NBER WORKING PAPER SERIES

A SUPERGAME-THEORETIC MODEL OF BUSINESS CYCLES AND PRICE WARS DURING BOOMS

Julio J. Rotemberg

Garth Saloner

Working Paper No. 1412

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 1984

Sloan School of Management and Department of Economics respectively.
We are very grateful to James Poterba and Lawrence Summers for many helpful conversations. Financial support from the National Science Foundation (grants SES-8209266 and SES-8308782 respectively) is gratefully acknowledged. The research reported here is part of the NBER's research program in Economic Fluctuations. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

NBER Working Paper #1412
August 1984

A Supergame-Theoretic Model of Business Cycles and Price Wars During Booms

ABSTRACT

This paper studies implicitly colluding oligopolists facing fluctuating demand. The credible threat of future punishments provides the discipline that facilitates collusion. However, we find that the temptation to unilaterally deviate from the collusive outcome is often greater when demand is high. To moderate this temptation, the optimizing oligopoly reduces its profitability at such times, resulting in lower prices. If the oligopolists' output is an input to other sectors, their output may increase too. This explains the co-movements of outputs which characterize business cycles. The behavior of the railroads in the 1880's, the automobile industry in the 1950's and the cyclical behavior of cement prices and price-cost margins support our theory. (J.E.L. Classification numbers: 020, 130, 610).

Julio J. Rotemberg
Alfred P. Sloan School
of Management, E52-250
50 Memorial Drive
M.I.T.
Cambridge, MA 02139

Garth Saloner
Department of Economics
E52-262B
M.I.T.
Cambridge, MA 02139

I. INTRODUCTION

This paper has two objectives. First it is an exploration of the way in which oligopolies behave over the business cycle. Second, it considers the possibility that this behaviour itself is a cause of business cycles and of sticky prices. We examine implicitly colluding oligopolies that attempt to sustain above competitive profits by the threat of reverting to competitive behavior to punish firms that do not cooperate. The basic point of the paper is that the oligopolists find implicit collusion of this kind more difficult when their demand is high. In other words when an industry faces a boom in its demand, chiseling away from the collusive level of output becomes more profitable for each individual firm and thus the oligopoly can only sustain a less collusive outcome. This suggests that when demand for goods produced by oligopolists is high, the economy produces an allocation which is "closer" to the competitive allocation and thus nearer the production possibility frontier. Insofar as the allocation in which the oligopoly acts collusively is inside the production possibility frontier, a shift in demand towards the oligopolistic sector can increase the output of all goods. The fact that the outputs of all goods tend to move together is, of course, the hallmark of business cycles. Thus we can interpret booms in aggregate economic activity as being due to a shift in demand towards the oligopolistic sectors and busts as shifts towards the competitive sectors.

This analysis still leaves unexplained the causes of the shifts in sectoral demands. To make sense of actual business cycles one would have to relate these shifts in demand to changes in the money supply and interest rates which are highly correlated with cyclical fluctuations.

While the connection between financial variables and shifts in demand is beyond the scope of this paper it must be noted that these shifts form part of the popular discussions of the early stages of recoveries. At that point consumers' desire for cars and other durables usually picks up.

The oligopolies we consider know that deviations from some agreed upon strategy lead to punishments. Unfortunately there are usually a multitude of equilibria in such settings. These equilibria differ in the mechanics by which reversion to punishing behavior takes place, by the length and intensity of the punishment interval as well as by the amount of collusion that takes place when the firms are not punishing each other. One standard technique for choosing among these equilibria (see, for example, Porter (1983a)) is to concentrate on the equilibrium that is optimal from the point of view of the oligopolists.

Unfortunately it is often very difficult to characterize these optima. Even Porter's paper considers only linear demand and optimizes only over a subset of all the possible strategies. In particular, he considers only punishments in which firms act as if they were involved in a sequence of one-shot noncooperative games. Thus the most firms can do to each other when they are punishing and being punished is to compete as if they were playing a sequence of static games. This considerably simplifies the analysis. Our otherwise optimal supergames also embody this assumption which is not essential in all cases.

In our model the reversion to competitive behaviour occurs for a period of infinite length. This length is optimal since it is the biggest credible threat and since, along the equilibrium path, firms never find themselves punishing each other. Instead for each state of

demand we focus on the outcome closest to monopoly that the oligopoly can sustain given the threat. Any outcome closer to monopoly would lead to a breakdown in discipline. Any outcome further from monopoly would simply result in lower oligopoly profits. We show that when demand rises, the best sustainable outcome generally becomes more competitive. Our strongest results are for the case in which prices are the strategic variable and there are constant marginal costs. Then an increase in demand actually lowers the oligopoly's prices monotonically after a certain point. This occurs because keeping the oligopoly's price constant when demand increases raises the payoff to a single firm from lowering its price slightly and thus capturing all of demand. To deter each firm from doing this the oligopoly must actually lower its price.

The paper proceeds as follows. Section II presents the optimal supergame for both the cases in which the oligopoly treats prices and the case in which it treats outputs as the strategic variable. We also discuss simpler games in which, as in Breshnahan (1981), Green and Porter (1984) and Porter (1983b) the oligopoly can only behave either monopolistically or competitively. It is then in general more likely to behave competitively when demand is high. Section III establishes the connection with macroeconomics. It describes a simple two sector general equilibrium model in which one sector is oligopolistic and the other sector is competitive. The oligopolistic sector's output is purchased both by consumers and by the competitive sector. When demand shifts towards the oligopolistic sector, this sector lowers its prices. This, in turn, leads the competitive sector to increase its purchases from the oligopolistic sector and thus increase its output as well. So both

sectors grow, only to shrink when demand moves back towards the competitive sector or when the punishment period is over.

Any theory whose foundation is that competitive behaviour is more likely to occur in booms must confront the fact that the industrial organization folklore is that price wars occur in recessions. This folklore is articulated in Sherer (1980) for example. Our basis for rejecting this folklore is not theoretical. We concede that it is possible to construct models in which recessions induce price wars.[1] Instead our rejection is based on facts. First, at a very general level, it certainly appears that business cycles are related to sluggish adjustment of prices (see Rotemberg (1982) for example). Prices rise too little in booms and fall too little in recessions. If recessions tended to produce massive price wars this would be an unlikely finding. More specifically we analyze some other sources of data capable of shedding light on the folklore. What we find is that both Scherer's evidence and our own study of the cyclical properties of price cost margins supports our theory. Our theory is also supported by an analysis of the price wars purported to have happened in the automobile industry (Bresnahan (1981)) and the railroad industry (Porter (1983a)). These wars have occurred in periods of high demand. Finally, since Sherer singles out the cement industry as having repeated break-ups of its cartel during recessions, we study the cyclical properties of cement prices. To our surprise, cement prices are strongly countercyclical even though cement, as construction as a whole, has a procyclical level of output. These empirical regularities are discussed in Section IV. We conclude with Section V.

II. EQUILIBRIUM IN OLIGOPOLISTIC SUPERGAMES WITH DEMAND FLUCTUATIONS

We consider an oligopoly of N symmetric firms in an infinite-horizon setting for both the case where the firms use price as the strategic variable and that in which the strategic variable is output. It is well-known that in such models even firms that cannot sign binding contracts, i.e. noncooperating firms in the usual sense, are usually able to sustain outcomes in any period that strictly dominate the outcome in the corresponding one-period game.

In order to achieve this the equilibrium strategies must involve a mechanism that deters an individual firm from "cheating" (by expanding output or by shading prices). One such mechanism and one that has been fruitfullly employed in theoretical models[2], is the use of punishments against the defecting firm in periods following the defection. If such punishments are large enough to outweigh the gain from a single period defection the collusive outcome is sustainable.

In order for the equilibrium strategies to be sequentially rational[3], however, it must be the case that if a defection actually occurs the non-defecting firms are willing to mete out the proposed punishment. One way to ensure this is for firms that defect from the punishment to be punished in turn, and so on. Rules which lead to optimal outcomes for the firms are provided by Abreu(1982). A simpler way to ensure sequential rationality and the one usually employed (see Green and Porter (1984), for example) is for punishments to involve playing the equilibrium strategies from the one-period game for some fixed period of time. In the sequel we restrict attention to strategies of this kind. As we will see shortly, in addition to their simplicity and conformity with the literature they are also optimal punishments when price is the strategic variable.

The major departure of our model from those that have previously been studied is that we allow for observable shifts in industry demand. We denote the inverse demand function by $P(Q_t, \tilde{\varepsilon})$ where Q_t is the industry output in period t and $\tilde{\varepsilon}$ is the random variable denoting the observable demand shock (with realization ε_t in period t). We assume that increases in ε_t result in higher prices for any Q_t, that $\tilde{\varepsilon}$ has domain $[\underline{\varepsilon}, \bar{\varepsilon}]$ and a distribution function $F(\varepsilon)$ and that these are the same across periods (i.e. shocks are i.i.d.). We denote firm i's output in period t by q_{it} so that

$$Q_t = \sum_{i=1}^{N} q_{it}.$$

The timing of events is as follows: At the beginning of the period all firms learn the realization of $\tilde{\varepsilon}$ (more precisely ε_t becomes common knowledge). Firms then simultaneously choose the level of their choice variable (price or quantity). These choices then determine the outcome for that period in a way that depends on the choice variable: in the case of quantities the price clears the market given Q_t; in the case of prices the firm with the lowest price sells as much as it wants at its quoted price, the firm with the second lowest price then supplies as much of the remaining demand at its quoted price as it wants, and so on. The strategic choices of all the firms then become common knowledge and this one-period game is repeated.

