Volume Title: The Economics of Information and Uncertainty

Volume Author/Editor: John J. McCall, ed.

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-55559-3

Volume URL: http://www.nber.org/books/mcca82-1

Publication Date: 1982

Chapter Title: Planning and Market Structure

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Chapter URL: http://www.nber.org/chapters/c4432

Chapter pages in book: (p. 47 - 76)

2 Planning and Market Structure

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2.1 Introduction

In many markets, the successful entrepreneur is the one who has the skill to plan his production in advance to take advantage of predicted demand conditions. Production takes time, and the entrepreneur who waits until the last moment to expand or contract production may often earn lower profits than an entrepreneur with better forecasting skills. In fact, a large fraction of many managers' time is spent trying to figure out what demand will be and how best to meet it. It is clear that early revelation of demand has a benefit from society's veiwpoint since it gives suppliers notice to expand or contract production. It is also clear that it may be costly to forecast demand.

How does information get transmitted from demanders to suppliers in a market? We show that a competitive market is not well suited to the efficient transmission of this information. We then show how a firm with some monopoly power will have a greater incentive than competitive firms to cause this transmission of information to occur. The stability of markets over time—measured in terms of price and quantity variance—will differ greatly depending on whether planning takes place or not. We argue that, when planning is possible, a market structure with some monopoly power may emerge. This market will have more quantity variation and less price variation than would the same market if it were competitively organized. To obtain insight into the likely behavior of a

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The author thanks the NSF for support and Gary Becker, William Brock, Carl Futia, Milton Harris, Jerry Hausman, Paul Joskow, Edward Lazear, Sam Peltzman, Edward Prescott, and participants in seminars at Northwestern University, Bell Laboratories, and the University of Chicago and at the NBER Conference on the Economics of Information and Uncertainty for helpful comments.

market structure with firms possessing some monopoly power, we analyze the behavior of a market with a dominant firm(s) and competitive fringe. The dominant firm will have an incentive to invest in information while the competitive fringe will not. The size of the competitive fringe will depend on such things as information costs and demand variability. The competitive fringe shrinks when there is a decrease in the marginal cost of information or an increase in the uncertainty of demand. An interesting result is that the dominant firm may choose to produce in some states of demand even though it knows for sure that prices will not cover constant marginal cost. This result occurs because the dominant firm realizes that the size of the competitive fringe responds to the dominant firm's production strategy. The dominant firm keeps prices low in some realizations of demand to make entry of new firms unattractive. This strategy turns out to be profit maximizing since the strategy increases the monopoly power of the dominant firm when demand is high. Such a strategy is closely related to the concepts of "predatory" or "limit" pricing. However, instead of having the undesirable welfare consequences usually associated with "predatory" pricing, in this case the strategy produces a market outcome that is superior to that of both competition and pure monopoly.

2.2 Competitive Case

We want to investigate the case where there are many demanders each of whom has a random demand that makes a negligible contribution to total demand, which will also be random. Initially, we let the random demands of each demander be independent of each other. Both the mean and variance of total demand are finite, even though we have many demanders. At a cost, the realization of random demand for any fraction of the market can be discovered early enough to allow suppliers to adjust their production plans if necessary. (An alternative interpretation is that at a cost the prediction error of forecast can be reduced.)

To formally model this situation we proceed as follows.[1] Let total demand be random and be given by $a-p+\epsilon$, where ϵ is a normal random variable with mean 0 and variance σ^2, a is a constant, and p is price.[2] Imagine a continuum of demanders between [0,1], and let $W(Z)$ be defined as a normal random variable with mean $Z(a-p)$ and variance $Z\sigma^2, Z \in [0,1]$. $W(Z)$ can be interpreted as the random demand for the first fraction Z of the market. Assume that the random demands of any nonoverlapping interval of demanders are independent of each other so that the increment to total demand by agents in the interval $[Z_0, Z_0 + dZ]$ is independent of the level of demand $W(Z_0)$ for the first fraction Z_0 of the market. $W(Z)$ is then a Wiener process with $W(1)$ equaling $a-p+\epsilon$.

