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Julio J. Rotemberg; Garth Saloner

The Quarterly Journal of Economics, Vol. 104, No. 1. (Feb., 1989), pp. 73-97.

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THE CYCLICAL BEHAVIOR OF STRATEGIC INVENTORIES*

JULIO J. ROTEMBERG AND GARTH SALONER

This paper presents a model in which inventories are used by a duopoly to deter deviations from an implicitly collusive arrangement. Higher inventories allow firms to punish cheaters more strongly and can thus help to maintain collusion. We show that when demand is high, the incentive to deviate increases so that increases in inventories may be optimal for the duopoly. This rationalizes the observed positive correlation between inventories and sales. In our empirical section we show that, as our model predicts, this correlation is more important in concentrated industries. We also provide several examples where inventories have been a factor in cartel behavior.

I. INTRODUCTION

In this paper we analyze the role of inventories in supporting collusion. This role of inventories derives from their usefulness in punishing firms that deviate from a collusive understanding and is quite different from the one stressed in standard neoclassical models where they help to smooth production. We show that inventories for collusive purposes may be most valuable when demand is high. Thus, equilibrium levels of inventories may be positively correlated with sales—a conclusion that is consistent with the empirical evidence, but that is inconsistent with the production smoothing model. Moreover, we present some empirical evidence that suggests that this positive correlation between inventories and sales arises in concentrated industries, precisely where a collusive explanation is most relevant.

We consider a model in which duopolists attempt to sustain collusive profits by the threat to revert to competitive behavior. In such a setting, collusion is easier to sustain the greater is the punishment that will follow a deviation from collusion, i.e., the larger the difference between future collusive and competitive profits. An important factor that affects the competitive profits of a single firm is its competitor's ability to increase sales following a deviation. A firm that realizes that its rival will be severely capacity

*Financial support from the National Science Foundation (grants IST-8510162 and SES-8308782, respectively) is gratefully acknowledged. We are deeply indebted to Ian Domowitz, Glenn Hubbard, and Bruce Petersen for making their data and regressions available to us as well as to their research assistant Craig Paxton for his help. We also thank Larry Summers for his comments and for urging us to explore the empirical relevance of our model.

constrained, and hence will be unable to mete out an effective punishment, has an inducement to cheat. By “stockpiling” inventories, its rival can relax its own future capacity constraint, making threatened future competition more severe, and collusion more attractive to a prospective deviator.

We model this effect in a setting where the firms first choose how much to produce and then how much to sell each period. In equilibrium each firm produces enough so that at the sales stage it has more goods on hand than it plans to sell that period. The surplus, the firm’s “arsenal” of inventories, is held solely for the deterrent effect that it has on the rival. While the same disciplinary role could be achieved with a permanent increase in capacity, inventories have the advantage that their level can be tailored to current market conditions. In particular, more inventories can be held when, as in Rotemberg and Saloner [1986], the incentive to deviate is temporarily higher because demand is higher.

In equilibrium the firms must have no incentive to deviate at either the production or the sales stage. At the sales stage, we find that inventories are a two-edged sword. Although they make it less attractive for the rival to deviate, they make it more attractive for the firm holding the inventories to deviate itself. Not only can it sell more when it deviates, but it also avoids inventory carrying costs by doing so. These dual effects of inventories tend to make the incentive to deviate a quadratic function of the firms’ inventory levels. For low levels of inventories an additional unit of inventories has a larger effect on the incentive to deviate than it has as a deterrent to cheating. For large levels of inventories, the reverse is true. There are thus typically two sales-stage equilibria. At one, the firms have relatively low levels of inventories. Each firm’s incentive to deviate is low and is exactly balanced by the mild deterrent effect of its rival’s inventories. At the high inventory equilibrium, each firm has a large incentive to deviate which is balanced by the large deterrent effect of its rival’s inventories.

A firm also has the opportunity to deviate at the production stage. In particular, a firm can expand production in anticipation of dramatically expanding its sales. In analyzing the incentive to deviate in this way, it is critical whether or not such overproduction is observable by the firm’s rival. If it is, then cooperation will break down at the sales stage. This makes overproduction unattractive even when there are few planned inventories. On the other hand, if it is not observable, a firm is capable of building up inventories to unleash in a “surprise attack” at the sales stage. This makes

deviations at the production stage more appealing and eliminates candidates for equilibria with few inventories. Therefore, observability can improve the equilibrium from the point of view of the oligopoly.

Independently of whether overproduction is observable, high production by one's rival (which ensues when there is a high level of planned inventories) reduces the incentive to cheat at the production stage. This occurs because such high production means that the rival is capable of strong punishments. As a result, the sales-stage equilibrium with higher inventories is more robust. We show that this equilibrium level of inventories is increasing in the current level of demand. The reason for this is that the incentive to cheat is higher if demand is higher. Therefore, in order to deter its rival from cheating, the firm must increase its punishment capability, and hence its level of inventories.

This result rationalizes the empirical finding that inventories are positively correlated with sales. This positive correlation has received a great deal of attention in the literature. In particular, this correlation is part of the explanation for the fact that the variance of production is larger than that of sales. If the role of inventories were simply to smooth production, they would, unlike what is observed, be drawn down in booms and built up in recessions. The empirical failures of the simple production smoothing model have been documented by Blinder [1984] and West [1986] among others.

At least two alternatives to this model, both of which are in principle capable of explaining the positive correlation between inventories and sales, have been proposed. The first, which is explored in Eichenbaum [1984], simply postulates that there are important productivity shocks. In response to such a shock, production and sales both increase. If the shock is temporary, inventories increase as well. The second is that inventories are simply necessary for sales. If more is to be sold, larger inventories must be on hand. This view underlies both the linear quadratic models in which "target" inventories are a function of sales (see West [1986]) and the more formal models of Prescott [1975], Abel [1985]), and Kahn [1987]. In the formal models demand is uncertain, and production takes place before the random realization of demand. Firms produce and hold inventories so that they can meet demand, at least for a certain range of demand realizations. The Prescott model applies to a competitive industry, while Abel and Kahn deal with monopolies.

What we wish to emphasize is that neither of these explanations predicts a relationship between the correlation of inventories and sales, on the one hand, and market structure, on the other.¹ Instead, our theory predicts that inventories and sales ought to be related principally in oligopolistic industries. Our own empirical investigation based on work by Domowitz, Hubbard, and Petersen suggest that, indeed, this relationship between inventories and sales is much more important in concentrated industries. Some of our point estimates even suggest that this relationship is absent in competitive industries.

Rather different evidence on the relevance of our model might be obtained from reports of the use of inventories by firms for the purposes our theory ascribes to them. Such reports could conceivably take two quite different forms: reports that the purpose of an increase in inventories was to provide a deterrent to rivals contemplating undercutting the implicitly collusive price; and references to the danger that excessively high levels of inventories present for continued maintenance of the collusive price.