The force of the observability of ε_t and the key to the difference between the model and its predecessors is the following: The punishments that firms face depend on the future realizations of $\tilde{\varepsilon}$. The expected value of such punishments therefore depends on the expected value of $\tilde{\varepsilon}$. However the reward for cheating in any period depends on the observable ε_t. We show that for a wide variety of interesting cases the reward for cheating from the joint profit-maximizing level

is monotonically increasing in ϵ_t. If ϵ_t is large enough, the temptation to cheat outweighs the punishment.[4] Being cognizant of this fact, an implicitly colluding oligopoly settles on a profit below the fully collusive level in periods of high demand so as to adequately reduce the temptation to cheat. Such moderation of its behavior tends to lower prices below what they would otherwise be, and may indeed cause them to be lower than for states with lower demand. We illustrate this phenomenon for both prices as well as for quantities as strategic variables.

(a) Price as the strategic variable

We begin with an analysis of the case in which marginal costs are equal to a constant c. We demonstrate that the basic characteristics of our analysis are not dependent on this assumption by means of an example below.

Let us point out at the outset that there always exists an equilibrium in which all the firms set P=c in all periods. In this competitive case firms expect future profits to be zero whether they cooperate at time t or not. Accordingly the game at time t is eesentially a one-shot game in which the unique equilibrium has all firms setting P=c. In what follows we concentrate instead on the equilibria that are optimal for the firms in the industry.

We begin by examining joint profit-maximization and the benefits to unilateral defections from it. Define $\Pi^m(Q_t^m(\epsilon_t), \epsilon_t)$ to be the profit of an individual firm in state ϵ_t if the firms each produce q^m which equals 1/N of the joint profit-maximizing output, Q^m. If a firm deviates from this proposed outcome it can earn approximately $N\Pi^m$ by cutting price by an arbitrarily small amount and supplying the entire market demand. Firm i would therefore deviate from joint profit-maximizing output if

$N\Pi^m(Q_t(\epsilon_t), \epsilon_t) - K_i(\epsilon_t) > \Pi^m(Q_t(\epsilon_t), \epsilon_t)$ i.e. if $\Pi^m(Q_t(\epsilon_t), \epsilon_t) > K_i(\epsilon_t)/(N-1)$

where $K_i(\varepsilon_t)$ is the punishment inflicted on firm i in the future if it deviates at time t.

The value of $K_i(\varepsilon_t)$ depends on both the expected level of future profits if there is no deviation at time t and on the nature of the punishment. Since we want to concern ourselves with equilibrium strategies that are optimal for the oligopoly and hence are interested in maintaining profits that are as large as possible, we concentrate on punishments that are as large as possible; namely those that have P=c for all t following a defection. While infinite punishment periods are extreme they are subgame perfect and need not actually be implemented in equilibrium. If the industry members change over time, however, infinite length punishments are not compelling. To moderate the effect of this assumption in the calculation of specific examples, we use reduced levels of the discount rate, δ.

Suppoee that the level of firm profits that can be sustained in a period with state ε_t is $\Pi^s(\varepsilon_t, K(\varepsilon_t))$ when the punishment is $K(\varepsilon_t)$. Then using infinite length punishments, the discounted future value of profits, and hence the punishment, is

$$K(\varepsilon_t) = \frac{\delta}{1-\delta} \int_{\underline{\varepsilon}}^{\bar{\varepsilon}} \Pi^s(\varepsilon', K(\varepsilon'))dF(\varepsilon'). \qquad (1)$$

Since the right hand side of (1) is independent of ε_t, the punishment is independent of the state and can be written merely as K.

Since $P(Q_t, \varepsilon_t') > P(Q_t, \varepsilon_t'')$ for all $\varepsilon_t' > \varepsilon_t''$, $\Pi(Q_t, \varepsilon_t') = (P(Q_t, \varepsilon_t')-c)Q_t > (P(Q_t, \varepsilon_t'')-c)Q_t = \Pi(Q_t, \varepsilon_t'')$. Therefore, for given K, there is some highest level of demand shock, $\varepsilon_t^*(K)$, for which $(N-1)\Pi^m(Q_t^m(\varepsilon_t), \varepsilon_t) = K$.
This means that for $\varepsilon_t \leq \varepsilon_t^*$, the monopoly outcome is sustainable so that $\Pi^s(\varepsilon_t, K) = \Pi^m(Q_t^m(\varepsilon_t), \varepsilon_t)$. By contrast, for $\varepsilon_t \geq \varepsilon_t^*$, an individual

firm has an incentive to cheat unless

$$\Pi^s(\varepsilon_t, K) = \frac{K}{N-1} = \Pi^m(Q_t^m(\varepsilon_t^*), \varepsilon_t^*). \tag{2}$$

Of course K in turn depends on ε_t^* from Equation (1). In particular we have

$$K(\varepsilon_t^*) = \frac{\delta}{1-\delta}\left[\int_{\underline{\varepsilon}}^{\varepsilon_t^*} \Pi^m(Q_t(\varepsilon_t), \varepsilon_t)dF(\varepsilon_t) + (1+F(\varepsilon_t^*))\Pi^m(Q_t^m(\varepsilon_t^*), \varepsilon_t^*)\right].^5 \tag{3}$$

Thus we have a mapping from the space of possible punishments into itself: a given punishment implies a cutoff ε_t^* which in turn implies a new punishment from (2). An equilibrium is a fixed point of this mapping.

It remains to provide sufficient conditions for the existence of such a fixed point i.e., to show there exists an $\varepsilon_t^* \in (\underline{\varepsilon}, \bar{\varepsilon})$ for which $\Pi^m(Q^m(\varepsilon_t^*), \varepsilon_t^*) = K(\varepsilon_t^*)/(N-1) = \Pi^s(\varepsilon_t^*, K(\varepsilon_t^*))$. Let

$$g(\varepsilon_t') = (N-1)\Pi^m(Q_t(\varepsilon_t'), \varepsilon_t') - K(\varepsilon_t') \tag{4}$$

where α is $\delta/(1-\delta)$.

We need to show there exists an ε_t' $(\underline{\varepsilon}, \bar{\varepsilon})$ such that $g(\varepsilon_t') = 0$.

Equations (2) and (3) imply that

$$K(\varepsilon_t') = \alpha\int_{\underline{\varepsilon}}^{\varepsilon_t'} \Pi^m(Q_t^m(\varepsilon_t'), \varepsilon_t')dF(\varepsilon_t) + \frac{\alpha(1-F(\varepsilon_t'))K(\varepsilon_t')}{(N-1)}$$

$$\text{or,}\quad K(\varepsilon_t') = \frac{\alpha\int_{\underline{\varepsilon}}^{\varepsilon_t'} \Pi^m(Q_t^m(\varepsilon_t), \varepsilon_t)dF(\varepsilon_t)}{(1 - \alpha/(N-1) - \alpha F(\varepsilon_m')/(N-1))}. \tag{5}$$

Therefore, using (4) and (5) $\lim_{\varepsilon_t' \to \underline{\varepsilon}} g(\varepsilon_t') = (N-1)\,\Pi^m(Q_t(\underline{\varepsilon}), \underline{\varepsilon}) - \frac{\alpha\Pi^m(Q_t(\underline{\varepsilon}), \underline{\varepsilon})}{(1-\alpha/(N-1))}$

which is negative if $N < (1+\delta)/((1-\delta)$ (Condition (i)).

At the other extreme,

$$g(\bar{\varepsilon}) = (N-1)\Pi^m(Q_t^m(\bar{\varepsilon}), \bar{\varepsilon}) - \alpha\int_{\underline{\varepsilon}}^{\bar{\varepsilon}} \Pi^m(Q_t^m(\varepsilon_t), \varepsilon_t)dF(\varepsilon_t) > 0$$

if $\Pi^m(Q_t(\bar{\varepsilon}), \bar{\varepsilon})/\int_{\underline{\varepsilon}}^{\bar{\varepsilon}} \Pi^m(Q_t^m, \varepsilon_t)dF(\varepsilon_t) > \alpha/(N-1)$ (Condition (ii)).

If Conditions (i) and (ii) hold, we have:

(a) $g(\varepsilon_t')$ is continuous, (b) $g(\bar{\varepsilon}) > 0$, and (c) $\lim_{\varepsilon_t' \to \underline{\varepsilon}} g(\varepsilon') < 0$, which imply the existence of an $\varepsilon_t' \in (\underline{\varepsilon}, \bar{\varepsilon})$ such that $g(\varepsilon_t') = 0$ as required.

Conditions (i) and (ii) have intuitively appealing interpretations. Condition (i) ensures that the firms are not tempted to "cheat" from the joint profit-maximizing output in all states. This requires that N not be "too" large relative to the discount rate. The larger is the discount rate (so that the future is more important and hence the effect of the punishment is greater) the larger the number of firms the industry is able to support without a complete breakdown in discipline.

