Durable-Goods Monopolists

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Durable-goods monopolists face special problems because the sale of their products creates a secondhand market not controlled by the monopolist. To the extent the monopolist is able to rent his product rather than sell it, or to make binding promises about his future production, such problems are ameliorated. Given the inability to do the above, the monopolist is led to producing goods less durable than those produced by either competitive firms or monopolist renters. A reverse Averch-Johnson result—that monopolist sellers may invest less in fixed costs (including plant modernization and research and development) than would the renters—is shown. It is also shown that, even though sellers have less monopoly power than renters and nondurable-goods monopolists, it is possible that the seller will cause a greater deadweight loss than the other types of monopolies.

Introduction

This paper explains the special type of monopoly power held by a firm that is a monopolist in the production and sale of a durable good. This power can be substantial but is notably less than the power held by a monopolist who produces a durable good which is rented rather than sold.

The distinction of the renter and the seller is what makes durable-goods monopolists interesting. When such a monopolist can rent, he

The author would like to thank Ben Bernanke, Ralph Braid, Stanley Fischer, David Garvin, Jay Helms, Eric Maskin, John Shoven, Robert Solow, and members of the Sloan Finance Seminar for reading earlier drafts of this paper and providing valuable comments. Also John Geanakoplos, David Kreps, Robert Wilson, and an anonymous referee for more recent help. The support of the Alfred P. Sloan Foundation is gratefully acknowledged.

[*Journal of Political Economy*, 1982, vol. 90, no. 2]

can achieve all the standard results of the nondurable monopolist.[1] Selling is a much more difficult problem, involving an important incompleteness of contracts and an expectational problem.

Coase (1972) brought the durable-goods monopoly problem to attention in an interesting paper.[2] Assume the seller cannot sign contracts limiting his future production. Then, upon his sale of a unit, the best thing for him to do seems to be to try to sell another unit at as high a price as he can get. Seemingly, this should go on until price equals marginal cost. Now suppose that very little time is needed to transact. Then intelligent consumers, assuming the price will soon fall to the competitive level, will be unwilling to pay more than the competitive price for the early units. It is possible that the monopolist can lose complete control of the situation and forfeit all his monopoly power.

For some products there may be a very simple way to convince buyers that future production will be limited. The simplest case is the artist who makes a lithograph and destroys the plates. In other markets, the seller may be able to create contracts that make his position mathematically equivalent to that of a renter. (That is, the producer remains responsible for any changes in the good's asset value.) However, there are many markets where renting or its mathematical equivalent is not feasible.

For example, durable intermediate products must be sold and not rented. When steel was first produced and began replacing iron for railroad tracks, it would have been impractical for the steel companies to rent the steel bars. What would have happened if, in year two, a rental price could not be agreed upon? It would have been possible to sign a long-term rental agreement, but for the purposes of this model such a contract is similar to an outright sale. Only a complicated, "floating-rate" rental contract, with rental price tied by formula to market prices, could replace the outright sale. Such contracts may be very costly to write. Repurchase agreements may also not be feasible for, say, designer clothing. Along the same lines, a consumer of diamonds may wish to cut and mount a stone. Since such a change is irreversible, a sale may be the only kind of arrangement which will allow for alteration of the stone.

A more compelling example involves products such as automobiles. While a rental market exists, few people will rent on a month-to-

[1] Those results have been best developed in Swan (1970*a*, 1970*b*, 1971, 1972, and 1977) and Sieper and Swan (1973).

[2] Another very good paper which discussed similar issues is Gaskins (1974), recently criticized by Swan (1980). Douglas and Goldman (1969) made an even earlier effort in this area, but their consumers were consistently fooled. For a comprehensive survey of the literature on durable-goods monopolists, see Schmalensee (1979).

month basis rather than buy. A significant factor is that people who rent cars may not find it in their interests to be as careful with them as owners are. This is because it may be extremely costly to measure the damage caused by an individual renter. Thus, we will argue that because the producer controls the supply side of the market he determines the general price level of the product. However, in many markets the user's behavior may have the more significant impact on the market value of a given individual unit. In such a market it may make more sense for the purchaser to be responsible for changes in unit value than for the producer to maintain ownership.

Finally, it must be noted that for the purposes of this paper "durable good" can be broadly defined. Of course, all products that yield a flow of services to the owner over a significant period of time may be included. However, other products whose current demand depends on previous consumption may also qualify. A ticket to a first-run movie has the durable quality that once someone has seen the film that person is unlikely to buy a second ticket. Thus, the movie company will find the demand for tickets on any rerelease of the film to be negatively related (ceteris paribus) to the number of viewers who saw the film when it first came out. Similarly, the expectation that a viewing will be available at a cheaper price on a second run affects demand for the first-run film. (The market for hardcovers and paperbacks works this way also.) It is quite clearly impractical for firms to sell first-run movie tickets and give viewers a right to get some money back if the film is ever rereleased with lower ticket sales prices.