For a variety of reasons, we are unlikely to find direct evidence of the first kind. Such evidence would consist of reports of implied threats of what would happen to a rival who undercuts the current implicitly collusive price. Such implied threats would risk the intervention of Antitrust authorities. Furthermore, buyers would probably not react favorably to a threat by one of their upstream suppliers to punish a rival that provides a discount to downstream firms!

Evidence is more likely to be found with respect to the effect of excessive inventories on collusion. And indeed, here the evidence is abundant. We report on anecdotes drawn from the chemical, rubber, sugar, and aluminum industries that illustrate concerns of excessive inventories on cartel stability, and attempts to monitor and regulate inventory holdings.

The model, empirical findings, and conclusions and possible extensions, are presented seriatim in the following sections.

II. THE MODEL

We assume that firms offer different "models" of their product over time. Each model is sold for two periods, and only one model is

1. It might be thought that in concentrated industries in which price exceeds marginal cost, firms would be more eager to accumulate inventories in case demand proves to be high. Yet, as Prescott [1975] demonstrates, if demand proves to be high, competitive firms will also be able to charge a price in excess of marginal cost.

available (from both firms) at any time. Furthermore, inventories are never carried between models, perhaps because consumers are willing to pay very little for older models.² So, firms sell whatever stock they have on hand at the end of the second period. As a result of this simplification, most intertemporal considerations take place between the first and second periods of a model.

For each model, three decisions must be made sequentially. These are the first-period level of production, the first-period level of sales (or, equivalently, the level of inventories at the end of the first period), and the second-period level of production.

Within each period, demand is given by $P = a - bS$, where S equals industry sales. The cost to a firm of producing output q is

$$c(q) = 0 \text{ if } q < Q$$

$$c(q) = f \text{ if } q > Q.$$

Thus, Q is a capacity constraint that can be circumvented by the payment of a fixed cost f . As with other of our simplifying assumptions, this can be relaxed without materially affecting the results.³

With zero marginal costs, industry profits are maximized when each firm sells $a/4b \equiv s^m$; whereas Cournot rivals would sell $a/3b \equiv s^c$. We assume that $s^m < Q < s^c$ and that the duopolists attempt to sustain sales of s^m each period.⁴ Unilateral deviations are prevented by fear that reversion to less cooperative behavior will ensue. To focus attention on the model year's first period, we assume that punishments in later periods are sufficiently large that no firm has an incentive to deviate in the second period of a model year. This simplification reduces the interesting strategic actions of firm i to first-period production q_i and sales s_i . The punishment that might sustain $s_i = s^m$ in equilibrium is the sum of that in the current model's second period and that in future model years. We denote the latter by K . We treat K as a crucial fixed parameter in what follows. If K is very large, s^m can be sustained without inventories; if it is very small, collusion is impossible. Some of K 's determinants are discussed in our conclusion.

Our main point is that in some cases firms can sustain $s_i = s^m$ in equilibrium *if and only if the firms also hold inventories*; i.e., if and only if $q_i > s_i$. Inventories help by increasing the second-period

2. See Saloner [1986] for a static treatment of model-years with inventories.

3. A more complicated version of the model with increasing marginal costs can be found in Rotemberg and Saloner [1985].

4. In Rotemberg and Saloner [1985] we also consider sustaining the equilibrium with the highest profits for the duopoly. Because inventories are costly, this equilibrium does not necessarily entail sales of s^m .

punishment. This punishment is that the second period becomes a one-shot noncooperative game. Suppose that firm i has inventories I_i . If, in addition, both firms produce to capacity, firm j 's second-period profits are $(a - b(Q + I_j) - b(Q + I_i))(Q + I_j)$. This expression is strictly decreasing in I_i , so firm j 's punishment is increasing in its rival's inventories.⁵

Since higher punishments sustain more collusive outcomes, firms like severe punishments. Why then do firms not threaten to exceed their second-period capacity constraint if their rival deviates in the first? The reason is that this may not be rational in period 2. Suppose that $Q + I_j < s^c$. Then, if firm i chooses to exceed Q , it sells $(a - b(Q + I_j))/2b$ (its best response to firm j 's sales) in the second period. Firm i 's profits are then $(a - b(Q + I_j))^2/4b - f$. If, on the other hand, it chooses not to exceed its capacity constraint, it earns $(a - b(Q + I_j) - b(Q + I_i))(Q + I_i)$. Clearly, if f is "large enough," firm i prefers not to exceed its capacity constraint.⁶ We focus on this case.

We now provide conditions for the "only if" part of the statement, i.e., conditions under which sustaining collusion requires inventories. These conditions provide the rationale for inventories and thus may be considered the sine qua non of the model. Suppose that firms are attempting to sustain sales of s^m in the first period with zero inventories. There are two cases depending on whether a deviating firm finds it profitable to exceed Q when it cheats. If the firm does not choose to exceed capacity, cheating is profitable if

$$(1) \quad (a - bQ - bs^m)Q + \delta(a - 2bQ)Q - K \\ > (1 + \delta)(a - 2bs^m)s^m = (1 + \delta)a^2/8b,$$

where δ is the discount rate. The first expression gives the firm's first-period profit when it deviates (its rival has not deviated so it can only sell s^m). The second expression gives second-period profits: neither firm carries inventories forward; neither finds it profitable to exceed its capacity constraint; and Q is assumed to be less than s^c . The final expression gives profits when neither firm deviates.

Suppose instead that the deviating firm chooses to produce

5. Notice that the assumption that the firms are willing to produce to capacity and sell their inventories will not hold for very large levels of inventories. Rather than working through all possible cases, which would not be terribly enlightening, in this and many subsequent calculations we have selected an interesting case to focus on and later demonstrate by means of a numerical example that the cases we have chosen are mutually consistent in that they can hold simultaneously for interesting parameter values.

6. A sufficient condition for the firm to prefer not to exceed Q even when it is most profitable because $I_i = I_j = 0$ is $f > (a^2 - 6abQ + 9b^2Q^2)/4b$.

more than Q . It then sells its best response to s^m in the first period, $(a - 2bs^m)/2b$, and also produces some output to carry to the next period. Anticipating that its rival will sell Q in the second period, its inventories I_i maximize $(a - bQ - b(Q + I_i))(Q + I_i) - dI_i$, where d is the unit cost of carrying the inventory to the second period. So, $I_i = (a - 3bQ - d)/2b$, and second-period profits of the deviating firm are $(a - bQ - d)^2/4b$. The firm therefore chooses to deviate if

$$(2) \quad 9a^2/64b - f + \delta(a - bQ - d)^2/4b - K > (1 + \delta)a^2/8b.$$

Provided that (1) or (2) holds, the collusive level of profits is unsustainable without inventories. We now examine a collusive equilibrium with positive inventories.

