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The Relative Rigidity of Monopoly Pricing

By JULIO J. ROTEMBERG AND GARTH SALONER*

This paper examines why monopolies change their nominal prices less often than do tight oligopolies. We show that cost (demand) changes create a larger incentive for duopolists (monopolists) to change their prices. When both costs and demand are affected by small changes in the overall price level, the cost effect dominates. In the presence of a small, fixed cost of changing prices, therefore, duopolists change their prices in response to smaller perturbations in underlying conditions.

The relationship between industry structure and pricing is a major focus of industrial organization. One of the most striking facts to have emerged about this relationship is that monopolies tend to change their prices less frequently than tight oligopolies. Although the first evidence in this regard was presented by George Stigler (1947) almost 40 years ago, no theoretical explanations have been offered. The objective of this paper is to develop a model capable of explaining these facts.

Stigler's objective in comparing the relative rigidity of monopoly and duopoly prices was to test the kinked demand curve theory of R.L. Hall and C.J. Hitch (1939) and Paul Sweezy (1939). Since the work of Gardiner Means (1935) seemed to show that concentrated industries exhibited greater price rigidity than their unconcentrated counterparts, the kinked demand curve was developed and embraced as providing a theoretical foundation for the rigidity of prices. It was widely regarded to be an implication of that theory that duopolists would not change their prices in response to small changes in their costs.¹

Stigler's test (1947) was a direct and simple test of the rigidity of oligopoly prices. Instead of comparing oligopoly pricing with pricing in unconcentrated industries, he simply compared the relative rigidity of monopoly and oligopoly prices. If it is the kink that leads to inflexible oligopoly prices, monopolists should have more flexible prices since monopolists do not face a kinked demand curve. Stigler found instead that monopolist's prices were even more rigid. Several later empirical studies have supported his original finding: monopolists change their prices less frequently than do oligopolists. This finding throws into question any theory in which prices are rigid only because individual oligopolists fear "upsetting the applecart."

In his study, Stigler tabulated the number of price changes for two monopolistically supplied commodities (aluminum and nickel) and 19 products, which were each supplied by a small number of firms. The source of the data on price changes was the Bureau of Labor Statistics (BLS) bulletins, *Wholesale Prices*, for the period June 1929–May 1937. The price of nickel did not change at all over this period and there were only two price changes for aluminum. Among the oligopolistically supplied products, however, only one had fewer than four price changes (sulfur) and half had more than 10 price changes.

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¹This view was emphasized by Martin Bronfenbrenner (1940), for example. It is now well recognized, however, that the kinked demand curve implies multiple

equilibria. When cost conditions change, one might well expect the equilibrium to change as well. It is only if the current price is somehow "focal" that the price will not change.

The finding has been replicated on other price data for different periods. Julian Simon (1969) studied advertising rates of business magazines from 1955 to 1964. Simon's data have the advantage that they contain the price series for each publication rather than simply an index of the industry price, as is the case for the BLS data. Simon finds that the larger the number of competitors a firm has, the higher the number of years in which it changes its price.

Walter Primeaux and Mark Bomball (1974) compare pricing of electric power when it is supplied by a duopoly versus a monopoly.² Their data cover 17 duopolies and 22 monopolies from 1959 to 1970. One advantage of their study is that there is no product differentiation in electric power, so that there is no danger of misspecifying the firms' competitors. Also, list prices are transactions prices since deviations from printed schedules are illegal for public utilities. They show that when there are two firms in the market they each change their prices more often than a corresponding monopolist. This is true for all levels of power usage. The effect is more pronounced for lower levels of power usage, where the duopolists changed their prices two or three times more frequently than it is for higher-power usages where they changed their prices roughly one-and-a-half times as often.

Finally, Primeaux and Mickey Smith (1976) study the pricing of 88 major drugs during the period 1963–73. For their sample they are unable to reject the hypothesis that oligopolists and monopolists have the same frequency of price changes.