This paper will show that often the seller can devise a production strategy that will make it better off than the competitive firm, though not nearly as well off as the renter. The crucial difference between the seller and the renter is that if a renter "overproduces" he suffers the capital loss on old units; thus, the costs of production are internalized. If a seller overproduces, the losses are suffered by old purchasers in whose welfare the seller has no direct interest. The loss is not internalized, and the firm will end up overproducing relative to the renter. Naturally, the intelligent buyers will foresee any incentives for overproduction and will factor those incentives into determining the price they will pay for a unit at any given time. Thus, it is the monopolist rather than his customers who must pay for this lack of complete contracts, for this inability to internalize the effects of overproduction.

In minimizing the effect of this incompleteness, the seller finds it in his interest to behave in a substantially different manner than either a renter or a competitive firm. The seller must find ways to make precommitments about production. Discrete-time models, of course, embody a certain amount of precommitment: You decide how much to produce and then produce no more until one period later. Sometimes a form of precommitment can be purchased by the firm at the price of producing a less durable product, running a high marginal-cost operation, or restricting capacity. Such induced behavior on the part of the seller produces the following results:

1. An almost perfect analogy can be drawn between the renter and the conventional nondurable-goods monopolist.
2. Sellers may choose to produce using an "inefficient" production technology. That is, the firm may select a technology and an output path such that the identical output would have been produced with a lower present value of total costs by using a different technology. In general, the seller will choose to produce by paying too little for fixed costs and too much for marginal costs—a reverse Averch-Johnson result.
3. Selling firms will prefer to produce goods that are less durable than those produced by competitive firms. However, a renter firm would produce goods just as durable as those produced by the competitive industry.
4. Society may suffer greater deadweight loss when a monopolist seller exists than when a renter exists. This is true even though the renter must necessarily make greater profits than the seller.

It is important to emphasize that this paper argues that the results of virtually all the literature on durable-goods monopolists yield correct results only for the case where the product can be rented or the firm can make some costless commitment to guarantee it will do the same thing as a renter. But such earlier results have limited value because a renter is a monopolist in a nondurable good (rental services).[3]

The Model

In the market studied here, the product produced never depreciates. There is no technological obsolescence. Demand for the services yielded by the good is constant, following the demand curve

$$p = \alpha - \beta q, \tag{1}$$

[3] An exception is a useful paper by Swan (1980) in this *Journal*. Swan makes the important point that, even if the producer can precommit on production, buyers may find recycling an attractive activity even if their costs exceed the cost of new production by the monopolist. These higher costs will come out of the monopolist's profit. The reason is that the present value of the monopolist's profit is equal to the present value of industry rents minus the present value of industry costs (competitive recyclers make nothing). The existence of recyclers who operate at cost levels greater than what the monopolist would find profitable if it also controlled the recycling market ends up thus reducing the monopolist's profits. The monopolist's effective marginal cost becomes that of the recycler.

where p is one-period rental price, q is cumulative quantity produced to date, and α and β are constants. That is, if the firm produced α/β units and sold them, it could literally only give its production away thereafter. There are no worries about another firm entering the market, perhaps due to a patent. The interest rate is assumed to be a constant. All available production technologies involve constant marginal costs.

The commodity produced is assumed to be perfectly divisible. All purchases are competitive—no individual purchaser believes he has any effect on the output of the firm. Perfect information about the demand curve, production costs, and production is available.

A perfect secondhand market exists. One way to think of the effect of the secondhand market in the case of the seller is to imagine that all output is sold to competitive leasing firms. These leasing firms charge a high enough rental so that the short-run leasing market always clears, implying that the consumers who are willing to pay the most for the output are always the ones who have it. The secondhand market serves two roles: (1) It eliminates price discrimination and (2) it makes allowance for the fact that even with a static demand curve different individuals may do the demanding each period. To elaborate on the second point, consider the demand for baby carriages. In 1954 my parents had a high demand for one unit. In the current period their demand is zero, while someone else is doing the demanding. With no secondhand market, even though the baby carriage has a long physical life, its economic life is very short because the demanders of one period have no demand in the next. The product is the equivalent of a nondurable good. If the demanders remained the same each period there would be no need for secondhand transactions. Thus, either correlation in demanders from one point in time to the next or a secondhand market is needed to make durability a significant characteristic. Aesthetically, perfect secondhand markets are preferable here so that it will be clear that all results derive strictly from the lone imperfection that firms must sell instead of rent.

Three types of markets are studied. Competitive firms may either sell or rent their output. A renter could sell if he wished but always makes more money by renting, given perfect foresight. A monopolist seller cannot rent, although he may be able to sell to competitive leasing firms which can rent to consumers. Renting generally may be ruled out for selling firms for legal or practical reasons. For example, United Shoe Company, IBM, and Xerox all began by only renting their products but are now required to also make sales. DeBeers, the diamond monopolists, are in a business where renting would simply not be practical. In other markets (such as the market for automobiles), renting may be uneconomic because renters may abuse products. For a product such as aluminum, renting is clearly an impossibility. For the purposes of this paper, it will be assumed that manufacturer renting does not occur for legal reasons, and future contracts between selling firms and customers are also not allowed.