In such equilibria first-period output equals (q_i^*, q_j^*) . As part of the collusive understanding, the firms plan to sell s^m in the first period. The rest, $I_i^* \equiv q_i^* - s^m$, is earmarked to provide the punishment capability that prevents either of the firms from deviating. The duopoly's problem is to find a pair of planned inventories $\{I_1^*, I_2^*\}$ such that firms do not want to deviate at either the production or the sales stage.

A. The Sales Stage in the First Period

Suppose that firms have produced $\{s^m + I_1, s^m + I_2\}$. If neither firm deviates at the sales stage, each earns $(1 + \delta)a^2/8b - dI_i$. Assuming for the moment that a firm that cheats (say firm 1) sells its entire output,⁷ it earns $(a - b(s^m + I_1) - bs^m)(s^m + I_1)$ in the first period. In the second period the one-shot game ensues with firm 1 selling Q , while firm 2 sells the lesser of $Q + I_2$ and its best response to Q . Assuming that it is $Q + I_2$, firm 1's discounted second-period profits are $\delta(a - b(Q + I_2) - bQ)Q$. Combining these calculations, the net benefits from deviating, $\Omega(I_1, I_2)$, are

$$(3) \quad \Omega(I_1, I_2) \equiv (a - b(s^m + I_1) - bs^m)(s^m + I_1) + \delta(a - b(Q + I_2) - bQ)Q - K - (1 + \delta)a^2/8b + dI_1.$$

Equation (3) shows that while high inventories may deter the firm's rival from deviating, they also increase the firm's own incentive to deviate. By deviating, the firm avoids the inventory

7. A sufficient condition for a firm that cheats to want to sell its entire output when it cheats can be obtained as follows: the total revenue in the first period when the firm sells $s^m + I_i^*$ is $(a - b(s^m + I_i^*) - bs^m)(s^m + I_i^*)$, and hence the marginal valuation of the last unit is $(a - 2b(s^m + I_i^*) - bs^m)$. On the other hand, in the second period, a marginal unit is worth $a - 3bQ - bI_i^*$ (since total revenue there is $(a - b(Q + I_i^*) - bQ)Q$). Thus, firm 1 will choose to sell all of $s^m + I_1^*$ in period 1 if $a - 2b(s^m + I_1^*) - bs^m > \delta(a - 3bQ - bI_1^*) - d$.

carrying cost dI_i . Also, at least for moderate levels of I_i , $(a - b(s^m + I_i) - bs^m)(s^m + I_i)$ is increasing in I_i ; i.e., a firm with higher inventories makes larger first-period profits when it does deviate.

Substituting s^m in (3), we obtain the level of inventories I_2 that makes $\Omega(I_1, I_2)$ zero so that it just deters firm 1 from deviating:⁸

$$(4) \quad I_2 = \{I_1(-bI_1 + a/4 + d) + M(a)\}/\delta bQ,$$

where

$$(5) \quad M(a) \equiv -\delta(a - 2bs^m)s^m + \delta(a - 2bQ)Q - K.$$

$M(a)$ is negative, since $(a - 2Q)Q$ is maximized at $Q = s^m$.

Of particular interest are symmetric Nash equilibria in which the inventories are such that deviations are just deterred. Setting $I_1 = I_2 = I^*$ in (4) and solving gives

$$(6) \quad I^* = [(a/4 + d - \delta bQ) \pm y]/2b$$

where

$$y \equiv \sqrt{(a/4 + d - \delta bQ)^2 + 4bM(a)}.$$

Thus, these equilibria come in pairs. We denote the one with the lower (higher) level of inventories by I^{L*} (I^{U*}).

The functions $I_2(I_1)$ and $I_1(I_2)$ are depicted in Figure I. I^{L*} and I^{U*} are given by their intersections. All points $\{I'_1, I'_2\}$ for which $I'_1 \geq I_1(I'_2)$ and $I'_2 \geq I_2(I'_1)$ are equilibria at the sales stage. This gives two regions; one with inventories between zero and I^{L*} ; and the other with inventories bigger than or equal to I^{U*} . In all these points with the exception of I^{U*} , I^{L*} , and the origin, at least one of the firms is holding more inventories than it needs to deter the other from cheating. Firms would not accumulate such excessive inventories unless they believed they would be punished for underproducing.⁹ If we rule out such implausible beliefs, the only candidates for equilibria that remain are the origin, I^{U*} , and I^{L*} . If either (1) or (2) holds, the origin is not an equilibrium. This leaves I^{U*} and I^{L*} .

To gain intuition for these two equilibria, suppose that both firms change their level of inventories together. Firm 1's incentive to deviate changes by $d\Omega/dI = (a/4 + d - bQ) - 2bI$, which is

8. This analysis implicitly assumes that I_2 is not so large that it implies optimal output of less than Q in the second period in the noncooperative game there.

9. This is equivalent to waging war against a country for having too small an arms buildup. It is also worth noting that, if the duopoly can sustain collusion using I^{U*} , inventories above this level are strictly worse for the duopoly. This gives another reason for ruling out the equilibria with inventories above I^{U*} .

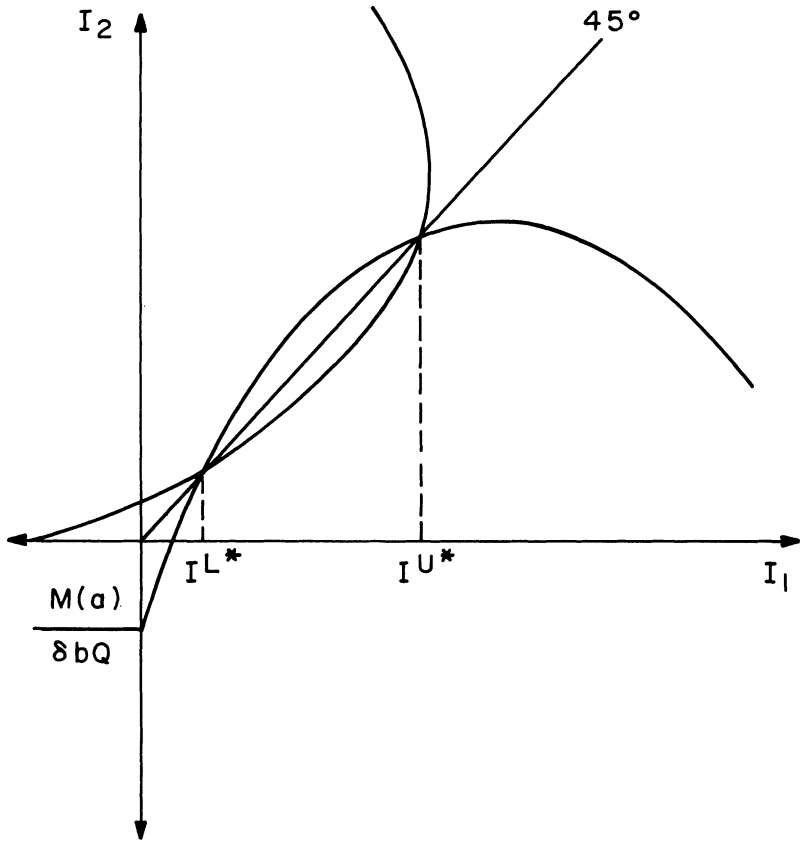


FIGURE I

The smallest level of I_i that firm i requires to deter firm j from deviating when its inventories are I_j