These studies suggest that monopolists generally change their prices less frequently than oligopolists. The explanation that we offer for this phenomenon is based on the

relative incentives of monopolists and oligopolists to adjust their prices when underlying cost and demand conditions change or when inflation erodes existing prices. We focus on the comparison between duopoly and monopoly and show that whether the products of the duopoly are homogeneous or differentiated, the duopolists have a greater incentive to change their prices than does a monopolist, facing the same configuration of demand. So, if there are other forces leading to price rigidity that are of roughly comparable magnitudes across industry structures, there will be a general tendency for duopoly prices to change more frequently. The particular reason why prices may be unresponsive to changes in underlying conditions that we focus on is that there may be a fixed cost of changing prices. This idea was first put forward by Robert Barro (1972) and has been used by Eytan Sheshinski and Yoram Weiss (1977, 1985), Julio Rotemberg (1983), and Gregory Mankiw (1985), among others. These costs are usually taken to include the physical costs of changing and disseminating price lists and the possibility of upsetting customers with frequent price changes. In the electric utility industry they also capture the costs of obtaining permission from regulatory authorities to change tariffs.

If it is costly for firms to change their prices, the question then is how the gains to the firms of changing their prices compare with the costs and, more importantly, how the gains differ across market structures. To see why duopolists in general have a greater incentive to change prices in response to costs changes, consider the following simple case. Suppose that two firms competing in Bertrand style and charging price equal to constant marginal costs unexpectedly discover that costs have increased. If neither firm increases its price, the firms share the loss of supplying the entire market demand at a price below costs. Each firm obviously has a large incentive to change its prices. Furthermore, if either firm believes its rival will change its price, then it has an even greater incentive to raise its own price in order to avoid suffering the entire loss itself. Put differently, when a firm changes its own price

²The duopoly cases were situations in which a municipally owned electric utility and a privately owned firm competed directly. Each firm had its own electricity generation facility, and customers had the choice of which firm they wished to be served by. In some cases, customers could switch from one company to the other at will; in other cases, new customers had a choice of supplier but once they had made a choice, it was not possible to switch suppliers.

it imposes a negative externality on its rival: it increases the amount that the firm must sell at the "wrong" price.

A similar phenomenon arises for cost decreases. In that case there is no incentive for the firms to make a combined price decrease. However, there are substantial incentives for either firm to make a unilateral price decrease to undercut the rival. Here again there is an externality: the deviating firm's gain is made at the rival's expense.

A monopolist's profits are differentiable in its price. Therefore, as George Akerlof and Janet Yellen (1985) show, the loss in profits from not changing its price is second order. Since the duopolist's incentives to change price are first order, if they face comparable costs of changing prices, the duopolists would change price more frequently in response to a cost change than a monopolist would.

The reverse is true for changes in demand. Since Bertrand competitors set price equal to marginal cost, they have no incentive to change price in response to a shift in demand. A monopolist, of course, does have an incentive to change price in these circumstances.

When oligopolists produce differentiated products, individual firms' profits are again differentiable in their own prices and the Akerlof-Yellen argument still applies. One might believe, therefore, that the result that monopolists change their prices less frequently than duopolists in response to a cost change would not hold true in the case of differentiated products. In fact it does. The reason has to do with the externalities discussed above.

Consider duopolists producing differentiated products and, as above, suppose that costs increase slightly. Now if one firm raises its price slightly, it no longer yields all of its customers to its rival. Profits are no longer discontinuous at the point of equal prices. However, it does lose some of its customers to its rival, and if the degree of substitutability is high, it loses them at a rapid rate. In other words, the externality that the duopolist inflicts on its rival is increasing in the degree of substitutability between the products. Thus, the increase in profits from

adjusting its price may be large. A monopolist, on the other hand, is able to internalize these externalities. For purposes of comparison, suppose that the monopolist offers both products. Now when it changes the price of either product it bears the full consequences: both the change in profits of the product whose price is changed and that of the product whose price is unchanged. Whereas the duopolists each have an incentive to change price in order to make a gain at the other's expense, the monopolist has no such incentive.

Thus even in the case of differentiated products, provided the degree of substitutability between the products is great enough, duopolists have a greater incentive to change their prices in response to a change in costs than a monopolist does. The incentive to change price in response to a change in demand, however, is greater for the monopolist. In order to see which effect is likely to dominate in practice, we examine the situation when both costs and demand are affected by overall changes in the price level. We find that for small changes in the price level, the cost effect dominates the demand effect and so duopolists have a greater incentive to change their prices than a monopolist does. Thus in the presence of fixed costs of changing prices the monopolist may adjust prices more sluggishly.

In Section I we develop intuition for our result via a homogeneous goods example. This model is generalized to differentiated products and an inflationary environment in Section II. We conclude with Section III.