Expectations

There are no expectational difficulties in the competitive case or in the case of the monopolist renter. Given the technologies available, this simple model yields deterministic competitive results directly from minimum average cost and zero-profit conditions.

The monopolist renter also poses no expectational problems. Firms need only examine the current rental price to determine whether a machine is worth renting this period. The monopolist's profits are the difference between the present value of rents and the present value of costs, and he simply adopts the strategy which maximizes this difference. The profit-maximization and cost-minimization problems are somewhat separable, in that for any given production stream the monopolist would clearly choose the technology which produced the lowest total costs. The renter's problem is as easy to solve as the competitive problem, being very similar to the problem of a monopolist in a nondurable-good industry. This is an intuitive result, since by renting his product rather than selling it the renter is effectively making his monopoly one in providing the (nondurable) services of his output.

The monopolist seller does provide severe expectational difficulties. Once he sells a machine he is no longer interested in what happens to the value of that machine. However, his customers presumably realize this and take this factor into account in determining how much they are willing to pay for a machine.

In a two-period model (or, in principle, in an n-period model) the expectational problem of the seller can be solved recursively: One can see what the trivial optimal strategy will be in period 2 given any strategy in period 1, and then the best strategy in period 1 can be calculated. I will develop the two-period model in the next section of the paper because it brings out most of the paper's important results and then will comment on its weaknesses in the following section.

The Two-Period Model

Assume for simplicity that there are no costs of production. The interest rate is ρ. The demand curve for rental services of the product is of the form $p = \alpha - \beta q$, as described in equation (1). (These assumptions are stronger than necessary, but generalization adds nothing to intuition.)

Next, make two artificial and crucial assumptions: (1) There are discrete periods of time, production occurs at the beginning of a period, and no further production occurs until the beginning of the next period; (2) there are two periods (the crucial element here is that there are a finite number of periods so that the problem can be solved recursively).

Let q_{iC} = quantity produced by the competitive industry in the ith period, q_{iR} = quantity produced by the monopolist renter in the ith period, and q_{iS} = quantity produced by the monopolist seller in the ith period.

In the competitive case, all production will occur immediately:

$$q_{1C} = \alpha/\beta;\ q_{2C} = 0. \tag{2}$$

Profits are zero and price = marginal cost of zero. Rental price is zero in both periods. The renter will also produce some units in period 1 and none in period 2, and then rent the same units in both periods. The renter's problem is

$$\max_{q_{1R},q_{2R}} q_{1R}(\alpha - \beta q_{1R}) + \frac{(q_{1R} + q_{2R})[\alpha - \beta(q_{1R} + q_{2R})]}{(1 + \rho)}, \tag{3}$$

which solves to $q_{1R} = \alpha/2\beta$; $q_{2R} = 0$.

Rental price in each period is $\alpha/2$. The number of units rented each period is $\alpha/2\beta$. Profits each period are $(\alpha/2\beta)(\alpha/2) = \alpha^2/4\beta$. The present value of all profits is $[(2 + \rho)/(1 + \rho)](\alpha^2/4\beta)$.

Now consider the case of the monopolist seller. Assume that the firm chooses to produce $\bar{q}_{1S}$ in period 1. Then in period 2 the firm faces an effective demand curve for rental services of $(\alpha - \beta\bar{q}_{1S}) - \beta q_{2S}$. Since this is also the last period, the demand curve for purchases equals the demand curve for rentals. To maximize profits in that situation the firm will choose to produce $q_{2S} = (\alpha - \beta\bar{q}_{1S})/2$ (see fig. 1).

The firm maximizes the revenue obtained from second-period sales by placing $[(\alpha/\beta) - \bar{q}_{1S}]/2$ units. That is the point where marginal revenue equals zero. At such a point marginal production reduces the value of previous sold units; however, this is not something for the firm to consider directly. Those units are already sold, and once they are sold the monopolist has no interest in maintaining their price. In the first period, then, upon observing the choice of q_{1S} consumers can reasonably be expected to form expectations that period 2 production will be $(\alpha - \beta q_{1S})/2\beta$. With this expectation about production it is easy to calculate the present value of rentals from period 1 sales (i.e., the