Condition (ii) ensures that the monopoly outcome is not the only solution in every state. This follows when there is sufficient dispersion in the distribution or profit maximizing outputs. Clearly if there is no dispersion, then for large enough punishments there is never any incentive to cheat. The LHS of condition (ii) is a measure of the dispersion of profits.

Although $g(\varepsilon')$ is continuous it is not necessarily monotone. As a result there may be multiple values of ε' for which $g(\varepsilon') = 0$. Since we are concerned with optimal schemes from the point of view of the firms in the industry, we concentrate on the greatest such value.

There are several interesting features of this equilibrium. First note that for $\varepsilon_t > \varepsilon_t^*$ we have $\Pi^s(\varepsilon_t, k) = \Pi^m((Q_t^m(\varepsilon_t^*), \varepsilon_t^*)$. When $\Pi^s(\varepsilon_t, K)$ is so constrained, Q_t must be as high as possible without reducing firm profits below the sustainable level. By the definition of the $\Pi^s(\cdot)$, if Q_t is lower

and P is higher an individual firm has an incentive to shade price slightly and supply the industry demand. When ϵ_t goes up, Q_t must go up if $P(Q_t, \epsilon_t)$ is to remain constant since P is increasing in ϵ_t and decreasing in Q_t. Moreover, if P is held constant at a level above c, the profits from deviating increase. Therefore P must fall. Beyond ϵ_t^*, prices fall monotonically as ϵ_t increases. Below ϵ_t^* the oligopoly charges the monopoly price thus P tends to increase with ϵ_t.

The model behaves as intuition would suggest with respect to changes in the relevant parameters. Note firstly that the equilibrium value of K is decreasing in N. Therefore, given (2) $\Pi^m(Q_t^m(\epsilon_t^*), \epsilon_t^*)$ is also decreasing in N. Thus the set of states in which the monopoly outcome is sustainable is strictly decreasing in N. In contrast to traditional models of oligopolistic interaction in which oligopolies of all sizes are always unable to achieve perfect collusion, the firms in this model are usually able to do so for a range of states of demand. However, as in Stigler's model (1964) the degree of implicit collusion varies inversely with N.

As δ decreases so that the future becomes less important, the equilibrium value of K decreases and hence the sustainable level of profits and the set of states in which monopoly profits are sustainable also shrinks.

As was mentioned above, punishments are never observed in equilibrium. Thus the oligopoly doesn't fluctuate between periods of cooperation and noncooperation as in the models of Green and Porter (1984) and Porter (1983b). This arises because of the complete observability of ϵ_t. To provide an analagous model to those just mentioned, we would have to further restrict the strategy space so that the oligopoly can choose only between the joint monopoly price and the

competitive price. Such a restriction is intuitively appealing since the resulting strategies are much simpler and less delicate. With this restriction on strategies the firms know that when demand is high the monopoly outcome cannot be maintained. They therefore assume that the competitive outcome will emerge, which is sufficient to fulfill their prophecy. In many states of the world the oligopoly will earn lower profits than under the optimal scheme we have analyzed. As a result, since punishments are lower, there will be fewer collusive states than before. There will still be some cutoff, ε_t^*, that delineates the cooperative and noncooperative regions. In contrast to the optimal model, however, the graph of price as a function of state will exhibit a sharp decline after ε_t^* with P = c thereafter.

The above models impose no restrictions on the demand function except that it be downward sloping and that demand shocks move it outwards. However the model does assume constant marginal costs. The case of increasing marginal cost is more complex than that of constant marginal costs for three reasons: (1) A firm that cheats by price-cutting does not always want to supply the industry demand at the price it is charging. Specifically, it would never supply an output at which its marginal cost exceeded the price. So whereas before cheating paid off when $(N-1)\Pi^m(\varepsilon_t, K) > K$ now it pays off when $\Pi^m(\varepsilon_t, K) > \Pi^d(\varepsilon_t, KP) - K$ where $\Pi^d(\varepsilon_t, K, P)$ is the profit to the firm that defects when its opponents charge P; (2) If a firm is to be deterred from cheating it must be the case that $\Pi^s(\varepsilon_t, K, P) = \Pi^d(\varepsilon_t, K, P) - K$ i.e., the sustainable profit varies by state (in contrast to the marginal cost case). (3) With increasing marginal cost cheating can occur by raising as well as by lowering prices. If its opponents are unwilling to supply all of demand at their quoted price a defecting firm is able to sell some output at higher prices.

A few results can nonetheless be demonstrated. First suppose that deviating firms do not meet all of demand. Instead the output which equates the monopoly price to their marginal cost is less than demand. This occurs when N is large and when marginal costs rise steeply. Then the deviating firms equate $P(Q_t^m, \varepsilon_t)$ and $c'(q_{it}^d)$ where c' is the derivative of total coets with respect to output. By the envelope theorem the change in the deviant's profit from an increase in ε_t is $\frac{q_{it}^d dP(Q_t^m, \varepsilon_t)}{d\varepsilon_t}$. The change in profits from going along is $\frac{q_{it}^m dP(Q_t^m, \varepsilon_t)}{d_{\varepsilon t}}$. It is thus smaller, ensuring that deviations become more tempting as ε_t rises. However, in this case, if the oligopoly keeps its price constant in response to the increase in ε_t the desire to deviate actually falls. This occurs because when the price is constant the profits from deviating are constant. Instead, since the oligopoly price exceeds marginal cost, an increase in ε_t accompanied by a constant price raises the profits from going along.

When deviating firms meet all of demand the analysis is more difficult. For this case we consider an example in which demand and marginal costs are linear:

$$P = a + \varepsilon_t - bQ_t \tag{6}$$

$$c(q_{it}) = cq_{it} + dq_{it}^2/2 \tag{7}$$

Then monopoly output and price are:[6]

$$Q_t^m = (a + \varepsilon_t - c)/(2b + d/N) \tag{8}$$

$$P^m = [(a + \varepsilon_t)(bN + d) + bNc]/(2bN + d) \tag{9}$$

If deviating firms could sell all they wanted at a price a shade below P^m they would equate (c+dq) to P^m. This would lead to output equal to $\bar{q}_{it}$:

$$\bar{q}_{it} = [(a + \varepsilon_t - c)(b + d/N)]/[d(2b + d/N)] \tag{10}$$

The actual output of the deviating firm, q_{it}^d, is the minimum of $\bar{q}$ and Q^m. So the deviating firm meets demand as long as b is bigger than or equal to (N-1)d/N. Marginal cost must not rise too rapidly and N must not be too big.

When the deviating firm meets demand its profits Π^d are:

$$\Pi^d = N\Pi^m + Nd(1-N)(q^m)^2/2 \tag{11}$$

The change in Π^m from a change in ε_t is simply q^m. Therefore using (8) the change in the benefits from deviating is:

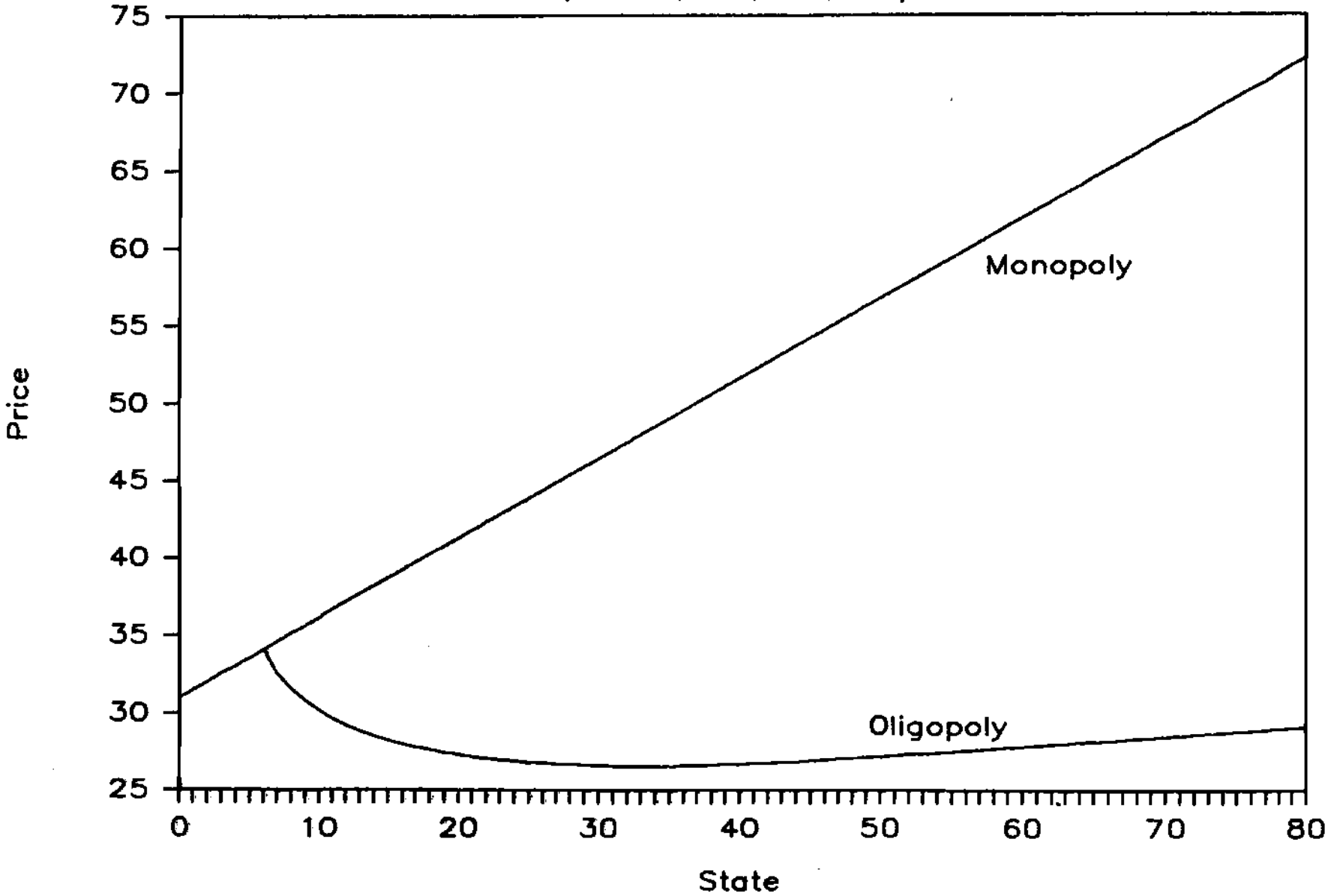
$$\frac{d(\Pi^d-\Pi^d)}{d\varepsilon_t} = \frac{(N-1)q^m(2bN - d(N-1)}{(2bN+d)} \tag{12}$$