positive if $I < (a/4 + d - bQ)/4b$. When inventories are low, the deterrent effect of the rival's extra inventories is outweighed by the increase in one's own temptation to deviate. Thus, $I_2(I_1)$ increases more rapidly than the 45° line at low values of I_1 . However, as I_1 increases, the relative strength of the two effects is reversed, and $I_2(I_1)$ bends back toward the 45° line.

Eventually $I_2(I_1)$ peaks and begins to fall. As firm 1's inventories increase beyond this point, firm 2 requires fewer inventories to deter it from cheating. This is an artifact of the assumption that the deviating firm sells all its inventory. Then, one's own large inventories decrease one's profitability from deviating. This is analogous to

a superpower using an arsenal of nuclear weapons sufficient to produce "Nuclear Winter." Below, we provide a sufficient condition for a deviating firm to actually want to sell its entire production.

At I^{L*} firm 1 has a very small incentive to deviate both because it cannot increase sales by much (it is constrained to sell less than $s^m + I_1^*$) and because its low level of inventories means it does not save much in inventory carrying costs by deviating. Thus, firm 2 also needs a relatively low level of inventories to prevent the deviation. At I^{U*} firm 1 has a large incentive to deviate, and firm 2 requires a large level of inventories to deter it from doing so.

Equilibria exist when $I_2(I_1)$ is as depicted in Figure I. I_2 starts below the x -axis if $M(a) < 0$ so $I_2(0) < 0$. Second, I_2 starts with a positive slope if

$$(7) \quad \left. \frac{dI_2}{dI_1} \right|_{I=0} = \frac{a/4 + d}{\delta bQ} > 0.$$

Third, $I_2(I_1)$ and the 45° line intersect if y is real; i.e., if

$$(8) \quad \left(\frac{a}{4} + d - \delta bQ \right) > 4b\delta \left(\frac{a^2}{8b} + \frac{K}{\delta} - (a - 2bQ)Q \right).$$

Thus, (8) is a sufficient condition for the existence of an equilibrium. It is more likely to be satisfied if δ and K are low and d is high. If δ and K are sufficiently high, then firm 2 can always deter firm 1 from cheating by holding fewer inventories than firm 1. High inventory carrying costs d , on the other hand, create a large incentive to deviate, so large inventories are required for deterrence. Thus, the $I_2(I_1)$ curve is more likely to rise above the 45° line when d is high.

Of particular interest is how equilibrium inventories vary with demand. Since $dM(a)/da = \delta(Q - 4b) = (Q - s^m) > 0$, it is immediate from (6) that $dI^{U*}/da > 0$. Now consider the derivative of I^{L*} with respect to a :

$$\frac{dI^{L*}}{da} = \left\{ y - \frac{a}{4} = d + \delta bQ - 4b\delta \left(Q - \frac{a}{4b} \right) \right\} / 8b_y.$$

Since $(a/4 + d - bQ) > y$ and $Q > s^m = a/4b$, $dI^{L*}/da < 0$. At the low inventory equilibrium, inventories fall when demand rises.

Intuition can be gained by totally differentiating $\Omega(I_1, I_2)$ at $I_1 = I_2 = I^*$ and equating to zero:

$$(9) \quad \frac{dI^*}{da} = \left(\frac{d\Omega(I^*)}{da} \right) / \left(\frac{d\Omega(I^*)}{dI^*} \right).$$

The incentive to deviate, Ω , is increasing in a , and $d\Omega/da$ which equals $a/4 + \delta(Q - s^m)$ is positive. Thus, inventories need to increase if the incentive to deviate falls when inventories rise so $d\Omega(I^*)/dI^* < 0$. As discussed above, this is true for large, but not for small, inventories.

While an increase in demand can lead to an increase or decrease in inventories, the former is often the more relevant case. As we shall demonstrate, deviations at the production stage often eliminate the lower equilibrium while leaving the upper equilibrium intact.

B. The Production Stage in the First Period

We now study whether firms have an incentive to deviate from the production of either $s^m + I^{L*}$ or $s^m + I^{U*}$ which, as we have seen, lead to sustainability of collusion at the sales stage. The analysis hinges critically on the degree of observability of production. Two forms of observability must be distinguished. The first is the ability of the firm to demonstrate to its rival that it has built up sufficient inventories so that the latter should not think of cheating at the sales stage. In the armaments analogy, this is equivalent to the Soviet's May Day Parade. This ability is obviously essential for inventories to play a deterrent role and is assumed throughout.

What we shall term observability of overproduction is stronger. It makes hiding overproduction impossible. This matters because it robs the ability to "spring a surprise attack" from deviating firms. It corresponds to "mutual verifiability" in the case of nuclear armaments. Such observability facilitates collusion.

When one firm produces either less than $s^m + I^*$ or, with observable overproduction, more than $s^m + I^*$, the firms play a noncooperative game at the sales stage. Suppose that firm 2 has produced $q_2 = s^m + I^*$ as planned but that firm 1 has produced q_1 instead. Firm 1 must now choose its inventory I_1 to maximize V_1 :

$$(10) \quad V_1 = [a - b(q_1 - I_1) - b(q_2 - I_2)](q_1 - I_1) + \delta[a - b(Q + I_1) - b(Q + I_2)](Q + I_1) - dI_1.$$

There is a similar expression for firm 2.

The first-order conditions for I_1 and I_2 , respectively, are

$$(11) \quad \begin{aligned} a - 2b(q_1 - I_1) - b(q_2 - I_2) - \delta A + \delta b(Q + I_1) + d &= 0 \\ a - b(q_1 - I_1) - 2b(q_2 - I_2) - \delta A + \delta b(Q + I_2) + d &= 0. \end{aligned}$$

Solving (11) simultaneously yields

$$(12) \quad I_{in} = h + q_i/(1 + \delta),$$

where $h \equiv [a(\delta - 1) - d]/3b(1 + \delta) - \delta Q/(1 + \delta)$ and the subscript n denotes the noncooperative equilibrium. Equilibrium inventories are the maximum of zero and the expression in (12). For large enough d , zero inventories are optimal.