I. A Model with Homogeneous Products

Throughout the paper we assume that duopolists treat prices as their strategic variables. This seems natural given that we focus on whether firms change their prices or not. In this section, in order to demonstrate how the incentives for a monopoly to change prices differ from those of a duopoly, we begin with a very simple model. In particular, we will assume that the duopolists produce a homogeneous good with constant (and equal) marginal costs. As we shall see below,

this formulation is useful for expository purposes since the incentives for changing prices are most apparent when the model is stripped down in this way.

Unfortunately, we will also see that this formulation is too stark in the sense that duopolists earn zero-profits gross of any fixed costs. Thus, if they must bear any such costs, their participation becomes unprofitable. However, any number of modifications in the direction of realism (such as differentiated products or increasing marginal costs) would provide the firms with sufficient profits to cover small fixed costs. We begin with the simplest model to develop the intuition for the result. We later consider product differentiation where the existence of profits guarantees the willingness of the firms to participate as long as costs of changing prices are small.

Time is divided into two "periods" by an unexpected increase in the firms' constant marginal costs of production from c_1 to c_2 . We will refer to the periods before and after the cost change as periods 1 and 2, respectively. Industry demand is given by $q = a - bP$, $a/b > c_2$, where P is the lowest price charged. Since the duopolists compete in Bertrand style $P_1^1 = P_1^2 = c_1$ (subscripts denote periods and the firm is indexed by the superscript). The monopolist, on the other hand, charges $P_1^m = (a + bc_1)/2b$ and sells $(a - bc_1)/2$.

We explore how the change in costs affects prices. We consider what happens when the new level of marginal costs, c_2 , is known to both firms before they select their period 2 prices, but where each firm must incur a fixed cost, f , to change its price.

If the monopolist leaves its price unchanged at P_1^m , it sells $(a - bc_1)/2$ and earns $\{(a + bc_1)/2b - c_2\}\{(a - bc_1)/2\}$. If, on the other hand, it changes its price, it earns $(a - bc_2)^2/4b - f$. It is therefore worthwhile for it to change its price if and only if

$$(1) \quad \frac{b(c_2 - c_1)^2}{4} > f.$$

Now consider a duopolist. The amount demanded at $P = c_1$ is $q_1 = a - bc_1$. Suppose

that firm 2 does not change its price. If firm 1 does not change its price either, the firms share the loss of $q_1(c_2 - c_1)$, that is, they each lose $(a - bc_1)(c_2 - c_1)/2$. What happens if firm 1 increases its price? To do so it must incur the cost, f . It then loses all its sales to firm 2. Thus firm 1 loses f if it raises its own price and firm 2 keeps its price unchanged. So, in this case, firm 1 prefers to change its price if

$$(2) \quad (a - bc_1)(c_2 - c_1)/2 > f.$$

Now consider what happens if firm 2 increases its price to c_2 . Now firm 1 loses $(a - bc_1)(c_2 - c_1)$ if it maintains its period 1 price (since it now bears the entire loss itself). On the other hand, it loses only f if it joins firm 2 in the price increase to c_2 . Thus it prefers to raise its price if

$$(3) \quad (a - bc_1)(c_2 - c_1) > f.$$

Equation (2) implies equation (3). Thus if (2) holds, changing price is a dominant strategy and the unique equilibrium involves both firms changing price. If (3) holds but (2) does not, each firm is willing to change its price only if the other also does. There are then two pure strategy equilibria: one in which the firms both change their prices and one in which neither does. Finally, if (3) does not hold, then the unique equilibrium is that neither firm changes its price.

Now compare the relative incentives for the duopoly and the monopoly to change prices. To make the comparison unfavorable to frequent price changes by the duopoly, we concentrate on the case in which changing price is the unique equilibrium. Then the duopoly changes prices if (2) holds while the monopoly changes prices if (1) holds. Since $a/b > (c_1 + c_2)/2$ by assumption, if (1) holds then (2) holds as well. Thus the duopolists would always change the price if the monopolist would. Moreover, if $(a - bc_1) > 2f/(c_2 - c_1) > b(c_2 - c_1)/2$, then (2) holds but (1) does not, so that, for parameters in this range, the duopolists would change their prices whereas the monopolist would not.