which is positive when demand is met. Cheating becomes more desirable as ε_t rises. If the oligopoly is restricted to either collude or compete, high ε_t's will generate price wars. Alternatively the oligopoly can pick prices P^s which just deter potentially deviating firms. These prices equate Π^s, the profits from going along, with Π^d - K where K is the expected present value of Π^s minus the profits obtained when all firms set price equal to marginal cost.

Since q^d is linear in P^s, whether deviating firms meet demand or marginal cost, Π^d is quadratic in P^s in both cases. Π^m is also quadratic in P^s. For a given K one can then find P^s in the states that do not support monopoly by solving two quadratic equations. The relevant root is the one with the highest value of Π^s which is consistent with the deviating firms planning to meet demand or marginal cost. The resulting P^s's then allow one to find a new value for K. One can thus iterate numerically on K starting with a large number. Since larger values of K induce more cooperation the first K which is a solution to the iterative procedure is the best equilibrium the oligopoly can enforce with competitive punishments. Figure 1 graphs these equilibrium prices and compares

PRICE AS A STRATEGIC VARIABLE

Parameters; a=60,b=1,c=0,d=1/3,δ=.7,N=5



them to the monopoly prices as a function of states for a specific configuration of parameters. In particular ε_t is uniformly destributed over $\{0,1,\ldots,80\}$.

As before the price rises monotonically to ε_t^* and then falls. The major difference here is that eventually the price begins to rise again. The explanation for this is straightforward. For high values of ε_t the equilibrium value of P_t is such that a deviating firm would increase its output only until P equals its marginal cost; it is not willing to supply all that is demanded at its lower price. An improvement in demand from this level accompanied by a constant price actually reduces the incentive to cheat. Thus the oligopoly can afford to increase its prices somewhat.

b) Quantities as strategic variables.

There are two differences between the case in which quantities are ueed as strategic variables and the case in which prices are. First, when an individual firm considers deviations from the behavior favored by the oligopoly, it assumes that the other firms will keep their quantities constant. The residual demand curve is therefore obtained by shifting the original demand curve to the left by the amount of their combined output. Second, when firms are punishing each other the outcome in punishment periods is the Cournot equilibrium.

The results we obtain with quantities as strategic variables are somewhat weaker than those we obtained with prices. In particular it is now not true that any increase in demand even with constant marginal costs leads to a bigger incentive to deviate from the collusive level of output. However, we present robust examples in which this is the case. We also show with an example that increases in demand can, as before, lead monotonically to "more competitive" behavior.

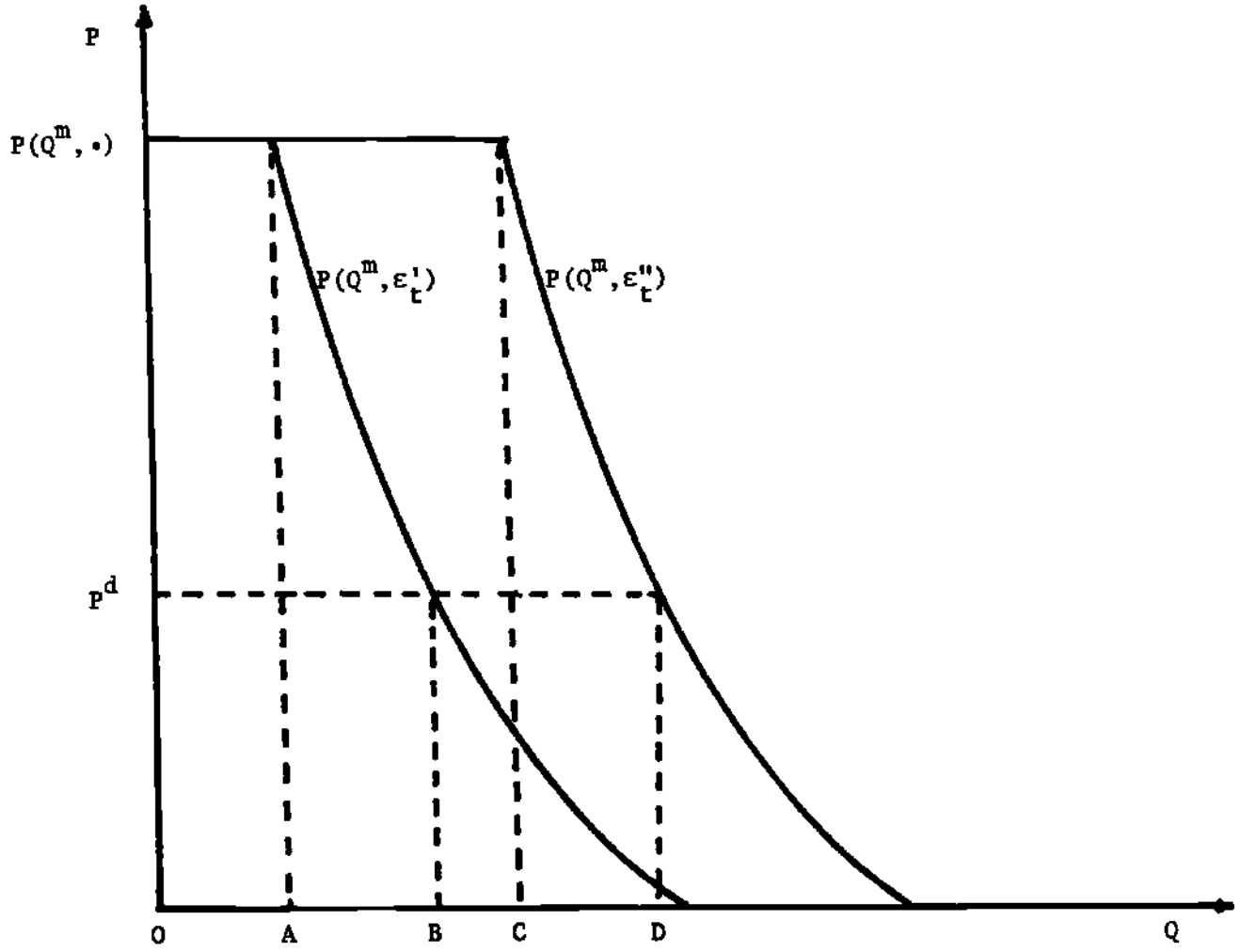
We show that increases in demand do not necessarily increase the incentive to deviate by means of a counterexample. Suppose that demand is characterized by constant elasticity and that a demand shock moves it horizontally from state ϵ_t' to state ϵ_t''. In this setup the collusive price is the same in both states. Therefore any firm that produces the collusive output sells more in state ϵ_t'' than in state ϵ_t'. The residual demand curves the firm faces are therefore as represented in Figure 2. A deviating firm chooses output to maximize profits given these residual demand curves. Suppose that this maximum is achieved at output D and price P^d for state ϵ_t''. For this to be a worthwhile deviation it must be the case that the revenues from the extra sales due to cheating (CD) are greater than the loss in revenues on the old sales from the decrease in price from $P(Q^m, \cdot)$ to P^d. But (except for a horizontal translation) the firm faces the same residual demand curve in both states. Thus by selling at P^d, the extra sales due to cheating are the same at ϵ_t' (AB) than at ϵ_t'' (CD). Moreover the loss in revenue on old sales is strictly smaller at ϵ_t'. Therefore the firm has a strictly greater incentive to deviate in state ϵ_t' than in state ϵ_t''.

The above counterexample exploits the assumption of the constant elasticity of demand only to establish that the collusive price is the same in both states. We have therefore also proved a related proposition: if the oligopoly keeps its price constant when ϵ_t increases (thus supplying all the increased demand), the incentive to cheat is reduced when demand shifts horizontally. Thus in the examples we provide below, the oligopoly is able to increase the price as the state improves.