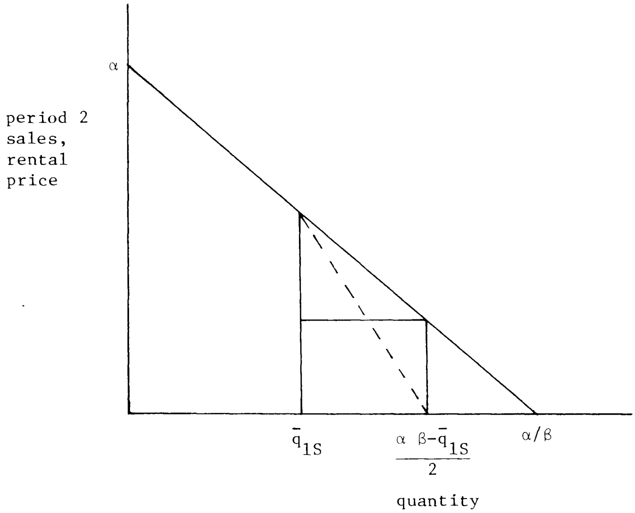

FIG. 1

period 1 sales demand curve). The sales price in period 1, p_1, can be written as

$$p_1 = (\alpha - \beta q_{1S}) + [(\alpha - \beta q_{1S})/2(1 + \rho)]. \tag{4}$$

The problem of the monopolist seller can now be written as

$$\max_{q_{1S}, q_{2S}} q_{1S}p_1(q_{1S}) + \frac{1}{1+\rho}(\alpha - \beta q_{1S} - \beta q_{2S})q_{2S}, \tag{5}$$

which solves to

$$q_{1S} = \frac{\alpha/\beta}{2 + \{1/[2(1 + \rho)]\}}\, q_{2S} = \frac{\alpha}{2\beta}\left(\frac{1 + \{1/[2(1 + \rho)]\}}{2 + \{1/[2(1 + \rho)]\}}\right). \tag{6}$$

Substituting (6) into (5) makes it possible to calculate firm profits, which are unambiguously lower than in the renter's case.

This two-period model can be extended to achieve results 2 and 3 in the Introduction:

2. The selling firm will choose to spend "too little" on fixed costs. Unlike the results of previous models (see, e.g., Swan 1972, 1977), the cost-minimization and revenue-maximization problems cannot be separated. Firms will choose to invest little in plant so as to keep their marginal costs high. High marginal costs are a signal of lower future output and thus high future prices; the prospect of high future prices raises current prices and thus firm revenues. The firm is therefore willing to sacrifice efficiency to achieve this result.

Assume that the firm can invest in a continuum of technologies which have constant marginal cost c and one-time fixed sunk cost $F(c)$.

Then proceeding as above, the problem of the monopolist seller can be written as

$$\max_{q_{1S}, q_{2S}, c} q_{1S}[p_1(q_{1S}, c) - c] + \frac{1}{1+\rho} q_{2S}(\alpha - \beta q_{1S} - \beta q_{2S} - c) - F(c), \tag{7}$$

$q_{1S}, q_{2S} \geqslant 0.$

The greater the value of c, the lower the optimal value of q_{2S}. The lower the projected q_{2S}, the greater the price p_1 given any level of q_{1S}.

To simplify further, consider the case where $\rho = 0$. Then (7) can be solved to find

$$\begin{aligned}
&a)\ q_{1S} = \frac{2}{5}\frac{\alpha}{\beta}, q_{2S} = \frac{3}{10}\frac{\alpha}{\beta} - \frac{c}{2\beta} && \text{for } 0 \leqslant c \leqslant \frac{3\alpha}{5};\\
&b)\ q_{1S} = \frac{\alpha}{\beta} - \frac{c}{\beta}, q_{2S} = 0 && \text{for } \frac{3\alpha}{5} \leqslant c \leqslant \frac{2\alpha}{3};\\
&c)\ q_{1S} = \frac{1}{2}\left(\frac{\alpha}{\beta} - \frac{c}{2\beta}\right), q_{2S} = 0 && \text{for } \frac{2\alpha}{3} \leqslant c \leqslant 2\alpha;\\
&d)\ q_{1S} = 0, q_{2S} = 0 && \text{for } c \geqslant 2\alpha.
\end{aligned} \tag{8}$$

In region a, as marginal costs rise firms do not cut first-period production: Rising costs convince customers that second-period output will be lower, thus raising prices and maintaining the attractiveness of first-period production.

In region b, the seller produces more than the renter with the same marginal cost curve. If the seller produced the renter's quantity ($\frac{1}{2}[(\alpha/\beta) - (c/2\beta)]$ throughout cases a, b, and c), customers would realize that it will make sense for the seller to produce a little more in the second period. It makes more sense for the seller to produce extra output now and at least get the benefit of reducing customers' expectations of second-period output.

In region c, the seller can do exactly the same thing as the renter: Profits can be maximized assuming period 2 production will be zero and, in fact, period 2 production will optimally be zero.

In region d, costs are so high that the firm closes up shop.