The intuition for these results is clear from Figure 1, which illustrates the effect of a cost increase. The profit for a monopolist who sets the optimal price for costs c_2 is given by the integral of marginal revenue minus marginal costs evaluated at q_2^m . This is equal to the shaded area in Figure 1. If the monopolist does not change its price (so that it sells q_1^m), it earns the profits it would earn if its costs were actually c_1 (the area ac_1z) minus $(c_2 - c_1) q_1^m = c_1c_2yz$. The loss from not changing its price is therefore the cross-hatched triangle

$$(4) \quad xyz = (c_2 - c_1)(q_1^m - q_2^m)/2 \\ = b(c_2 - c_1)^2/4.$$

The monopolist is willing to change its price if this area exceeds f .

Now consider the duopolists. If firm 1 believes that firm 2 will not change its price, firm 1 can raise its price to c_2 and earn zero (less the fixed cost f). On the other hand, if it does not change its price, it shares the industry loss of c_1c_2vw . Clearly, $(c_1c_2vw)/2$ always exceeds (xyz) . Thus the duopolist always has a greater incentive to increase its price.³

From Figure 1 we can see that the greater incentive for the duopolist to change its price does not hinge on the linearity of demand. For an arbitrary demand function and its corresponding marginal revenue function, the relevant question is how the area corresponding to the crosshatched area xyz compares with the corresponding $(c_2c_1vw)/2$.

Notice that $(q_1^m - q_2^m)(c_2 - c_1)$ is an upper bound for the area xyz and the area $(c_2c_1vw)/2$ is equal to $q_1^c(c_2 - c_1)/2$, where q_1^c is the duopoly output in period 1. Therefore the area xyz is less than $(c_2c_1vw)/2$ if $q_1^m - q_2^m < q_1^c/2$, that is, if $q_1^c > 2(q_1^m - q_2^m)$.

³ This result should not be taken to mean that duopolists have a larger incentive to respond to changes in costs whatever the form of their strategic interaction. For instance, if Cournot duopolists with linear demand and constant marginal costs face an increase in these costs, each firm's loss from not adjusting its quantity exactly equals the corresponding loss for a monopolist.

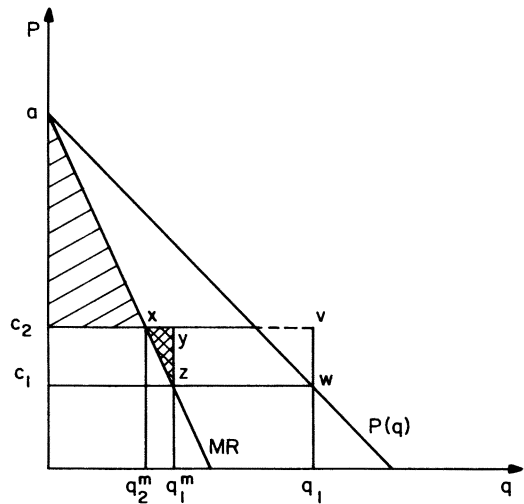


FIGURE 1. THE EFFECT OF A COST INCREASE FROM c_1 TO c_2 .

Since $q_1^c > q_1^m$ (the duopoly output is at least as great as the monopoly output), a sufficient condition for this is $q_1^m > 2(q_1^m - q_2^m)$ or $q_2^m > q_1^m/2$. This condition holds for small changes in costs. In particular, it is satisfied unless the change in costs is so large that the optimal monopoly output is halved. Since it seems unlikely that a monopolist would prefer to halve its output at the current price in preference to changing the price, the result is quite general.

In some sense the result of this section is not surprising since, as Akerlof-Yellen argue, the cost from not changing one's price is of second order in the change in costs only if the profit function is differentiable with respect to price. For Bertrand duopolies the profit function is not differentiable, and indeed (2) is of first order in the change in costs while (1) is of second order. However, if we let the duopoly produce differentiated products, the profit functions become differentiable and both losses are of second order. Yet we show in the following section that as the two goods become better and better substitutes, the analysis in this section becomes more relevant.

It is important to note that while Bertrand duopolists respond more to changes in costs,

they respond less to changes in demand. With constant marginal costs the duopoly never changes its price when demand changes. On the other hand, apart from the exceptional case where the elasticity of demand is unaffected, the monopolist loses by not changing its price in response to a change in demand.