Suppose that, instead, demand and costs are linear as in (6) and (7). Then an increase in ϵ_t always leads to a bigger incentive to deviate from the collusive output. This can be seen as follows. Suppose that in this case the

FIGURE 2

The Incentive to Deviate with Quantities as the Strategic Variable



oligopoly agrees that each firm should produce q_t^s. The deviating firm therefore maximizes:

$$\Pi^d = q_{it}\,[a + \varepsilon_t - c - b((N-1)q_t^s + q_{it})] - dq_{it}^2/2 \qquad (13)$$

with respect to q_{it}. So its output is:

$$q_{it}^d = [a + \varepsilon_t - c - b(N-1)q_t^s]/(2b + d) \qquad (14)$$

The derivative of Π^d at the optimum with respect to ε_t is $q_{it}^d(1-b(N-1)dq_t^s/d\varepsilon_t)$. Therefore, using (8), the derivative of the benefit from deviating from the collusive output in any one period is:

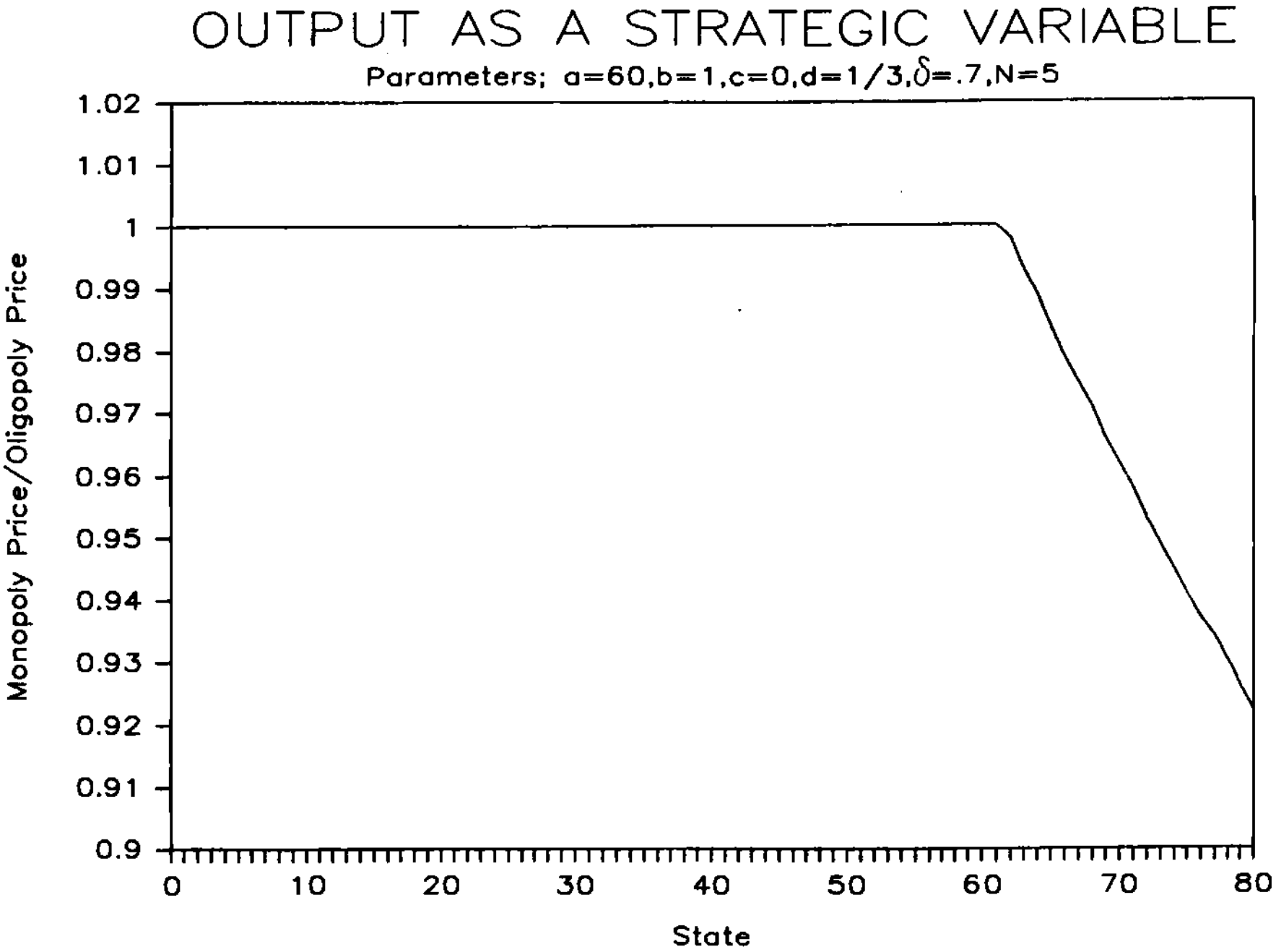
$$\frac{d(\Pi^d - \Pi^m)}{d\varepsilon_t} = \frac{[b(N-1)]^2(a+\varepsilon_t-c)}{(d+2bN)^2(2b+d)}$$

which is always positive. Deviating becomes more tempting as ε_t increases, independently of b and d, as long as both are finite. Therefore in the repeated setting as long as the discount rate is not too large or N too small, individual firms will deviate from the collusive outcome when demand is high. This leads to price wars when the only options for the oligopoly are to either compete or collude.

Alternatively the oligopoly can choose a level of output q^s that will just deter firms from deviating when demand is high. These levels of output can be obtained numerically in a manner analogous to the one used to obtain the P^s's in the previous subsection. These outputs equate Π^s, the profits from going along, to $(\Pi^d - K)$ where K is the expected discounted difference between Π^s and the profits from the Cournot equilibrium. By substituting (16) in (13) Π^d becomes quadratic in q^s. Since Π^s is also quadratic in q^s the q^s's are obtained as solutions to quadratic equations for given K.[7] The resulting q^s's allow us to compute a new value of K. By iterating in a manner analagous to the one used to

derive Figure 1 we obtain the best equilibrium for the oligopoly. Figure 3 plots the ratio of this equilibrium price to the monopoly price as a function of ε_t. While a variant of the argument made earlier guarantees that equilibrium price rises as ε_t rises, it can be seen that beyond a certain ε_t the ratio of equilibrium price to monopoly price falls monotonically.

FIGURE 3


OUTPUT AS A STRATEGIC VARIABLE
Parameters; a=60,b=1,c=0,d=1/3,δ=.7,N=5
Monopoly Price/Oligopoly Price
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9
0
10
20
30
40
50
60
70
80
State

III. BUSINESS CYCLES

So far we have considered only the behavior of an oligopoly in isolation. For this behavior to form the foundation of business cycles we need to model the rest of the economy. While the principle which underlies these business cycles is probably quite general we illustrate it with a simple example. We consider a "real" two sector general equilibrium model in which the first sector is competitive while the other is oligopolistic. There is also a competitive labor market. To keep the model simple it is assumed that workers have a horizontal supply of labor at a wage equal to P_{1t} the price of the competitive good. Since the model is homogeneous of degree zero in prices, the wage itself can be normalized to equal one. So the price of the good produced competitively must also equal one. This good can be produced with various combinations of labor and good 2. In particular the industry-wide production function of good 1 is given by:

$$Q_{1t} = \alpha Q_{21t} - \frac{\beta Q^2_{21t}}{2} + \gamma L_{1t} - \frac{\xi L^2_{1t}}{2} \tag{13}$$

where Q_{1t} is the output of the competitive sector at t, Q_{21t} is the amount of good two employed in the production of good 1 at t and L_{1t} is the amount of labor used in the production of good 1. Since the sector is competitive the price of each factor and its marginal revenue product are equated. Thus:

$$L_{1t} = (1 + \gamma)/\xi \tag{14}$$

$$P_{2t} = \alpha - \beta Q_{21t}. \tag{15}$$

On the other hand the demand for good 2 by consumers is given by:

$$P_{2t} = n - mQ_{2ct} + e_t$$

where Q_{2ct} is the quantity of good 2 purchased by consumers, n and m are parameters and e_t is an i.i.d. random variable. Therefore total demand for good 2 is given by:

$$P_{2t} = a + \varepsilon_t - bQ_{2t}$$
$$a = (n\beta + m\gamma)/(m + \beta) \qquad \varepsilon_t = e_t\beta/(m + \beta) \tag{16}$$
$$b = m\beta/(m + \beta)$$

Note that equation (16) is identical to equation (6). To continue the parallel with our sections on partial equilibrium we assume that the labor requirement to produce Q_{2t} is:

$$L_{2t} = cQ_{2t} + (d/2)Q_{2t}^2.$$

which implies that, as before, marginal cost is $c + dQ_{2t}$. The model would be unaffected if good 1 were also an input into good 2 since P_{1t} is always equal to the wage. If sector 2 behaved competitively marginal cost would equal P_{2t}. Then output of good 2 would be Q_{2t}^c while price would be P_{2t}^c:

$$Q_{2t}^c = (a + \varepsilon_t - c)/(b/2 + d)$$
$$P_{2t}^c = ((a + \varepsilon_t)d + bc/2)/(b/2 + d)$$

An increase in ε_t raises both the competitive price and the competitive quantity of good 2. By (15) less of good 2 will be used in the production of good 1 thus leading to a fall in the output of good 1. So, a shift in tastes raises the output of one good and lowers that of the other. The economy implicitly has, given people's desire for leisure, a production possibility frontier.