Examining region a more carefully, we find the present value of profits to be

$$\pi = \frac{.20\alpha^2}{\beta} + \frac{.25(\alpha - c)^2}{\beta} - F. \tag{9}$$

A profit-maximizing firm would, by (8), be willing (in this region) to spend an extra dollar on fixed costs only up to the point where $\partial c/\partial F$

$= \beta/[-.5(\alpha - c)]$ (assuming $\partial^2 c/\partial F > 0$). However, production over the two periods is $(.7\alpha/\beta) - (.5c/\beta)$ from (8a). Thus an extra dollar spent on fixed costs would reduce the total marginal costs of producing the same output by $[(.7\alpha/\beta) - (.5c/\beta)]/[(.5\alpha/\beta) - (.5c/\beta)] = (1.4\alpha - c)/(\alpha - c)$, or between \$1.40 and \$2.00 for $0 \leqslant c \leqslant 3/5\alpha$, at the point where the firm would stop making its fixed investment. In region b, the seller will also invest less in fixed investment than the renter because his benefit from reducing costs is lower—even though his output is higher.

As a numerical example, consider the firm that is choosing between two technologies. One technology involves zero marginal costs ($c = 0$) and fixed costs $F(0) = .22\alpha^2/\beta$. Assume that the interest rate $\rho = 0$. The second technology involves constant marginal costs $c = .6\alpha$ but zero fixed costs.

Then the firm with zero marginal costs will, by (6), produce $.4\alpha/\beta$ in period 1 and $.3\alpha/\beta$ in period 2. Its total revenues (which need not be discounted because $\rho = 0$) will be $.45\alpha^2/\beta$. In period 1 the sales price will be $.9\alpha$, while in period 2 the sales price drops to $.3\alpha$. Imputed rental prices are $.6\alpha$ in period 1 and $.3\alpha$ in period 2. After subtracting off fixed costs of $.22\alpha^2/\beta$ the firm is left with net profits of $.23\alpha^2/\beta$.

The firm with marginal costs equal to $.6\alpha$ will also produce $.4\alpha/\beta$ in period 1. However, it will produce zero units in period 2. Its total revenues will be $.48\alpha^2/\beta$. In period 1 the sales price will be 1.2α, while in period 2 the resale price drops to $.6\alpha$. Customers know that the firm cannot produce any more cheaply than for $.6\alpha$; thus any positive second-period production would be a money-losing venture. The total costs for this firm are $.24\alpha^2/\beta$—all incurred in the first period. Net profits are $.24\alpha^2/\beta$.

The result here is as follows. By adopting the low (no) fixed-cost strategy, the firm's optimal production path has been altered so that in each period it produces less than or equal to the number of units it would have produced with low marginal costs. The present value of total costs associated with producing this reduced output is higher than the present value of costs associated with the higher production. Nevertheless, the high-cost strategy is still more profitable because a commitment to hold down future output is effectively developed.

3. Selling firms will produce goods that are less durable than those produced by renting firms, or a competitive market. Again, this is in contrast to the results of Swan (1972), who implicitly treats renters and sellers identically and concludes that durable-goods monopolists will produce output as durable as competitive firms.

The reason for this "planned obsolescence" result is quite simple: We have shown that renters can make more money than sellers. By producing a less durable product the monopoly seller becomes more like a renter. A renter provides services for his market one period at a time. A monopolist seller can achieve the same result by producing goods that only last one period at a time.

Again, consider a numerical example derived from the two-period model. Setting the interest rate $\rho = 0$, the profits for a monopolist seller with no fixed or marginal costs is $.45\alpha^2/\beta$. However, assume that the life of the product is shortened to one period. Then first-period production will be $[.5(\alpha - c)]/\beta$ and first-period profits will be $[.25(\alpha - c)^2]/\beta$. In the second period profits will be either $[.25(\alpha - c)^2]/\beta$ or $.25\alpha^2/\beta$, depending upon whether the firm can switch back to producing the cheaper (and more durable) output in the second period. In any event, cumulative profits will be at least $[.5(\alpha - c)^2]/\beta$. If $c < (1 - .9^{1/2})\alpha \approx .0513\alpha$, then the firm does better by producing the less durable good.

Thus, the result in this example is that the firm produces a version of its product that is costly to build rather than a more durable version that can be constructed at zero cost. This result is achieved even though firms and consumers face the same discount rate (in contrast to Barro [1972]), and consumers have full knowledge of the product's durability—and thus pay less for the product that has a shorter life.

In general, the seller will not produce as durable a product as the competitive market, or the renter. Roughly speaking, if production costs are very low relative to rental price (as in the example above), the firm could conceivably be willing to pay more to produce a less durable product. More usually, as the cost becomes a larger fraction of price, durability will be a virtue—but not as much of a virtue to a seller as a renter.

It is possible to speculate that this relationship between the value of durability and the cost/price ratio of the product may also provide insights into research and development by a monopolist. If R & D serves the role of making an old product obsolete, monopolists in fields with low cost/price ratios may be willing to spend a good deal on new product development so that they can sell new products to their customers. Firms with high costs will have less incentive to make old products obsolete—it is important for such firms that customers be willing to pay a significant purchase price, representing the value of several years' worth of services, in order to make production profitable. A company with low per unit costs will do better to make profits by creating obsolescence and selling new units.