Suppose that at a cost it is possible to determine the realization of the random component of demand one period early.[3] Suppose that demanders are ordered in terms of increasing cost of acquiring information so that it costs $C(F)$ to learn in advance the demands of the first F percent[4] of the market with $C'(F) > 0$ and $C''(F) > 0$. If a firm has devoted $C(F)$ resources to information gathering, then it follows from the properties of a Wiener process that the firm knows that the market demand can be written as

$$a - p + \sqrt{F}\, V_1 + \sqrt{1-F}\, V_2, \tag{1}$$

where V_1 and V_2 are independent normal random variables, with mean 0 and variance σ^2, and where the realization of V_1 becomes known to the firm but that of V_2 remains unknown at the time the firm must make some productive decisions.[5]

Competitive risk neutral suppliers must produce[6] one period before all demand is costlessly revealed. Only if someone has invested resources to predict demand will suppliers know enough to adapt to changes in demand. There are constant returns to production rates, which are required to be finite. Let it cost c to produce one unit of the good. No production can take place once the market opens. For simplicity we assume that the good cannot be stored for more than one period. Therefore, the supply of the good in any period is exactly equal to the previous period's production. A risk neutral supplier will sign a fixed price forward contract to sell at price p^* only if the expected price paid on the spot market $\bar{p}$ is less than or equal to p^*. Hence, a supplier will offer fixed price contracts only if $p^* \geq \bar{p}$.

If no information about the random components of demand is available to any supplier, then ex ante a supply firm's random profit stream is unchanged over time and each supplier will produce a fixed amount. In equilibrium, the total market supply S must be such that expected price equals the cost of production c. For the linear demand curve presented earlier, it is straightforward to show that, in equilibrium with no information about the randomness in demand, $S = a - c$, $p = c + \epsilon$, $E(p) = c$, and $\text{var}(p) = \sigma^2$.

It is clear that if it were always possible for suppliers to expand and contract production so that price equaled c, then society would be operating efficiently. Exactly the amount demanded would be produced at a price equal to the marginal cost. If information acquisition and transmission are costless, we can imagine demanders costlessly announcing their demands in advance and the market responding efficiently.

What happens when information acquisition is not costless? Clearly, for sufficiently small information costs it will still be efficient for investment in information to occur to enable the planning of next period's supply. However, in this situation each demander will have no incentive to spend resources to figure out his demand and a supplier will have no incentive to purchase information from an individual demander. Although society would be made better off by information investment and transmission, individual agents do not invest in information because they do not perceive the general equilibrium effects of their (collective) noninvestment in information since each agent by assumption is infinitesimal and thus correctly ignores the effect of his actions on the price distribution.

To illustrate the lack of incentives for information transmission, first consider a demander. A demander has two choices. He can choose not to invest in information and next period pay random price p, or he can spend some amount δ to figure out his next period's demand.[7] If he has invested in information, he can sell his information to a supplier (only one for now) for some amount $\underline{I}$ and then buy on the spot market paying random price p. Because the demander is small, his information has no effect on the distribution of p. Alternatively, instead of the demander separately selling his information and then buying on the spot market, we can imagine the demander being offered a fixed price forward contract at some p^* in return for his information. A demander prefers to face a variable price distribution rather than a price stabilized at the mean of the price distribution. Under variable prices the demander could consume the fixed amount he finds optimal under the fixed mean price. However, substitution possibilities enable the demander to take advantage of the variable price by consuming more of the product when its price is low and less of the product when its price is high. In this way demanders can achieve higher utility or profits. Stated in another way, since the expenditure function (if the demander is a consumer) and the cost function (if the demander is a firm) are concave in price, Jensen's inequality ensures that demanders have a preference for a variable price instead of a price stabilized at the mean.[8] For the buyer to accept a contract with fixed price p^*, p^* would have to be below $\bar{p}$, where $\bar{p}$ is the expected spot price; otherwise, it follows from the above discussion that there is no expected gain to the demander from investing in the information.

Now consider suppliers. How much would any one supplier pay for information from an individual demander? An individual demander has no influence on price, and since each supplier can sell all he wants at the (unknown) market price next period, no supplier has an incentive to buy (valueless) information from one demander. This means that the amount $\underline{I}$ a supplier would pay for information from one demander is zero.[9] The same reasoning shows that a risk neutral supplier would never sign a fixed price contract at p^*, if $p^* < \bar{p}$, in return for knowing an individual's demand. Since the demander invests in information only if he can either sell the information for $I > \delta$ or sign a fixed price contract at p^*, with $p^* <$

$\bar{p}$, we see that under the stated assumptions in a competitive market no incentive for information transmission between individual buyers and sellers will arise if it is costly to acquire information.