Similarly, if sector 2 always behaves like a monopolist, output and price are given equations (8) and (9) respectively. Therefore increases in ε_t raise both P_{2t} and Q_{2t} thus lowering Q_{1t}. Once again shifts in

demand are unable to change the levels of both outputs in the same direction. On the other hand if the industry behaves like the oligopoly considered in the previous sections, an increase in ε_t can easily lead to a fall in the relative price of good 2. This occurs in three out of the four scenarios considered in previous sections. It occurs when the unsustainability of monopoly leads to competitive outcomes whether the strategic variable is price or output as long as increases in ε_t make monopoly harder to sustain. It also always occurs when the strategic variable is prices and the oligopoly plays an optimal supergame. The decrease in P_{2t} in turn leads firms in the first sector to demand more of good 2 as an input and to increase their output. So, a shift in demand towards the oligopolistic goods raises all outpute much as all outputs move together during business cycles.

A number of comments deserve to be made about this model of business cycles. First our assumption that the real wage in terms of good 1 is constant does not play an important role. In equilibrium the reduction in P_{2t} raises real wages thus inducing workers to work more even if they have an upwardly sloping supply schedule for labor. Whether this increased supply of labor would be sufficient to meet the increased demand for employees by sector 2 is unclear. If it wasn't the wage would have to rise in terms of good 1. More interestingly if the increased supply of labor was large, P_{1t} would have to rise thus increasing employment also in sector 1. This would lead to an expansion even if good 2 was not an input into good 1. This pattern of price movements is consistent with the evidence on the correlation between product wages and employment presented below.

Second, the model can easily be made consistent with the procyclical variation of profits. Even though sector 2 reduces the margin between price and marginal coet as output expands, the difference between revenues and total costs can increase as long as there are fixed costs.

Third, it is quite plausible that changes in financial variables like the money stock and interest rates lead shifts in the composition of demand. For instance increases in the money stock might be associated with lower interest rates and a higher demand for durable goods. As shown below, durable good industries appear to be more oligopolistic than other industries. These shifts in demand form a large part of the informal discussion surrounding the 1983 recovery in the US , for example.

Random shifts in demand have already been showed to cause movements in employment in the asymetric information model of Grossman, Hart and Maskin (1983). However, contrary to the claims of Lilien (1982) such random sectoral shifts do not appear to be correlated with agregate fluctuations. Instead Abraham and Katz (1984) show that different sectors only have distinct correlations with agregate output. Moreover the sectors whose output is more correlated with agregate output appear to have a higher rate of growth on average. This leads to the statistical illusion that when output grows faster, as in a recovery, there is more intersectoral variance in output growth then when output growth is small, as in a recession. Note that Abraham and Katz's finding that some sectors are more "cyclic" than others accords well with our theory that shifts towards oligopolistic sectors are necessary to expand aggregate output. This finding also appears to be somewhat at odds with the literature on real business cycles (Long and Plosser (1983) and King

and Plosser (1984)). In this literature expansions are caused by favorable unobservable technological shocks. Aside from the fact that there is no independent evidence for the importance of these shocks and that they do not appear in the caeual discussions of the people who are directly affected by business cycles it is somewhat peculiar that these favorable shocks always recur in the same "cyclic" industries.[8]

Our model also sheds light on some slightly unfashionable concepts of Keynesian economics. One of the most pervasive facts about increases in the money supply is that they are not accompanied by equiproportional increases in prices. Prices appear to be sticky (cf Rotemberg (1982)). Suppose that, increases in ε_t are correlated with increases in the money supply. Then increases in output are correlated with increases in the money supply. As long as increases in output raise the demand for real money balances, increases in the money supply will be correlated with increases in real money balances. Prices do not rise equiproportionately. A second concept we can usefully discuss in the context of our model is that of a multiplier. This concept reflects the idea that increases in demand lead output to rise which then leads to further increases in demand. Here a shift in demand towards an oligopolistic sector can raise that sector's output, lower its prices and thus raise national income. In turn this increased national income can lead to increases in the demand for other goods produced in oligopolistic markets thus lowering their prices and raising their output as well. This process can continue until almost all oligopolistic markets have lower prices.

IV. SOME RELEVANT FACTS

a) The folklore

The theory presented in section II runs counter to the industrial organization folklore. This folklore is best articulated in Scherer (1980 p.208) who says: "Yet it is precisely when business conditions really turn sour that price cutting runs moet rampant among oligopolists with high fixed costs". Our attempt at finding the facts that support this folklore has, however, been unsucceesful. Scherer cites three industries whose experience is preeented as supporting the folklore. These are rayon, cement and steel. For rayon he cites a study by Markham (1952) which ehcws mainly that the nominal price of rayon fell during the Great Depression. Since broad price indices fell during this period this is hardly proof of a price war. Rayon has since been replaced by other plastics making it difficult to use postwar data to check whether any real price cutting took place during postwar recessions. For steel Scherer in fact admits the following: "... up to 1968 and except for some episodes during the 1929-38 depression, it was more successful than either cement or rayon in avoiding widespread price deterioration, even when operating at less than 65% capacity between 1958 and 1962 (p. 210).

This leaves cement. We study the cyclical properties of real cement prices below. To dc this we collected data on the average price of portland cement from the Minerals Yearbook published by the Bureau of Mines. We then compare this price with the Producer Price Index and the price index of construction materials published by the Bureau of Labor statistics. Regressions of the yearly rate of growth of real cement prices on the contemporaneous rate of growth of GNP are reported in Table

1. The coefficient of the rate of growth of GNP is alwaye meaningfully negative. A 1% increaee in the rate of growth of GNP leads to a 0.5-1.0% fall in the price of cement. To test whether the coefficients are eignificant the regreesion equations must be quasi-differenced since their Durbin-Watson statistics are small. Indeed the coefficients are all significantly different from zero at the five percent level. More caeually, the real price of cement rose in the recession year 1954 while it fell in the boom year 1955. Similarly, it rose during the recession year 1958 and fell in 1959.

These results show uniformly that the price of cement has a tendency to move countercyclically as our theory predicts for an oligopoly. These results are of course not conclusive. First, it might be argued that the demand for cement might be only weakly related to GNP. Without a structural model, which is well beyond the scope of this paper, this question cannot be completely settled. The rate of growth of the output of the cement industry has a correlation of .69 with the rate of growth of GNP and of .77 with the rate of growth of construction activity which is well known to be procyclical. However, these correlations are not sufficient to prove that cement is "more procyclical" than the typical sector included in GNP. Second our regressions do not include all the variables one would expect to see in a reduced form. Thus the effect of GNP might be proxying for an excluded variable like the capacity of cement mines which Scherer would probably expect to exercise a negative effect on the real price of cement. While this is indeed a possibility it must be pointed out that capacity itself is an endogenous variable which also responds to demand. It would thus be surprising if enough capacity were built in a boom to more than offset the increase in

Table 1

THE CYCLICAL PROPERTIES OF CEMENT PRICES

Yearly Data from 1947 to 1981

Dependent Variable / Coefficient	P^c/PPI	P^c/PPI	P^c/P^{con}	P^c/P^{con}
Constant	.025 (.010)	.025 (.012)	.038 (.007)	.037 (.008)
GNP	-.438 (.236)	-.456 (.197)	-.875 (.161)	-.876 (.149)
ρ		.464 (.173)		.315 (.183)
R^2	.10	.15	.48	.52
D.W	1.03	1.73	1.28	1.92

P^c is the price of cement, PPI is the producer price index and P^{con} is the price index of construction materials. Standard errors are in parenthesis.

demand. If anything, the presence of costs of adjusting capacity would make capacity relatively unresponsive to increases in GNP.

b) Actual price wars

There have been two recent studies showing that some industries alternate beetween cooperative and noncooperative behavior. The first is due to Bresnahan (1981). He studies the automobile industry in 1954, 1955 and 1956. He tries to evaluate the different interpretations of the events of 1955. That year production of automobiles climbed by 45% only to fall 44% the following year. Bresnahan formally models the automobile industry as carrying out two sequential games each year. The first involves the choice of models and the second the choice of prices. He concludes that the competitive model of pricing fits the 1955 data taken by themselves while the collusive model fits the 1954 and 1956 data. Those two years exhibited at best sluggish GNP growth. GNP fell 1% in 1954 while it rose 2% in 1956. Instead 1955 was a genuine boom with GNP growing 7%. Insofar as cartels can only sustain either competitive or collusive outcomes, this is what our theory predicts. Indeed, in our model, the competitive outcomes will be observed only in booms.