The analysis presented in this section has two shortcomings. First, the duopolists lose money in equilibrium. If they do not change their prices, the new equilibrium has $P_2 = c_2$, but they must incur the fixed cost of changing their prices. If they do not change their prices, they sell at a price less than marginal cost.

Second, the analysis does not carry over to the case of a cost decrease. In that case the new Bertrand equilibrium has $P_2 = c_2$. However, if each firm changed its price to that level it would lose f . Thus one firm can do better by not changing its price, selling nothing, and earning zero profits. It is therefore not a Nash equilibrium for both firms to decrease their prices to c_2 . However, it is also not a Nash equilibrium for neither firm to change its price since one firm could profitably deviate by undercutting the price $P_1 = c_1$ slightly. The only equilibrium involves mixed strategies.⁴

Both of these shortcomings are due to the zero-profit nature of Bertrand competition. We show in Section II that if one allows for some degree of product differentiation, these problems disappear. Although the incentive for a duopolist to change its price is somewhat dampened with differentiated products

since demand is less responsive to price differences, we show that duopolists may nonetheless change their prices more frequently than monopolists.

II. A Model with Differentiated Products

In Section I we showed that cost changes and demand changes have differing effects on the incentives of duopolists and monopolists to change their prices. Both costs and demand are affected when overall prices move, and it is such movements that are probably the main reason for price changes in the studies mentioned in the introductory section. Therefore, in this section, our focus is on the effects of changes in the overall price level.

We consider an industry in which two goods are produced. The demand for goods 1 and 2 is given by

$$(5) \quad q_1^1 = a/2 - (b/2 + d)P_t^1/S_t + dP_t^2/S_t \\ q_2^2 = a/2 - (b/2 + d)P_t^2/S_t + dP_t^1/S_t,$$

where a , b , and d are positive constants, S is the general price level, and $t=1$ or 2 denotes the period. As can be seen from equation (5), the two goods are symmetric and d is a measure of their substitutability. The goods can be produced at constant marginal cost $S_t c$. Note that increases in S do not just raise costs, but also increase the quantity demanded at any price. This occurs because any given price now represents a smaller amount of real purchasing power. Therefore, profits deflated by S_t from producing good 1, π_t^1 are given by

$$(6) \quad \pi_t^1 = [a/2 - (b/2 + d)P_t^1/S_t + dP_t^2/S_t] \\ \times (P_t^1/S_t - c),$$

and similarly for good 2.

If the firms simultaneously choose prices and behave noncooperatively, firm 1 chooses P_t^1 to maximize (6). The first-order condition is

$$(7) \quad P_t^1 = dP_t^2/(b + 2d) + aS_t/(2b + 4d) \\ + cS_t/2.$$

⁴The symmetric mixed strategies are straightforward to calculate. Suppose each firm charges a price in excess of P with probability $F(P)$. If a firm lowers its price to P , it has the lowest price with probability $F(P)$ (the probability that its rival has a higher price). Therefore, a firm that lowers its price to P earns $(P - c_2)q(P)F(P) - f$. In equilibrium the firm must be indifferent between lowering its price to P and leaving it unchanged. This implies that $F(P) = f/(P - c_2)q(P) = f/(P - c_2)(a - bP)$ in the linear case. The mixed strategy involves not changing the price with positive probability and has no other mass points. The lowest price charged is that in which the firm earns f if it is the only firm charging that price.

The Nash equilibrium prices in period 1 if the firms expect S_1 to be equal to S_2 are then

$$P_1^1 = P_1^2 = [a + c(b + 2d)]S_1/2(b + d).$$

It is useful to rewrite (6) as

$$(8) \quad \pi_i^1 = -(b/2 + d)[P_i^1 - dP_i^2/(b + 2d) - aS_i/(2b + 4d) - cS_i/2]^2/S_i^2 + (b/2 + d)[dP_i^2/S_i(b + 2d) + a/(2b + 4d) - c/2]^2.$$

Equation (8) decomposes π_i^1 into a term incorporating the first-order condition (7), and a term that is independent of P_i^1 . Now suppose that S changes unexpectedly from S_1 to S_2 . We then ask how big this change in S has to be in order to induce the firms to change their prices in the presence of a fixed cost to changing prices, f .