In the above discussion we only considered information transmission between one demander and one seller. A demander was not allowed to resell his information. Information from one demander (of measure zero) is valueless to a firm. However, it is true that information from a number of demanders (of positive measure) is valuable since their demand will influence price. Could one imagine a market in which each supplying firm pays an infinitesimal amount to a group of demanders and thus each supplier knows something about the entire demand? The special problems associated with information suggest that such an information market may not be feasible. Since these problems have been extensively discussed in the literature (see, e.g., Arrow 1971; Green 1973; Grossman 1976, 1977; Grossman and Stiglitz 1976, 1980), we give only a brief discussion here.

First, consider the monitoring problem. Is each supplier expected to keep track of the accuracy of each of the infinite number of demanders' response? (Notice that an exchange of information between a demander and a supplier automatically does this if the demander reveals his information to a supplier by signing a purchase contract specifying a quantity and if the demander does not break the contract.) Second and more important, whenever a group of suppliers obtain information about demand, the only possible equilibrium consistent with competitive assumptions is one in which the suppliers adjust production until expected price equals the constant marginal cost c. When this happens, the incentives of supplying firms to invest resources to learn total demand in order to predict price totally vanish.[10]

Could there be a competitive equilibrium in which supplying firms have different information sets purchased from different groups of demanders? The answer again is no because the supplying firms would then have incentives to merge their information sets to improve the accuracy of their demand forecasts and then we would return to the situation just discussed where expected price would fall to constant marginal cost c, or else to a situation where the firms would collectively try to earn a return on the information by cartelizing and behaving monopolistically. Could a trade association form, assess fees on supplying firms, and provide incentives for some demanders to figure out and reveal their future demands? For the reasons just discussed it would be difficult to enforce participation in the association.[11] But even if a trade association did organize, it is plausible that the trade association would not only coordinate information flows but also serve as a vehicle toward cartelization of the industry. In fact, any time the information is provided by one central source, the possessor of the information can become a producer and behave monopolistically to take advantage of the information. In short, purely competitive behavior and information transmission do not seem compatible in the model under examination.

The same exact problems persist in the case where individual demands are correlated. Any time firms have spent resources to acquire the same information set, they have an incentive to merge to avoid the duplicative costs of acquiring the same information. Any time firms have different information sets, they have an incentive to merge to pool information to more accurately predict demand. Any time a group of competitive firms obtain information about demand, the only possible equilibrium consistent with competitive behavior requires production to be adjusted until expected price equals constant marginal costs.[12]

The conclusion of this analysis is that under competition there is no mechanism to ensure that investment in information occurs to the degree that society finds optimal. In the special case just examined here, no investment occurs. This does *not* mean that there can never be situations in which competitive supplying firms have an incentive to discover demand by offering a lower price to those who order in advance, only that it is unlikely that a competitive environment will provide the correct investment incentives. For example, if those who order in advance are less costly to serve, if supply curves are upward sloping, or if firms can lower operating costs by reducing the variability of their cash flow, then we can expect some forward contracts to emerge which will as a by-product transmit information from suppliers to demanders. (See Carlton 1978, 1979a, 1979b, for incentives for forward contracting.) The point is that although forward contracts may come into existence even when it is costly to obtain information on demand, the correct incentives to transmit information will not necessarily be provided.

We have argued that for the market conditions under examination there may be incentives for mergers. In an industry where information considerations, and not other issues like probability of obtaining delivery, are important, it is plausible to expect that the industry may evolve until one large firm (or a few) emerges which has some market power. It is only by the acquisition of market power that a firm in the model acquires an incentive to invest in information. Information is valuable only if the recipients of the information have the power to prevent industry production from expanding to the point where expected price equals constant marginal cost.[13] Before we examine the stability and consequences of this market power, let us investigate and compare the behavior of a monopolist and a social planner.

2.3 The Monopoly Case

How would a monopolist operate—would he have an incentive to invest in information, and would he invest an optimal amount? Let us use the simple example of the previous section to illustrate the monopolist's incentives to invest in information. Suppose as before that there is a continuum of demanders between 0 and 1, that demanders are ordered in terms of the increasing cost of eliciting information, and that the demands of agents in nonoverlapping intervals are independent. Let F be the number between 0 and 1 such that all information about demanders between 0 and F is collected while information about all demanders between F and 1 is not.[14] By the argument given in the previous section, the demand curve the monopolist sees after his collection of information can be written as

$$D(P) = \mathrm{a} - \mathrm{p} + \sqrt{F}\, V_1 + \sqrt{1-F}\, V_2,$$

where V_1 and V_2 are independent normal variables with mean 0 and variance σ^2, and where the realization of V_1 is observed by the monopolist before production occurs.