Difficulties with the Two-Period Model

The crucial difference between the Coase model and the two-period model is the ability of the firm to precommit to limiting its production. With Coase, once one unit is sold the second unit is then quickly sold as well. With a two-period model, once today's output is sold no more is marketed for an entire period. If periods have significant length, this is important. (In a one-period model the sellers' and renters' problems are trivially identical.) Stokey (1980), in a paper which criticizes an earlier version of this paper, rigorously shows that in the limit, as period length becomes small, the Coase result is achieved. The Coase result is most intuitive when output is not infinitely divisible. Then following Coase's logic it is clear that in each period it will make sense to sell at least one unit. Delay for a period will not alter the firm's situation (except that in a finite-time model there will be a period less until the end), but a period's worth of interest is lost. As time periods grow smaller, sales of one unit each period will produce the competitive quantity in less and less real time.

The Coase result is also analogous to results by Calvo (1978) and others in the time-consistency literature in monetary theory.[4] Calvo asks how the government can maximize the seignorage it will receive from printing money. If the government can, it will do something like the monopolist renter does. In a stagnant economy the government may print an arbitrary quantity of money in the first period, and by promising not to print any more it will hold the level of real balances at a constant level. All seignorage is earned at the outset. In a growing economy there may be some optimal positive money growth.

However, suppose the government cannot precommit. If there are t periods left the firm will choose a path of money production independent of past money growth. (Optimal growth rates can be solved optimally from the last period back.) This implies that real balances held with $t - 1$ periods to go are independent of money growth at period t. Seignorage in period t is the real balance held at $t - 1$ times the percentage of the nominal money supply printed in period t. Obviously, the higher the period-t inflation rate is, the higher is seignorage in that period. Future seignorage is unhurt by printing a great deal of money, because $t - 1$ real balances are unaffected by the current money growth rate. Thus the firm produces money at the maximum possible rate in each period. Because it is assumed that holding down the current rate of money growth does not provide any information about what will be done in the future, there is no incentive to hold down the current growth rate. Similarly, in the durable-goods monopolist case Coase (and Stokey) does not permit the firm to reduce customer expectations about production over the next few periods by simply lowering current production.

Three questions arise out of this discussion. First, can firms successfully lengthen periods, and if so how? Second, can firms actually

[4] Important papers in this literature include Pollak (1968), Friedman (1969), and Kydland and Prescott (1977).

influence expectations of future production via their current production behavior? Third, what alternative methods are available for restricting production?

All three questions are clearly related: They all amount to questions about the firm making commitments about future production either through explicit action (such as building a less durable product or a high marginal cost plant) or through implicit action (creating beliefs about future behavior by following a consistent strategy different from the Nash equilibrium in this model or developing a reputation in other markets that convinces people you will restrict production).

There may be some "natural" constraints on the firm that effectively make periods last a long time. For example, it may be quite costly to alter production levels. Thus there is an inertia which causes current production rates to be maintained. Costs of changing prices work in the same direction.

Periods may also be limited implicitly. Virtually all major commercial banks will only sell certificates of deposit once a day—so dealers know that at least for that day (the typical trader's longest possible time horizon) there will be no more of that specific product flooding the market.

Implicit restrictions on production—without the firm incurring the cost of producing inefficiently—may be possible via establishing a reputation. For example, people may be willing to believe that a monetary authority which has printed little money in the last 10 years will not start to print great amounts tomorrow, despite the theoretical arguments made above. Kreps and Wilson (1980) have done rigorous work in the area of reputation. They argue that a conglomerate, operating in many markets, may be able to maintain its monopoly positions by responding in a very tough manner to anyone who tries to enter an individual market—even if profits in the individual market are hurt by following a tough strategy.

In the extreme form, a firm which had monopolies in many markets at different times might even be able to convince customers that it would operate like a renter. A more likely outcome is that the producer will be able to establish a less than perfect reputation. For example, an author may be able to establish that he will not put out a low-cost edition (paperback) for at least a year after the hardcover comes out. However, it may be difficult to convince anyone that a paperback will never come out.

If the firm must decide its production a long time in advance (for technological reasons, say) it will benefit from being able to precommit itself. Another promising way to gain some monopoly power is to be in a situation where the firm has some maximum productive capacity. Even if the firm has the ability to construct additional capacity, it might be against its interest to do so. Consider, for example, the optimal seignorage problem. Calvo (1978) shows that the government will print money as fast as it can. However, its seignorage will be highest if the maximum printing rate possible is relatively low. The durable-goods monopolist with a capacity constraint can commit to only gradually pushing the price down and thus do better than the unconstrained seller.

A Model with Capacity Constraints

As a numerical example, consider a firm which faces a demand curve for the rental services of its product of $p_T = \alpha e^{-\beta Q_T}$, where p is the rental price and $Q_T = \int_0^T q_t$ or the cumulative production at time t. Assume marginal costs of production are zero.