We now show that I^{U*} is more robust against deviations. The benefits from deviating at the production stage equal the difference between the maximized value of $V_1 - K$ and the profits from going along $[(1 + \delta)a^2/8b - dI^*]$. For zero planned inventories, we know this difference to be positive, and this logic must also apply for arbitrarily small levels of inventories. Therefore, low inventory equilibria tend to be unsustainable. To show that higher inventory equilibria are most robust, we need to show that increases in inventories reduce the incentive to cheat at the production stage.

An increase in I^* by one unit raises q_2 in (10) by one unit and therefore raises I_2 in the noncooperative game by $1/(1 - \delta)$ units. Firm 1 optimizes with respect to both q_1 and I_1 so the effect on its profits can be obtained by applying the envelope theorem to (10):

$$(13) \quad \frac{dV_1}{dI^*} = -b\delta \left(\frac{q_1 + Q}{1 - \delta} \right),$$

which is clearly negative. When the other firm has more inventories, the deviating firm sells less at a lower price, thereby making lower profits. Increasing I^* by one unit not only lowers V_1 but also lowers the profits from going along by d . For inventories to ever serve as a deterrent effect, the first effect must dominate (so d must be relatively small). Then, relatively low inventory levels cannot deter deviations at the production stage while higher levels of inventories can.¹⁰

We now show that when overproduction is not observable, the incentive to cheat at the production stage exceeds that when it is observable. The difference between the two situations is that whereas in the latter case the inventories of both firms are given by (12), in the former case the inventories of the nondeviating firm are equal to the planned level of inventories. This planned level is larger, as can be seen from (12) when $(s^m + I)$ is substituted for q_i . Thus, deviating is more tempting when overproduction is unobserv-

10. When the equilibrium with inventories equal to I^{U*} is not sustainable at the production stage, this analysis implies that the equilibria with lower inventories are unsustainable as well. It is also worth pointing out that as I^* rises, the deviator's output q_1 falls. This means that the value of dV_1/dI^* rises. For relatively large values of d this means that equilibria with truly large levels of inventories are not sustainable at the production stage: firms would prefer to deviate by underproducing.

able if the deviating firm 1 would prefer to see firm 2 keep a larger level of inventories. To see that this holds, we differentiate (10) and use the envelope theorem:

$$(14) \quad \frac{dV_1}{dI_2} = b[(q_1 - I_1) - \delta(Q + I_1)] = -b[\delta Q + (1 + \delta)h],$$

where the second equality follows from using (12) to replace $q_1 - (1 - \delta)I_1$. The expression (14) is clearly positive. In (14), $(q_1 - I_1)$ and $(Q + I_1)$ equal sales in the first and second period, respectively. As more inventories are carried over by the nondeviating firm, the former go up while the latter go down. Thus, the more inventories the nondeviating firm carries over, the more firm 1 benefits from an increase in firm 2's inventories. Firm 2 is increasingly ruining the second-period market, in which firm 1 is already selling little, and improving the first-period market, in which firm 1 sells a lot. The effect of lack of observability is so strong in our model that we have been unable to find numerical examples where collusion is sustainable in this case.

C. A Numerical Example

To keep the discussion manageable, we have imposed a variety of seemingly reasonable conditions. We have assumed that a deviating firm at the sales stage finds it optimal to carry over no inventories; that the firm which does not deviate at this stage has insufficient capacity (including inventories) in the second period to sell its best response to the deviating firm's second-period sales Q ; and that this nondeviating firm finds it unprofitable to exceed capacity at that point.

It would not be particularly instructive to work through all possible cases that the parameters could yield. However, it is important to verify that there are parameter values for which an equilibrium of the kind we have discussed exists, where all the conditions we have imposed are met, and where our basic premise that inventories are required to sustain collusion is satisfied. We have checked that this is indeed the case for the parameter values $a = 100$, $b = 1$, $d = 10$, $\delta = 0.9$, $K = 25$, $Q = 26$, and $f = 150$. In that case it turns out that $I^{U*} = 8.42$ and $I^{L*} = 3.18$. The lower equilibrium I^{L*} is destroyed by the incentive to overproduce with observable overproduction, while the higher equilibrium is not. Thus, as discussed above, the upper equilibrium is indeed more robust than the lower one.

III. EMPIRICAL RELEVANCE

We present two kinds of empirical evidence for our model. First, we present and discuss some cross-sectional regularities in the correlations between inventories and demand for different levels of industry concentration. Second, we provide some anecdotes from past cartels in which there were concerns for the levels of inventories and discuss their relevance for our model.

A. Cross-Section Regressions

The model we have presented suggests that when inventories are used to deter deviations from collusive outcomes, production will be more variable than sales and that inventories will be high when demand is high. Our model thus appears capable of explaining some of the correlations that are observed with aggregate data [Blinder, 1984]. Yet, it is difficult to believe that all industries hold inventories for the strategic motive we outline. Therefore, it seems important to verify that industries which are more likely to be subject to these strategic interactions are also more likely to exhibit the "perverse" correlations documented by Blinder. At the outset, it is important to clarify that the analysis of these correlations cannot be viewed as a formal test of the model we presented. That model has many special features in both the demand that faces the firms and the technology to which they have access. Yet the correlations can shed light on whether models of this type have the potential for being important explanations of actual inventory movements.

We thus present and discuss briefly some cross-sectional regularities in the correlations between inventories and demand. We focus on these correlations instead of the relationship between the variability of production and that of sales because the latter comparison is affected by a serious measurement problem. While inventories and sales are measured directly by the census bureau, the production figures are imputed by adding the change in inventories to the value of shipments. This obviously introduces variability into the production figures.

The regressions we consider have been run using the data set constructed by Domowitz, Hubbard, and Petersen [1986]. Indeed the regressions we report are variations on regressions they themselves originally ran.¹¹ Their data set is particularly appropriate for

11. They called these regressions to our attention in the summer of 1984. We have since worked with their research assistant, Craig Paxton, and modified the specification somewhat. While we report only the results from our regressions, their results were qualitatively similar.

this task, since it provides an extensive coverage of industries for a relatively long period. It has annual data from 1963 to 1981 for 284 four-digit manufacturing industries.¹² Of these industries we select only those which, according to Belsley [1969], produce "to stock." Our model applies only to these because only they keep as inventory any excess of production over sales. This means that we use only the 75 four-digit industries belonging to SIC codes 20 (Food and Kindred Products), 21 (Tobacco), 23 (Textiles), 28 (Chemicals), 29 (Petroleum and Coal Products), and 30 (Rubber). In particular, we do not use any data on industries that produce goods classified as durable by the Census.