Porter (1983b) studies the railroad cartel which operated in the 1880's on the Chicago-New York route. He uses time series evidence (as opposed to the cross section evidence of Bresnahan) to show that some months were collusive while others were not. His theory which is developed in Green and Porter (1984) is that the breakdowns from the collusive output ought to occur in periods of unexpectedly low demand. He finds no support for this theory from the residuals of his estimated equations. Instead, we will argue his results support out theory. Table 2 presents the relevant facts. The first three columns are taken from Porter's paper. The first

Table 2

RAILROADS IN THE 1880's

	Estimated Nonadherence	Rail Shipments (Million Bushels)	Fraction Shipped by Rail	Total Grain Production (Billion Tons)	Days Lakes Closed from 4/1 - 12/31
1880	0.00	4.73	22.1	2.70	35
1881	0.44	7.68	50.0	2.05	69
1882	0.21	2.39	13.8	2.69	35
1883	0.00	2.59	26.8	2.62	58
1884	0.40	5.90	34.0	2.98	58
1885	0.67	5.12	48.5	3.00	61
1886	0.06	2.21	17.4	2.83	50

column shows an index of cartel nonadherence estimated by Porter. He shows this index paralells quite closely the discussions in the Railway Review and in the Chicago Tribune which are reported by Ulen (1978). The second column reports rail shipments of wheat from Chicago to New York. The third column shows the percentage of wheat shipped by rail from Chicago relative to the wheat shipped by both lake and rail. The last two columns are from the Chicago Board of Trade Annual Reports. The fourth column presents the national production of grains estimated by the Department of Agriculture. This total is constructed by adding the productions of wheat, corn, rye, oats and barley in tons. This aggregation is not too difficult to justify since the density of different grains is fairly similar. Finally the last column represents the number of days beetween April 1 and December 31 that the Straits of Mackinac remained closed to navigation. (They were always closed beetween January 1 and March 31.) Such closures prevented lake shipments of grain.

As can readily be seen from the table the three years in which the most severe price wars occurred were 1881, 1884 and 1885. Those are also the years in which rail shipments are the largest both in absolute terms and relative to lake shipments. This certainly does not suggest that these wars occurred in periods of depressed demand. However, shipments may have been high only because the railroads were competing even though demand was low. To analyze this possibility we report the values of two natural determinants of demand. The first is the length of time during which the lakes were closed. The longer these lakes remained closed the larger was the demand for rail transport. This is the only demand variable included in Porter's study. The lakes were closed the longest

in 1881 and 1885. These are also the years in which the index of cartel nonadmerence is highest. In 1883 and 1884 the lakes remained closed only slightly less time than in 1885 and yet there were price wars only in 1884. The second natural determinant of demand, total grain production, readily explains the anomalous behaviour of 1883. This was also the year in which the total grain production was the second lowest in the entire period and in particular, was 12% lower than in 1884. This must have depressed demand so much that, in spite of the lake closings, total demand for rail transport was low enough to warrant cooperation. A number of objections can be raised against this interpretation of Porter's facts. First, Porter used weekly data instead of our annual aggregates and it might be thought that weekly data provide a stronger basis for accepting or rejecting our theory. In fact, however, the price wars followed a seasonal time pattern. The first price war started around January 1881 and lasted for the whole year. The second price war started around January 1884 and ended at the end of 1885. We suspect that around midwinter agents could form a fairly accurate prediction of the opening of the lakes by studying the thickness of the ice. If they expected the lakes to be closed for a long period they naturally expected a price war to develop. Once the individual railroads predicted a war for the future they were tempted to cut their prices immediatly for two reasons. First, the penalties for deviating were reduced since in the future the outcome will be competitive in any event. Second, individuals who had the capacity to store grain would postpone shipments if they knew a price war was imminent thus lowering even the monopoly price. The presence of such storage facilities would also seem to make identification of the weekly changes in demand difficult. On the other

hand years with high grain production or with a short lake shipping season will nonetheless be years of high demand.

The second objection to our analysis is that we use aggregate production in the entire United States as our proxy for grain production in the Chicago region. The reason for this is that it is very difficult to define the Chicago region. It clearly includes more than the state of Illinois but less than our proxy. In any event the movements in total production figures represent mostly movements in the production of the grain belt which includes Illinois.

c) Price-cost margins

One natural test of our theory is whether there is substantial price cutting by oligopolists when demand is high. What is difficult about carrying out this test is that prices must be compared to marginal costs and that data on marginal costs at the firm or even at the industry level is notoriously scarce. Traditionally researchers in Industrial Organization have focused on price-cost margins which are given by sales minus payroll and material costs divided by sales. This is a crude approximation to the Lerner Index which has the advantage of being easy to compute. Indeed Scherer cites a number of studies which analyzed the cyclical variability of these margins in different industries. These studies have led to somewhat mixed conclusions. However Scherer concludes on p.357: "The weight of the available statistical evidence suggests that concentrated industries do exhibit somewhat different pricing propensities over time than their atomistic counterparts. They reduce prices (and more importantly) price-cost margins by less in response to a demand slump and increase them by less in the boom phase". This does not fit well with the folklore which would predict that on

average prices would tend to fall more in recessions the more concentrated is the industry. Our theory would explain these facts as follows. It requires that prices fall relative to marginal cost in booms. This is consistent with rising price cost margins as long as some of the expenditure on labor is in fact a fixed cost. This can be seen as follows: Suppose that price and marginal cost are constant and that there are some fixed costs. Then if the labor costs include some fixed costs an increase in output will lower the importance of these fixed costs thus raieing price-cost margins. The key is that price-cost margins rise by less in concentrated industries. So either the fixed costs are less important in the concentrated industries, which seems a priori unlikely, or the concentrated industries tend to reduce prices relative to marginal cost.

We also study some independent evidence on margins. Burda (1984) reports correlations between employment and real product wages in various two digit industriee. These real product wages are given by the average hourly wage paid by the industry divided by the value added deflator for the industry. They can be interpreted as a different crude measure of marginal cost over prices. Their disadvantage over the traditional price-cost margin is that, unlike the latter, they not only require that materials be proportional to output but also that materials costs be simply passed on as they would in a competitive industry with this cost structure. On the other hand, their advantage over the traditional measure ie that they remain valid when some of the payroll expenditure is a fixed cost as long as, at the margin, labor has a constant marginal product. Moreover it turns out that if the marginal product of labor

actually falls as employment rises our evidence provides even stronger support for our theory.

The correlations reported by Burda for the real product wage and employment using detrended yearly data from 1947 to 1978 are reported in Table 3 which also reports the average four firm concentration ratio for each two digit industry. This average is obtained by weighting each four digit SIC code industry within a particular 2 digit SIC code industry by its sales in 1967. These weights were then applied to the 1967 four firm concentration indices for each 4 digit SIC code industry obtained from the Census.[9]

TABLE 3
CONCENTRATION AND THE CORRELATION BEETWEEN REAL WAGES AND EMPLOYMENT

SIC#	INDUSTRY DESIGNATION	CORREL.	CONCEN.
	DURABLES MANUFACTURING		
24	Lumber and wood products	-.33	17.6
25	Furniture and fixtures	-.18	21.6
32	Stone, clay and glass	.39	37.4
33	Primary metals	.32	42.9
34	Fabricated metal industries	.23	29.1
35	Machinery except electrical	.12	36.3
36	Electrical and electronic equipment	.34	45.0
371	Motor vehicles and equipment	.19	80.8
372-9	Other transportation equipment	.02	50.1
38	Instruments and related products	-.36	47.8
	NONDURABLE MANUFACTURING		
20	Food and Kindred products	-.30	34.5
21	Tobacco manufactures	-.64	73.6
22	Textile mill products	.04	34.1
23	Apparel and related products	-.53	19.7
26	Paper and allied products	-.42	31.2
27	Printing and publishing	.40	18.9
28	Chemical and allied products	-.03	49.9
29	Petroleum and coal products	-.48	32.9
30	Rubber	.16	69.1
31	Leather and leather products	-.44	24.5

At first glance it is clear from the table that more concentrated industries like motor vehicles and electrical machinery tend to have positive correlations while less concentrated industries like leather, food and wood products tend to have negative correlations. Statistical testing of this correlation with the concentration index is, however, somewhat delicate. That is because our theory does not predict that an industry which is 5% more concentrated than another will reduce prices more severely in a boom. On the contrary a fully fledged monopoly will always charge the monopoly price which usually increases when demand increases. All our theory says is that as soon as an industry becomes an oligopoly it becomes likely that it will cut prices in booms. Naturally the concentration index is not a perfect measure of whether an industry is an oligopoly. Indeed printing has a low concentration index even though its large components are newspapers, books and magazines which are in fact highly concentrated once location in space or type is taken into account. Nonetheless higher concentration indices are at least indicators of a smaller number of important sellers. Glass is undoubtely a more oligopolistic industry than shoes. So we decided to classify the sample into relatively unconcentrated and relatively concentrated and chose, somewhat arbitrarily, as the dividing line the median concentration of 35.4. This lies between food and nonelectrical machinery. We can then construct the following 2X2 contingency table:

TABLE 4

	Unconcentrated	Concentrated	Total
Negatively correlated	7	3	10
Positively correlated	3	7	10
Total	10	10	20

An alternative table can be obtained by neglecting the three observations whose correlations are effectively zero. These are sectors 22, 28 and 372-9. Their correlations are at most equal in abeolute value to a third of the next lowest correlation. Then the contingency table has, instead of the values 7:3:3:7, the values 7:2:2:6.

It is now natural to test whether concentrated industries have the same ratio of positive correlations to negative ones against the alternative that this ratio is significantly higher. The χ^2 test of independence actually only tests whether the values are unusual under the hypothesis of independence without focusing on our particular alternative. It rejects the hypothesis of independence with 92% confidence using the values of Table 4 and with 97% confidence using the values 7:2:2:6. This test is, however, likely to be flawed for the small sample we consider. Fisher's test would appear more appropiate since it is an exact test against the alternative that more concentrated sectors have more positive correlations. With this test the hypothesis that the ratio of positive correlations is the same can be rejected with 91%

confidence using the data of Table 4 and with 96% confidence using 7:2:2:6.