Furthermore, assume that capacity can be constructed costlessly, but once it is constructed it cannot be destroyed. (Allowing the capacity to also be destroyed costlessly would mean that the problem is in no way different from the case of not having a capacity constraint.) For the time being, make the important assumption that there is an infinite horizon.

The exponential demand curve is chosen because no matter how many units have been sold in the past the firm is still facing an exponential demand curve with the same relative slope. That is, a change in the monetary unit will make the demand curve the firm faces after producing a large number of units identical with the one it faced at the outset. This means that if at any time in the future the firm were to again choose its optimal capacity it would opt for the same amount—given that capacity is costless. If capacity is costly, obviously it will become less attractive to build as the market winds down. This factor will be important when we discuss relaxing the infinite time horizon assumption.

Given that whatever capacity q the firm chooses everyone accurately assumes will be the production level from here on (an assumption to be justified soon), the firm's problem can be written as

$$\max_q \pi = \int_0^\infty qt\alpha e^{-(\beta q+\rho)t}dt. \tag{10}$$

The explanation of (10) is that the firm's profits will equal the present value of the rental value of all output to be on the market at each point in time. After t periods qt units will be outstanding, each receiving a rent of $\alpha e^{-\beta qt}$, which must be discounted by $e^{-\rho t}$.

Solving (10) yields $q = \rho/\beta$, $\pi = \alpha/4\rho\beta$.

It can now be easily seen that the firm will produce up to capacity at each moment: At time t the sales price of a unit of output will be

$\alpha e^{-\rho t}/2\rho$ while the present value of future profits will be $\alpha e^{-\rho t}/4\beta\rho$. Producing an extra unit today with future output unchanged would increase current revenues by $\alpha e^{-\rho t}/2\rho$, while the present value of future profits would be decreased by $\alpha e^{-\rho t}/4\rho$. Thus, the firm would find an increase in current output to be profitable, if only adding capacity did not increase customers' expectations about future output. For this level of capacity, then, it is true that the firm would produce up to capacity at each moment regardless of what consumers think (if consumers expect lower future production, current sales are made even more attractive), and consumers will rationally expect the firm to always produce at capacity.

No additions to capacity will be expected. The reason is that if capacity is raised customers will realize that at each individual moment it would pay the firm to produce at the higher level. This would lead customers to pay lower sales prices and reduce profits. Thus, if the extra capacity is built the firm will use it at each moment and profits will be lower. There is therefore no incentive to ever build more capacity.

In this example, a renter would have produced $1/\beta$ units immediately and never any future output. Comparing the seller and the renter, the seller's franchise would be 32 percent less valuable. Discounting the deadweight loss caused by the renter and seller at the interest rate ρ yields the result that deadweight loss is 36 percent greater with a seller than a renter. Even though the renter eventually reaches the point of producing almost the competitive quantity, it takes a long time to get there. Early on the seller has fewer units on the market than the renter and so causes a larger deadweight loss. The effects of these early periods dominate. The present value of consumers' surplus is 5 percent lower with a seller than with a renter. All these results are independent of α, β, and ρ. Furthermore, the deadweight loss result is fairly insensitive to the exact level of production chosen by the seller. Even if a constant output 70 percent greater than profit maximizing is chosen, deadweight loss is still greater with a seller than with a renter.

Thus, the effect of forcing a renter monopolist to sell is that the present value of profits falls by almost a third. However, this loss of monopoly power does not make consumers any better off. In fact, they end up slightly worse off, and deadweight loss increases dramatically.

A problem with the capacity model above is that it does depend on the infinite horizon. A finite horizon would cause the problem to unravel from the end, much like a repeated game of Prisoner's Dilemma: It is clear that the firm would decide to add capacity in any final period. This would make adding capacity in the next-to-last period more attractive, and so on. The problem would solve out in exactly the same way as the no-capacity-limitation problem.

There are suggestions for saving the capacity solution. The first is to make capacity costly. Then even in a finite-time version of the model the problem will not reduce to the competitive problem. The reason is that at the end of the game there will be no incentive to build new capacity because the costs could not be recaptured through higher output in the brief remaining time. Now adding capacity in an earlier period has two costs—the cost of building and the cost that customers will rationally expect higher output (than without the new capacity) in the remaining periods. If capacity is costless, neither of these costs appears. The firm can effectively constrain itself and earn some monopoly profits. A finite-horizon model with costly capacity has not yet been developed.

Moorthy (1980) has developed a solution for the finite-capacity problem when there is asymmetrical information about the firm's capacity. In Moorthy's model capacity is exogenously given, as might be true with a diamond mine where there is a maximum rate at which the diamonds can be extracted before the costs of increasing output become prohibitive. The firm knows its capacity, but customers only have a probability distribution as to whether capacity is high or low.