We consider a regression of the ratio of inventories to sales on the unemployment rate, where this latter variable captures the effect of aggregate demand. We want to know whether the effect of this variable is more important in oligopolistic industries where implicit collusion plays a role. Since such implicit collusion requires a relatively small number of existing firms, we use as a crude proxy for its presence the four-firm concentration ratio C_4 . We thus consider regressions of the following type:

$$(15) \quad I/S_{it} = n_i + m_1 U_t + m_2 C_{4it} + m_3 C_{4it} U_t,$$

where I/S_{it} is the ratio of inventories of industry i at the end of period t to sales of industry i during period t . The n 's and m 's are parameters to be estimated. In these regressions we let concentration have a direct effect on inventories. However, since concentration alone cannot possibly account for all the cross-sectional variation in the inventory-sales ratio, we allow for industry fixed effects. These fixed effects are estimated in practice by removing within-cell means. Once fixed effects are allowed, the coefficient m_1 is estimated exclusively on the basis of the time variation of the concentration ratio.

We allow unemployment to affect the inventory-sales ratio directly. As we discussed in the introduction, there are reasons why inventories might be correlated with unemployment other than those we model. One possibility is that there are technology shocks. Favorable technology shocks will raise production, inventories, and sales while reducing unemployment. The response of the ratio of inventories to sales will depend on the permanence of the productivity improvement. If it is very transient, sales might be expected to go up little and the inventory-sales ratio would rise, leading

12. These industries produce approximately 80 percent of the value added by the manufacturing sector.

to a negative association between the inventory-sales ratio and unemployment.

Another possibility, which permeates the models in which "target" inventories depend on sales, is that more inventories are needed if more is to be sold. According to this view, an increase in unemployment, which now represents a low state of demand, would lead to a reduction in inventories. The effect on the inventory-sales ratio is ambiguous. Yet, if there are economies of scale in inventory holding, high unemployment should be associated with high levels of the inventory-sales ratio.

The coefficient m_3 captures whether the effect of unemployment on the inventory-sales ratio is more pronounced in concentrated industries. Both the technology shocks theory of inventory changes and the view that inventories are held because they are necessary for sales lack particular predictions for m_3 . In other words, departures of m_3 from zero would require amending these theories by postulating, for instance, a relationship between concentration and the persistence of shocks. Thus, we take the simple versions of these theories as predicting that m_3 should be zero. On the other hand, if inventories in oligopolistic industries rise to deter cheating when demand is high, m_3 should be negative.

Equation (15) obviously leaves out a host of important considerations. Since the excluded determinants of inventories are likely to be serially correlated, the residual is likely to be serially correlated. More generally, any movement of inventories toward their equilibrium level might be gradual for other reasons. For this reason, we also experiment with the inclusion of a lagged dependent variable in our regressions.

We run the regressions for two measures of the inventory-sales ratio. The first uses only finished goods inventories as is done in our formal model. Presumably, however, rapid access to inputs also facilitates the punishing of a deviating firm. Thus, it is plausible that if strategic considerations play a role in finished inventories, they do so as well for inventories of materials and work-in-progress. Our other measure of the inventory-sales ratio therefore uses these other "unfinished goods" inventories. We also experiment with the possibility that the behavior of inventories is different in industries that sell to other firms (producer goods) and industries that sell to consumers. The results are presented in Tables I and II.

The first thing to note in these tables is that the coefficient on the lagged dependent variable always differs significantly from both zero and one. Inclusion of this lagged dependent variable tends

TABLE I
REGRESSIONS EXPLAINING RATIO OF FINISHED GOODS INVENTORIES TO SALES

Explanatory variable	All industries		Producer goods		Consumer goods	
C_4	0.030 (0.012)	0.011 (0.010)	0.033 (0.024)	0.026 (0.022)	0.035 (0.016)	0.009 (0.012)
U	0.178 (0.073)	0.058 (0.058)	0.385 (0.151)	0.251 (0.133)	0.116 (0.085)	-0.001 (0.061)
C_4U	-0.718 (0.154)	-0.308 (0.123)	-1.036 (0.272)	-0.623 (0.241)	-0.658 (0.206)	-0.219 (0.149)
I/S_{-1}		1.634 (0.023)		0.539 (0.042)		0.700 (0.027)
R^2	0.026	0.378	0.038	0.277	0.023	0.470

to reduce the absolute magnitude of the other coefficients without affecting their standard error. Thus, their statistical significance is reduced. In spite of this, the variable we are most interested in, C_4U , always has a negative coefficient, and it is generally different from zero at the 5 percent level. This provides mild evidence for our theory and against the view that the inventory-sales ratio is high in

TABLE II
REGRESSIONS EXPLAINING RATIO OF UNFINISHED GOODS INVENTORIES TO SALES

Explanatory variable	All industries		Producer goods		Consumer goods	
C_4	0.029 (0.014)	-0.004 (0.009)	0.050 (0.032)	-0.011 (0.016)	-0.001 (0.016)	0.0001 (0.013)
U	0.559 (0.083)	0.114 (0.053)	0.537 (0.199)	0.040 (0.101)	0.516 (0.084)	0.169 (0.066)
C_4U	-1.177 (0.175)	-0.267 (0.112)	-1.261 (0.359)	-0.097 (0.183)	-0.893 (0.204)	-0.395 (0.156)
I/S_{-1}		0.726 (0.017)		0.765 (0.022)		0.675 (0.027)
R^2	0.038	0.587	0.026	0.470	0.061	0.464

booms simply because firms need the extra inventories to sell more.

As might be expected if there are some economies of scale in the use of inventories for this purpose, the coefficient on the unemployment rate is generally positive. Thus, for firms with average concentration, booms are associated with reductions in the ratio of inventories to sales. In particular, since the mean of C_4 is 0.424, for a totally unconcentrated industry (one whose C_4 is zero), a 1 percent increase in unemployment is associated with an increase of about 0.19 percent in the final inventories-sales ratio and of about 0.23 percent in the materials plus work-in-progress inventories-sales ratio. These results are obtained using the estimates in the second column of the two tables. We now study what these point estimates imply for the change in inventories. For this purpose we write the change in I/S as follows:

$$d\left(\frac{I}{S}\right) = \frac{(dI)}{S} - \left(\frac{I}{S}\right)\left(\frac{dS}{S}\right).$$

The ratio of final inventories to sales averages 0.066 and that of materials plus work-in-progress inventories to sales averages 0.074. Therefore, changes in the ratio of inventories to sales of the magnitude described, are consistent with constant inventories of final goods as long as sales fall by 2.84 percent when unemployment increases by 1 percent. The corresponding number for unfinished goods inventories is 2.86 percent. This relationship between sales and unemployment is not out of line with standard estimates of Okun's law.¹³ So our results for the aggregate of all our industries can be taken to mean that inventories would not go up in booms if American industry were unconcentrated.