We first calculate the increase in firm 1's profits from changing its price from P_1^1 to P_2^1 , assuming that firm 2 does not change its price ($P_2^2 = P_1^2$). We will show shortly that this gives a lower bound on the increase in firm 1's profits from changing its price. Notice that the second line of (8) is the same regardless of the price that firm 1 charges. The change in firm 1's profit if it changes its price is therefore

$$(9) \quad \Delta\pi^1 = -(b/2 + d)[P_2^1 - dP_2^2/(b + 2d) - aS_2/(2b + 4d) - cS_2/2]^2/S_2^2 + (b/2 + d)[P_1^1 - dP_2^2/(b + 2d) - aS_2/(2b + 4d) - cS_2/2]^2/S_2^2.$$

But notice that P_2^1 will be set equal to the price that maximizes π_1^1 given that firm 2 is setting P_2^2 . Using (7), the first term is equal to zero. Thus we have

$$(10) \quad \Delta\pi^1 = (b/2 + d)[P_1^1 - dP_2^2/(b + 2d) - aS_2/(2b + 4d) - cS_2/2]^2/S_2^2.$$

Using (7) and rearranging this gives

$$(11) \quad \Delta\pi^1 = (b/2 + d)(\Delta S)^2/S_2 \times [a/(b + 2d) + c]^2/4,$$

where ΔS is $S_1 - S_2$.

It is immediate from (10) that (11) gives a lower bound to the change in firm 1's profits from changing its price. This can be seen by noting that increases (decreases) in firm 2's price tend to increase (decrease) S when S increases (decreases). (To see this, notice that if $P_1^2 = P_2^2$, then $P_1^1 = dP_2^2/(b + 2d) + aS_1/(2b + 4d) + cS_1/2$. If S increases, the right-hand side of this expression exceeds P_1^1 . This difference is even greater if P_2^2 exceeds P_1^2 . Similarly, if S decreases, the right-hand side is less than P_1^1 . The difference between the left- and right-hand sides is then even greater if P_2^2 is less than P_1^2 .) Thus when (11) exceeds f , a duopolist will always change its price.

Compare this with the situation for a monopolist who sells both products. To bias the argument against our case, we suppose that the monopolist can change both of its prices if it incurs the cost f . Algebra analogous to that above yields the result that the increase in a monopolist's profits from changing its price is

$$(12) \quad \frac{(\Delta S)^2}{S_2} \frac{b(a/b + c)^2}{4}.$$

The difference between (12) and (11), the monopolist's and duopolist's incentives to change price, is proportional to

$$(13) \quad b(a/b + c)^2 - (b/2 + d) \times (a/(b + 2d) + c)^2.$$

The derivative of (13) with respect to d is

$$[a/(b + 2d)]^2 - c^2,$$

which is negative for d bigger than $(a - bc)/2c$. As d increases this derivative converges to the constant $-c^2$ so that, for d

sufficiently big, (11) exceeds (12) and duopolists change their prices in response to a smaller change in S . If one considers the example in which a equals 10, c equals 5, and b equals 1, then if d exceeds 7, there exists a change in the price level such that duopolists will change their prices whereas the monopolist will not.

The above analysis assumes that if only one of the firms (say firm 2) changes its price, that both firms nonetheless sell non-negative quantities. However, it is clear from (5) that if $P_i^2 > P_i^1$, and d is sufficiently large, then q_i^2 can become negative. Substituting (7) into the second equation in (5), one can see that this problem does not arise for ΔS sufficiently small. If the increase in S is sufficiently small, firm 2 will still wish to produce a positive output at its best response to firm 1's "old" price. This is equivalent to a requirement that f not be "too large." As a numerical example, for the case in which $a = 10$, $c = 5$, and $b = 1$, if f is less than 10 percent of a duopolist's period 1 profits, this problem of being driven to a "corner" does not arise as long as $d < 90$.

We now turn to an interpretation of these results. An increase in S has two effects: it raises demand and costs at the current price. The simplified model of Section I provides the intuition for why the duopolists have a greater incentive to change their prices in response to a cost change. A monopolist that changes the prices of both products together (so that $P_i^1 = P_i^2$) faces aggregate demand with (negative) slope b as in the previous section. Referring back to Figure 1, the gain to changing price is thus given by the area xyz . The individual duopolist, on the other hand, faces demand with slope $b/2 + d$. As a consequence, the marginal revenue curve is flatter if $d > b/2$ and in that case the area corresponding to xyz is larger for the duopolist.