There is thus a fair amount of evidence for the hypothesis that more concentrated sectors are more likely to have positive correlations. We interpret this by imagining a world in which technology is subject to technological progress at a constant rate and in which capital is accumulated smoothly. The deviations of employment from its trend then occur only in response to increased demand. Then if the firms behave monopolistically the real product wage will tend to fall when demand increases. The same will occur if the firms are competitive and the marginal product of labor falls as employment rises. Particularly when there are diminishing returns to labor the finding that the product wage rises when employment rises suggests the widespread price cutting our theory implies.

There are alternative explanations for our findings, however. The first is that the positive correlations are due to monopolistic pricing in the face of increasing returns to labor in the short run. The existence of such increasing retuns strike us as unlikely. When production is curtailed this is usually done by temporary closings of plants or reductions of hours worked. These reductions would always start with the most inefficient plants and workers thus suggesting at most constant returns to labor in the short run. The second alternative explanation relies on technological shocks. These shocks can, in principle either increase or decrease the demand for labor by a particular sector. If they increase the demand and the sector faces an upwards sloping labor supply function, employment and real wages can both increase. The difficulty with this alternative explanation is that the

sectors with positive correlations do not appear to be those which a casual observer would characterize as having many technological shocks of this type. In particular stone, clay and glass, printing and publishing and rubber appear to be sectors with fairly stagnant technologies. On the other hand instruments and chemicals may well be among those whose technology has been changing the fastest.

V. CONCLUSIONS

This paper basically consists of three parts. The first is a somewhat novel theory of oligopolies in situations in which demand fluctuates. The second is an analysis of the business cycles that such oligopolies can induce, while the third is a study of the plausibility of the idea that oligopolistic industries tend to behave more competitively in booms. Since the data appear consistent with this idea they consitute fairly direct evidence in favor of both our theory of oligopoly and that of business cycles. This suggests that both theories and their empirical validation deserve to be extended.

The theory of oligopoly might be extended to include also imperfectly observable demand shifts, prices and outputs. This type of imperfect observability is the main concern of Green and Porter (1984) who study markets with no observable shifts in demand. The advantage of introducing unobservable shifts in demand is that these can induce reversions to punishing behavior even when all firms are acting collusively. A natural question to ask is whether reversions to punishing behavior that result from unobservable shocks are more likely when everybody expects the demand curve to have shifted out. Unfortunately this appears to be a very difficult question to answer. Even the features of the optimal supergame without observable shocks discussed in Porter (1983a) are hard to characterize. Adding the complication that both the length of the punishment period as well as the price that triggers a reversion depend on observable demand is a

formidable task.

In this paper we considered only business cycles which are due to the tendency of oligopolists to act more competitively when demand shifts towards their products. An alternative and commonly held view is that business cycles are due to changes in aggregate demand which do not get reflected in nominal wages. In that case a decrease in aggregate demand raises real wages thereby reducing all outputs. In our theory of oligopoly, firms tend to collude more in these periods. Hence recessions are not only bad because output is low but also because microeconomic distortions are greater. This suggests that stabilization of output at a high level is desirable because it reduces these distortions.

On the other hand, the business cycles discussed here do not necessarily warrant stabilization policy. While models of real business cycles merely feature ineffective stabilization policies here such policies might actually be harmfull. Booms occur because, occasionally, demand shifts towards oligopolistic products. In these periods the incentive to deviate from the collusive outcome is greatest because the punishment will be felt in periods which, on average have lower demand and hence lower profits. If instead future demand were also known to be high, the threat of losing the monopoly profits in those good periods might well be enough to induce the members of the oligopoly to collude now. So, if demand for the goods produced by oligopolies were stable they might collude always, leaving the economy in a permanent recession.[10] Therefore the merits of stabilization policy hinge crucially on whether business cycles are due to shifts in demand

unaccompanied by nominal rigidities or whether they are due to changes in aggregate demand accompanied by such rigidities. Disentangling the nature of the shifts in the demand faced by oligolopies therefore seems to be a promising line of research.

Much work also remains to be done empirically validating our model itself. In section IV we presented a variety of simple tests capable of discriminating between the Industrial Organization folklore and our theory. Since none of them favored the folklore it may well be without empirical content. On the other hand, our theory deserves to be tested more severely. First a more disagregated study of the cyclical properties of price-cost margins seems warranted. Unfortunately, data on valued added deflators does not appear to exist at a more disagregated level so a different methodology will have to be employed. Second our theory has strong implications for the behaviour of structural models of specific industries. The study of such models ought to shed light on the extent to which observable shifts in demand affect the degree of collusion.

FOOTNOTES

[1]If firms find borrowing difficult, recessions might be the ideal occasions for large established firms to elbow out their smaller competitors.

[2]See, for example, Friedman (1971), Green and Porter (1984) and Radner (1980).

[3]Sequentially rational strategies are analysed in games of incomplete information by Kreps and Wilson (1982). For the game of complete information that we analyse we use Selten's concept of subgame perfection (1965).

[4]In an informal discussion, Kurz (1979) recognizes the link between short-run profitability and the sustainability of collusive outcomes. However, the relationship between profits, demand, and costs is not make explicit.

[5]The argument of K, ε_t^*, in (3) should not be confused with that in (1). The latter represents the realization of the shock at t whereas the former is the state beyond which monopoly becomes unsustainable.

[6]In this case an increase in ε_t can directly be interpreted as either a shift outwards in demand or a reduction in c, that part of marginal cost which is independent of q. This results from the fact that the profit functions depend on ε_t only through $(a+\varepsilon_t-c)$.

[7]The relevant root is the one with the highest profits for the oligopoly.

[8]The intersectoral pattern of output movements can be independent of the sector which has a technological shock if (as seems unlikely) goods are consumed in fixed proportions which depend on the level of utility only. Otherwise "normal" substitution effects will make the expansion biggest in the sector which has the most favorable technological shock.

[9]When constructing these aggregate concentration indices we systematically neglected the 4 digit SIC code industries which ended in 99. These contain miscellaneous or "not classified elsewhere" items whose concentration index does not measure market power in a relatiely homogeneous market.

[10]For the examples in Figures 2 and 3 this occurs as long as $\delta \geq 0.8$ when prize is the strategic variable or $\delta \geq 0.25$ when quantities are the strategic variable.

References

Abraham, G. and F. Katz, "Cyclical Unemployment: Sectoral Shifts or Aggregate Disturbances" Sloan School of Management Working Paper No 1579-84, June 1984.

Abreu, D , "Repeated Games with Discounting: A General Theory and an Application to Oligopoly", Princeton University, December 1982, mimeo.

Bresnahan, T.F., "Competition and Collusion in the American Automobile Industry: The 1955 Price War", February 1981, mimeo.

Burda, M.C., "Dynamic Labor Demand Schedules Reconsidered: A Sectoral Approach", June 1984, mimeo.

Friedman, J.W., "A Non-Cooperative Equilibrium for Supergames," Review of Economic Studies, 28(1971), 1-12.

Green, E.J. and R.H. Porter, "Noncooperative Collusion Under Imperfect Price Information", Econometrica, 52 (January 1984), 87-100.

Grossman, S.J., O.D. Hart, and E. S. Maskin, "Unemployment with Observable Aggregate Shocks", Journal of Political Economy, 91 (December 1983) 907-28.

Lilien, D.M., "Sectoral Shifts and Cyclic Unemployment", Journal of Political Economy, 90 (August 1982), 777-93.

Long, J.B. Jr. and C.I. Plosser, "Real Business Cycles" Journal of Political Economy, 91 (February 1983), 39-69.

Kreps, D. and R. Wilson, "Sequential Equilibrium", Econometrica, 50(1982), 863-894.

King, R.G. and C.I. Plosser, "Money, Credit and Prices in a Real Business Cycle", American Economic Review 74 (June 1984), 363-80.

Kurz, M., "A Strategic Theory of Inflation", IMSSS Technical Report No. 283, April 1979.

Markham, J.W., Competition in the Rayon Industry, Harvard University Press, Cambridge, 1952.

Porter, R.H., "Optimal Cartel Trigger-Price Strategies", Journal of Economic Theory, 29(1983a), 313-338.

Porter, R.H., "A Study of Cartel Stability: The Joint Economic Committee, 1880-1886", The Bell Journal of Economics, 14 (Autumn 1983b), 301-14.

Radner, R. "Collusive Behavior in Noncooperative Epsilon-Equilibria of Oligopolies with Long but Finite Lives", Journal of Economic Theory, 22(1980), 136-154.

Rotemberg, J.J., "Sticky Prices in the United States", Journal of Political Economy, 90 (December 1982), 1187-211.

Scherer, F.M., Industrial Market Structure and Economic Performance (2nd Ed.) Houghton-Mifflin, Boston, 1980.

Selten, R., "Spieltheoretische Behandlung eines Oligopolsmodells mit Nachfragetragheit", Zeitschrift für die Gesante Staatswissenschaft, 121(1965), 301-324 and 667-689.

Stigler, G.J. "A Theory of Oligopoly", Journal of Political Economy, 72 (February 1964), 44-61.

Ulen, T.S., Cartele and Regulation, unpublished PH.D. Dissertation, Stanford University, 1978.