On the other hand, for industries with concentrations above 0.61, not only do inventories rise, but the ratio of finished goods inventories to sales actually increases when the unemployment rate drops. Similarly, the ratio of unfinished goods inventories to sales rise when the four-firm concentration tops 85 percent.

The tables also make it clear that the direct effect of the level of concentration on the level of inventories is estimated rather imprecisely. As we pointed out before, these estimates are based only on the time variation in concentration. Yet, concentration changes very slowly and is measured accurately only every ten

13. The usual estimate is that GNP falls by 3 percent when unemployment rises by 1 percent. Gordon [1982] reports a number in the vicinity of 2.5 percent.

years; the measure we use is splined between these observations. Thus, the weakness of these results is not surprising.

Finally, it is worth noting that the negative effect of C_4U is present in both producer and consumer goods industries. Indeed, while the effect of C_4U appears stronger on finished goods in producer goods industries, the effect on unfinished goods inventories is stronger in consumer goods industries. On the other hand, the point estimates do not suggest that, within each type of industry, inventories in unconcentrated industries remain constant when unemployment changes.¹⁴

B. Anecdotal Evidence

As discussed in the Introduction, there are several reasons to suggest that one should not expect to see direct references to the deterrent role of inventories. The closest we have seen is an oblique reference in the chemical industry to endeavors to gear up for a price war when "an excess of zeal or a lapse of prudence leads to an 'unfriendly act.'" [Stocking and Watkins (hereinafter S and W), 1946, p. 421]. Such an action, it is reported, "is likely to bring threats of reprisals and warlike preparations."

There is evidence, however, with respect to the effect of excessive inventories on collusion. In *Cartels in Action*, Stocking and Watkins provide examples from a number of industries in which inventory behavior has been a concern to a cartel. The relevant anecdotes can be categorized as follows: concern that an excessive buildup of inventories would destabilize price; attempts to prevent the destabilizing effects of excessive inventories by centralizing the holding of excessive inventories; and explicit attention to monitoring inventory levels.

We begin with the concern that excessive inventories may destabilize price. There are several ways in which such a concern might arise in our model. To begin, consider the low-inventory equilibrium I^{L*} in Figure I. If both firms exceed that level slightly, neither firm has sufficient inventories to keep the other in line. Even if only one of the firms exceeds its desired inventory level, this occurs: asymmetric inventory buildups may be destabilizing. Of course, in our model the firms are able to choose precisely the level

14. Instead, when unemployment falls, finished goods inventories in unconcentrated producer goods industries and unfinished goods inventories in unconcentrated consumer goods industries tend to rise. Conversely, unfinished goods inventories in producer goods industries and final goods inventories in consumer goods industries fall.

of inventories they desire, and hence neither will increase its level beyond this critical point. In practice, however, the firms are unable to exactly choose their inventory levels. A positive productivity shock will result in a higher-than-planned level of inventories. Similarly, even if production can be precisely planned, a negative demand shock would have the same effect. In that case, the firms would find themselves with more inventories than were sustainable in equilibrium. As a result, price would fall to the highest sustainable level.

Now consider the high-inventory equilibrium I^{U*} in Figure I. Since $I_2(I_1)$ is increasing at I^{U*} , the same effect occurs here: an "accidentally" high level of inventories will upset the equilibrium. But notice that in this case the firms can insulate themselves against this effect by planning for a small "buffer" stock in excess of I^{U*} . If both firms implement a buffer policy, their inventories will lie on the 45° line above I^{U*} . Then, each firm will have more than enough inventories to deter the other from cheating, and a small "accident" will not trigger a breakdown of collusive pricing.

Nonetheless, even at this high-inventory equilibrium, the firms are not insulated against large unexpected inventories. As discussed in footnote 5, our maintained assumption that firms are willing to produce to capacity and sell all their inventories in the second period if there has been a first-period deviation does not hold for very large levels of inventories. When inventories are "too large," they have little value in the future even if firms collude because of the low prices that would be necessary to sell them. Accordingly, it becomes more worthwhile to "dump" them in the first period, even if it means destabilizing the cartel.

Thus, even when inventories are used to help sustain collusion, as in our model, excessive inventories can destabilize the implicitly collusive equilibria that emerge.

Stocking and Watkins present two anecdotes that illustrate that excessive inventories can indeed lead to cartel instability. The rubber industry entered the depression with normal levels of inventory holdings: "At the 1929 rate of consumption, stocks were nowhere near excessive" [S and W, p. 76]. However, with the Depression, consumption fell, and stocks mounted. Eventually inventory levels were so high that collusion could no longer be sustained: "By 1933 world stocks were twice as large as in 1929, reaching the unprecedented level of 655,000 tons. . . . Prices promptly declined" [S and W, p. 76].

Similarly, when inventory levels fell in 1940, prices rose:

“World stocks at the end of the year were reduced to the critical level of less than five months’ supply. Prices continued to advance, rising 15%” [S and W, p. 83].

However, it is important to note that the evidence of the destabilizing effect of excessive inventories which we present is also consistent with a model in which inventories are not used to help sustain a collusive agreement. For example, suppose that the sine qua non of our model is not satisfied; i.e., it is possible to sustain collusion without inventories. This is the case where (0,0) in Figure I is sustainable as an equilibrium. In that case a small productivity or demand shock which led to (unplanned) inventories of less than I^{L*} would not destabilize the cartel, however, (unplanned) inventories of more than that level would.

To put this differently, take the case of an unexpected downturn in demand. Planning for a higher level of demand, the firms produce as much as they expect to sell. Because of the downturn it is no longer profitable to sell as much as otherwise. However, in order to maintain the monopoly price consistent with this (lower) level of demand, the firms will be called upon to carry substantial inventories. If the inventory carrying costs are sufficiently high, however, the incentive to cheat so as to avoid those costs is great. This effect destabilizes the cartel.

While the mechanism at work is the same as in Rotemberg and Saloner [1986], the implication is different. There, the incentive to cheat is highest during booms: the gain from cheating is highest there, and yet the punishment is independent of the current state of demand. Thus, implicitly collusive schemes may not be able to sustain monopoly pricing during the boom. Here, where production must be done in advance of sales and inventory carrying costs are high, there may be an added incentive to cheat during a downturn in order to avoid the inventory carrying costs.

Where excessive inventories have the potential of undermining cartel stability, it is not surprising to see attempts to control them. If shocks to productivity or demand give rise to inventories that are unsustainable, as above, it makes sense to remove those inventories from the hands of the firms themselves, to avoid their incentive to “dump” them on the market. In such circumstances, the firms might agree to place the excessive inventories in “neutral hands.”