If the firm ever produces a large amount it will be obvious that capacity is high, and customers will assume high output in the remaining periods. It may pay the firm in the early periods to produce at a low level even if it has high capacity to keep customers from altering their probabilistic estimates of capacity and lowering the prices they will pay. Finally, when only a few periods remain it will pay to produce at the high level.

Extensions of the Results

This section is meant to indicate further types of activity which may be observed due to the durable monopolist's special problem.

1. *Price guarantees.*—A firm which could only sell rather than rent might wish to write various types of contracts to give its customers the same kind of protection that a renter would have. In the models in this paper, if the firm were able to give its customers an American put (money-back guarantee exercisable at any time), it could achieve the renter's profits. However, that is because we did not consider products where user abuse can affect the value (like automobiles) and products that cannot be easily transferred (such as installed railroad tracks). Such realistic problems do not render price guarantees worthless but do prevent sellers from being able to reproduce renters' results.

2. *Service contracts.*—If the monopolist also has a monopoly in servicing his product he may be able to come closer to achieving the renter's result. Services are nondurables, so to the extent that the firm can transfer its monopoly power to the service area it can take greater advantage of its position. (Polaroid may choose to take its profits in film rather than cameras; Gillette, in blades rather than razors—even independent of the usual price-discrimination reasons for these two particular results.) Another type of service contract may tend to reduce the liquidity of the secondhand market. A firm may agree to guarantee performance so long as the original owner holds the product. Naturally, this discourages secondhand sales. If demand among different customers fluctuates substantially (as opposed to aggregate demand varying), then normally an active secondhand market would ensue. If production costs are low relative to price, the monopolist is more likely to want a poor secondhand market and write such a contract.

3. *Implicit contracts.*—If a firm cannot write explicit contracts to control its future production and be like a renter, it may make implicit contracts. For example, DeBeers, the South African diamond monopolist, has a policy of never reducing the nominal price of its diamonds. This is an implicit contract that DeBeers will hold down sales sufficiently to keep the market price of its product up. In 1978 there was a tremendous surge in the speculative demand for diamonds, and DeBeers's fixed price was below the market level. This placed the firm in a dilemma. If it raised its prices substantially and the speculative bubble burst, then it would either have to violate its implicit contract or have very low sales for a long time. (That is, increased uncertainty about future equilibrium prices reduced the desirability of a permanent commitment to a high price.) On the other hand, if sales prices were not raised, DeBeers would be rationing its output at below market prices and not capturing the maximum potential profits. The firm's solution to the problem was to impose a *price surcharge* rather than a price increase. Using the surcharge was a way to signal that the current price increase was revocable and not in the nature of the more usual increases. This way, price could be first raised and then lowered without violating the implicit contract. What actually occurred was that the surcharge was reduced and then replaced by a permanent price increase.

Summary of Results and Applications

On some occasions firms have been required by law to sell rather than rent their products. In some durable-goods markets renting is simply impractical. This paper discusses the contrasting problems of the durable-goods monopolists who can rent their products and those who must sell.

Firms that can rent resemble monopolists producing nondurable goods. The direct analogy between monopolists renting a durable and those producing a nondurable good is always transparent. As with the nondurable-goods monopolist, the renter will always choose the cost-minimizing production strategy for any chosen stream of rental services to be produced.

Monopolist sellers do not do as well as renters. This is a perfectly general result unless it is assumed that consumers can be fooled as to future production. The seller makes less money because he has the ability to reduce the capital value of the outstanding stock of durables (via new production) and no way of guaranteeing that this power will not be used. As a matter of policy, however, it is unclear that the government should force durable-goods monopolists to sell. There may be a welfare cost in forcing firms to sell their products. Of course, a policy of forcing monopolists to sell will also discourage the development of monopolies, which may be good or bad.

The monopolist seller cannot choose his production technology independent of the demand for his products. Thus, if one is told what the production strategy of the seller will be, one cannot assume that the production will be produced in the most efficient way possible. A "reverse Averch-Johnson" result—that the seller will choose to spend too little on fixed costs and too much on marginal costs—is derived.

A similar, curious application of this work involves DeBeers. Diamonds must be sold rather than rented for various institutional reasons. However, suppose DeBeers was able to guarantee that it would close its mines 10 or 15 years from now and in the interim their production was limited by some capacity constraints. Then DeBeers's position would be more like that of the monopoly renter. Prices of currently sold diamonds would rise enough so that the value of the firm would rise despite profits from the mines going to zero once they close.

Of course, DeBeers cannot make such a promise. However, suppose political turmoil in South Africa increases so that people think the government will eventually go under, and it is believed that after the government falls DeBeers's production will be sharply curtailed for a long time. The company's stock could easily rise because of this predicted future trouble. On the other hand, if the trouble increases the chance of the mine being closed very soon, the firm is obviously going to be worth less. Presumably, the best thing for DeBeers then is news which decreases the chance of a short-term problem and increases the chance that they will be forced to shut down at some date in the medium-distant future.

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