On the other hand, duopolists are less affected by the change in demand. If d is zero, each duopolist faces the same incentives in its market as a monopolist would. If the monopolist can change both of its prices by paying f , it will change its prices in response to a smaller change in demand. Moreover, as d increases the duopolist be-

comes even less concerned, until with $d = \infty$ demand stops mattering. This is because the duopolists face more elastic perceived demand curves. They are therefore less able to exploit increases in demand and, consequently, have less incentive to increase price.

It remains to explain why the cost effect dominates the demand effect (locally) when d is large. The reason is that, although second order, a small change in one duopolist's price can have a very large effect on the outputs (and hence the profits) of both duopolists if d is sufficiently large. Thus, if an arbitrarily small increase in S induces firm 1 to raise its price an arbitrarily small amount, firm 1 loses a large proportion of its sales to firm 2. It is the presence of this externality that makes the effect of a cost change for a duopolist qualitatively different from a demand change for a monopolist.⁵

III. Conclusions

In an industry subject to fluctuations in the firms' costs, it is more costly for each member of a tight oligopoly to keep its price constant than it is for a monopolist. The reverse is true for fluctuations in demand. When both costs and demand are subject to

⁵These results are broadly consistent with the simulations of Akerlof-Yellen (1985) and Olivier Blanchard and Nobuhiro Kiyotaki (1985). They compute the lost profit from keeping prices unchanged as a fraction of profits in the former case and as a fraction of revenues in the latter. Both show that in response to a small increase in the money supply that these fractions are higher, the higher is the elasticity of the demand facing firms. This is consistent with our paper insofar as our results also depend on duopolists having flatter perceived demand curves than monopolists. Yet this apparent similarity masks some important differences. First, comparing only the elasticity of demand across firms does not take into account that monopolists are different from individual oligopolists both in that they are larger and are subject to fewer strategic interactions. Second, insofar as monopolists have higher profits (or revenues) than oligopolists, considering only such ratios tends to make monopolists automatically appear to view fixed prices as less onerous. Finally, their simulations do not place firms in contexts in which general inflation (or, as in the 1930's, deflation) affects costs together with demand.

inflationary or deflationary shocks, the cost effect dominates. As a result, in the two period models we present, circumstances that lead a monopolist to change its prices would always encourage duopolists to do so as well, while the reverse is not true. In this conclusion, we point out a few caveats and possible extensions of the analysis.

First, our analysis has been concerned exclusively with the monopoly–duopoly comparison. Yet, Dennis Carlton (1986) as well as Stigler suggest that price rigidity is monotonic in concentration so that duopolies change their prices less often than three firm oligopolies and so on. The analysis of this paper can probably be extended to cover these cases as well. What was crucial in our analysis is that perceived demand curves become flatter as there are more competitors. This makes price changes more attractive because some of the benefits derive at the expense of competitors. Insofar as oligopolists with many competitors can reasonably be thought to have perceived demand curves that are more elastic (because there are better substitutes produced by competitors, for instance), they will change their prices more frequently.

Second, our analysis of the actual frequency of price adjustment applies strictly only in our two-period setting. An extension to a more general dynamic setting thus seems desirable. In some sense this extension should be straightforward; as the incentives for changing prices are bigger for oligopolies, we should observe them changing their prices more often. Unfortunately, when considering dynamic games between duopolists one must allow the strategies of the firms to depend on the history of their relationship. This considerably complicates the analysis. In particular, since price changes may precipitate price wars, there may be equilibria in which duopolies are reluctant to change their prices.⁶

Finally, the incentives to change price that firms face in this paper in response to exoge-

nous changes in costs and demand, are related to the incentives that firms have to endogenously change costs and demand through innovation. Innovation on the cost and demand side corresponds to process and product innovation, respectively. To the extent that a product innovation cannot be appropriated by an individual firm but rather leads to a general change in industry demand, our model suggests that monopolists have a greater incentive to pursue such product improvements. With respect to process innovations, however, two effects operate to make the incentives for innovation greater for duopolists. First, as Kenneth Arrow (1962) has pointed out, such an innovation may be worth more in a competitive industry simply because of its greater output. Second, as our model suggests, each duopolist's fear that its rival will gain an advantage by innovating alone, provides a great incentive for each duopolist to innovate.

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