Reports (1997, 1999, 2000).

Figure 2 - Graphite Electrodes, Cost Indices, 1992-2000



Source: Bureau of Labor Statistics, U.S. Department of Labor

Table 1. Prices and Bias: $(b, e) = (10, 5)$

$\alpha\theta$	n	P^m	P^c	P^*	$\hat{P}$	*Bias*
1	2	55	55.00	47.50	40.00	0.19
1	3	55	54.93	36.26	32.50	0.12
1	4	55	52.79	30.36	28.00	0.08
1	5	55	50.45	26.65	25.00	0.07
1	6	55	48.16	24.09	22.86	0.05
1	7	55	46.03	22.21	21.25	0.05
1	8	55	44.06	20.78	20.00	0.04
3	3	55	54.93	43.77	32.50	0.35
3	4	55	52.79	35.08	28.00	0.25
3	5	55	50.45	29.96	25.00	0.20
3	6	55	48.16	26.56	22.86	0.16
3	7	55	46.03	24.14	21.25	0.14
3	8	55	44.06	22.33	20.00	0.12
6	4	55	52.79	42.16	28.00	0.51
6	5	55	50.45	34.91	25.00	0.40
6	6	55	48.16	30.26	22.86	0.32
6	7	55	46.03	27.03	21.25	0.27
6	8	55	44.06	24.66	20.00	0.23

Table 2. Prices and Bias: $(b, e) = (10, 9)$

$\alpha\theta$	n	P^m	P^c	P^*	$\hat{P}$	*Bias*
1	2	55	40.62	20.88	18.18	0.15
1	3	55	30.80	15.65	14.50	0.08
1	4	55	25.68	13.74	13.10	0.05
1	5	55	22.57	12.78	12.37	0.03
1	6	55	20.48	12.20	11.91	0.02
1	7	55	18.99	11.81	11.61	0.02
1	8	55	17.87	11.54	11.38	0.01
3	2	55	40.62	26.28	18.18	0.45
3	3	55	30.80	17.96	14.50	0.24
3	4	55	25.68	15.03	13.10	0.15
3	5	55	22.57	13.59	12.37	0.10
3	6	55	20.48	12.76	11.91	0.07
3	7	55	18.99	12.23	11.61	0.05
3	8	55	17.87	11.86	11.38	0.04
6	2	55	40.62	34.38	18.18	0.89
6	3	55	30.80	21.42	14.50	0.48
6	4	55	25.68	16.95	13.10	0.29
6	5	55	22.57	14.81	12.37	0.20
6	6	55	20.48	13.61	11.91	0.14
6	7	55	18.99	12.85	11.61	0.11
6	8	55	17.87	12.33	11.38	0.08