There are at least two examples of such behavior in the aluminum industry. First, in 1939 when the Alliance Aluminium Compagnie was established to cartelize the aluminum industry, the Foundation Agreement required the members to remove invento-

ries in excess of certain levels from the market: "The Foundation Agreement required the Alliance to remove from the market, at the outset, all accumulated stocks of members in excess of forty tons per Alliance share and to pay £55 a ton for them. With excessive stocks thus "frozen," a similar device for regulating prices in the ordinary course of business came into play" [S and W, p. 264]. When the cartel agreement was replaced with a new agreement in 1936, in addition to imposing a tax on overproduction, "the Alliance imposed a graduated tax on accumulation of stocks" [S and W, p. 272].

In the sugar industry, the Vereenigde Javasuiker Producenten (VJP) was organized when Javanese sugar stocks reached an unprecedented level and individual producers "lacking the finances to hold those stocks" had begun to dump them, depressing prices. "The VJP . . . was able to hold such temporary surpluses off the market, and thus to check the price decline." [S and W, p. 21]. Later, the "Chadbourne Plan" of 1931 also explicitly accounted for inventories: "[T]o neutralize the depressing effects of enormous stocks, . . . , each country with excess stocks agreed to centralize and segregate them. Their release was authorized only in specified annual amounts, distributed over the life of the agreement" [S and W, p. 38].

Our final anecdote relates to the question of monitoring. As we stressed in our discussion of the theory, collusive firms will find it easier to maintain collusion if it is not possible to "secretly" increase inventories. This fact seems to have been recognized by the members of the aluminum cartel which, at their seventh international aluminum convention, agreed to submit quarterly accounts to the association of, *inter alia*, their levels of inventories [S and W, p. 253].

IV. CONCLUSIONS

We have presented a model in which inventories are accumulated exclusively to deter deviations from an implicitly collusive arrangement. This model can explain why inventories are large when demand is high. Moreover, according to this model, this association between inventories and sales should be observed mainly in concentrated industries. Our empirical work confirms this implication of our model. Finally, it is a feature of the equilibrium of our model that excessive inventories destabilize implicit collusion. Our anecdotal evidence is consistent with this

aspect of the model, and moreover, there is evidence that cartels take pains to regulate member firms' inventory behavior.

In our model inventories are accumulated because they help punish deviations from implicit collusion. Excess capacity can play a similar role as demonstrated by Brock and Scheinkman [1985]. A major advantage of inventories, however, is that they are less costly to change than capacity and therefore can be tailored to current market conditions. A second difference between inventories and capacity is that the former is more of a two-edged sword because, by deviating, a firm avoids the inventory carrying costs.

Since inventories can be used only for a short period of time, they are only useful when K is relatively small; i.e., when the oligopoly can sustain only little collusion in the absence of inventories. In this sense our paper takes a different view from Friedman [1971] and Abreu [1982] where punishments are so strong that, for plausible discount factors, the cooperative outcome can always be enforced. We believe instead, for three reasons, that actual punishments are substantially shorter and smaller.

The first reason for this is provided in Green and Porter [1984]. In their model the observation of rivals' actions are subject to noise. The firm must attempt to infer from its noisy observation when a deviation has taken place. Punishment are, in part, triggered by observation error. So, while an infinite punishment minimizes the incentive to deviate, it has the disadvantage of guaranteeing only a finite period of collusion. As Porter [1983] shows, finite punishments are often optimal in this case.

The second reason for finite punishments is that the identity of the firms in the industry, and their managers, changes over time. This may be especially true in situations where the firm faces a sequence of product models. Thus, the system only has a finite memory. Once the action that triggered the reversion has been forgotten by the system, it seems likely that the oligopoly will again attempt to reestablish implicitly collusive behavior.¹⁵

Third, and perhaps more importantly, it is hard to believe that the firms would really resign themselves to an infinite period of punishment. In fact, what makes it plausible to imagine firms actually punishing each other in the first place is that the response to their perception of chiseling on the part of their rivals is likely to

15. A number of methods for moving to an implicitly collusive scheme have been documented in the literature. "Price leadership" and "industrial statesmanship" are the most commonly mentioned.

be one of anger. However, the anger dissipates over time, and the individuals revert to being "sensible."¹⁶

Our model is special in several respects. It is special in that it is based on explicit functional forms and in that we rely strongly on the presence of differing "models" to simplify the analysis. The next step is to consider a storage good that is not subject to model years. It is plausible that, even in this context, an increase in demand which raises the incentive to deviate in the absence of inventories, raises the level of inventories necessary to deter deviations. This positive relationship between demand and inventories in a stationary setting would explain both the positive correlation between sales and inventories and the "excess" volatility of production.

In this paper we have assumed that quantities are the strategic variable. However, it may well be the case that inventories perform an even stronger deterrent role when prices are the strategic variable. In this case deviations may be more tempting because a deviating firm captures a substantial fraction of the market. On the other hand, its rivals may respond more promptly in this case. The difficulty with analyzing inventories when prices are the strategic variable is that the optimal strategies, at least after a deviation has occurred, involve the use of mixed strategies.

A related issue that deserves exploration is the role of the inventory accumulation we predict when demand is high in accentuating fluctuations in aggregate output. It has often been pointed out (see Blinder and Fischer [1981], for example) that the fluctuations in inventories are a large fraction of these output fluctuations. Thus, the inventory fluctuations we predict are potentially important. However, it is not the case that only concentrated industries increase their output during booms. For our model to explain that together with aggregate inventory fluctuations, we must integrate the oligopolistic sector we consider with more competitive sectors in a general equilibrium model as is done in Rotemberg and Saloner [1986].

In that model, booms are caused by shifts in demand toward oligopolistic sectors. These sectors respond by lowering their prices to deter deviations. In an integrated model they would, of course, also increase their inventories. It is the reduction in oligopolistic prices that encourages the competitive sector to expand either

16. In this interpretation the "irrational" sentiment of anger serves a useful function. It induces cooperation as others fear anger's consequences. An application of economic reasoning might suggest that the amount of anger that is triggered by bad behavior is optimal. It balances the energy "wasted" by the anger itself with its social advantages. See Hirschleifer [1985] for a similar view.

because it uses the output of the oligopolistic sector directly or because workers increase their labor supply in response to the fall in oligopolistic prices. Note that the expansion in the competitive sector takes place because the prices in this sector are temporarily high. Thus, this expansion in the output of the competitive sector will not necessarily be accompanied by increases in that sector's inventories. Thus, an integrated model might explain why, as in our empirical section, only the inventories of concentrated industries rise in booms.

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[Footnotes]

¹⁶ **The Expanding Domain of Economics**

Jack Hirshleifer

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