Conditional on knowing V_1 and F, the monopolist must decide how much to produce and offer on the market next period. The price will be random and will equate supply to demand. Production S occurs before total demand is observed, and it costs c to produce a unit of the good.

The monopolist sets S to maximize expected profits,[15] which are given by

$$E(\pi(S)/V_1, F) = E[p-c]S.$$

Price p is given by equating demand $D(p)$ to supply S. Therefore,

$$p = a - S + \sqrt{F}\, V_1 + \sqrt{(1-F)}\, V_2,$$

and

$$E(\pi(S)\,|\,V_1, F) = E[a - S + \sqrt{F}\, V_1 + \sqrt{(1-F)}\, V_2 - c]S,$$

or

$$E(\pi(S)\,|\,V_1, F) = S(a - S + \sqrt{F}\, V_1 - c).$$

Hence, in the profit maximizing solution,

$$S = \frac{a+c+\sqrt{F}\, V_1}{2}, \quad p = \frac{a+c}{2} + \frac{\sqrt{F}}{2} V_1 + \sqrt{1-F}\, V_2,$$

and

$$E(\pi/V_1, F) = \left(\frac{a-c+\sqrt{F}\, V_1}{2}\right)^2.$$

Since F must be chosen before V_1 is observed, the expected value H from observing the fraction F of the population is[16]

$$H(F) = E(\pi | V_1, F) = E\left(\frac{a - c + \sqrt{F}V_1}{2}\right)^2 = \frac{(a - c)^2 + F\sigma^2}{4}.$$

Expected profits are increasing in F and σ^2. Marginal expected profits are increasing in σ^2. If $C(F)$ is the cost of acquiring information on fraction F of the population, then the optimal (interior) F satisfies

$$H'(F) = C'(F) \text{ or } \frac{\sigma^2}{4} = C'(F) \text{ and } C''(F) > 0.$$

Three solutions are possible. Either $(a) F = 0$ and $C'(0) \geq H'(0)$, $(b) 0 < F < 1$ and $C(F)$ rises faster than $H(F)$, or $(c) F = 1$ and $C'(1) \leq H'(1)$. It immediately follows that investment in information will be higher the higher is σ^2 and the lower is the marginal cost of information schedule.

The monopolist has an incentive to invest in information because by learning about demand next period he is better able to plan production this period and thereby more fully exploit his monopoly power next period. The expected monopoly price is $(a+c)/2$, which exceeds the expected competitive price c derived in the previous section; the variance of the monopoly price is $\sigma^2(1-(3F/4))$, which is lower than the variance of the competitive price σ^2; while the variance of the quantity is $(F/4)\sigma^2$, which of course exceeds the zero variance in quantity supplied under competition. As one would expect, planning reduces price variance but increases quantity variance.

2.4 Social Planner

How would a social planner invest in information to maximize expected consumer surplus?[17] Using the same production and demand example as before, we have that, conditional on observing V_1 for fraction F of the population, consumer surplus equals

$$\text{SUR}(S, F, V_1) = \int_0^S [a + \sqrt{F}\, V_1 + \sqrt{(1-F)}\, V_2 - q]\, dq - cS.$$

Expected surplus[18] conditional on V_1 and F is therefore

$$\text{SUR}(S, F, V_2) = [a + \sqrt{F}\, V_1 - c]S - \frac{S^2}{2}.$$

The optimal values satisfy $S = (a + \sqrt{F}\, V_1 - c)$, $p = c + \sqrt{1-F}\, V_2$, variance $(p) = (1-F)\sigma^2$, variance $(S) = F\sigma^2$, and SUR $= (a + \sqrt{F}\, V_1 - c)^2/2$. To choose F optimally, the social planner must maximize

$$E(\text{SUR}) - C(F),$$

or

$$\frac{(a-c)^2}{2} + \frac{F\sigma^2}{2} - C(F).$$

Hence $$\sigma^2/2 = C'(F).$$

The marginal benefits of increasing F are greater for the social planner than for the monopolist ($\sigma^2/2$ versus $\sigma^2/4$); therefore, the monopolist underinvests in information. The intuitive reason for the discrepancy in incentives is the usual one that explains why a monopolist's conduct is not efficient. The benefit to the social planner of finding out and satisfying some increase in demand is related to the area bounded by the initial expected demand curve, the new demand curve, and the marginal cost curve. In contrast, the corresponding benefit to the monopolist is related to the area bounded by the initial expected marginal revenue curve, the new marginal revenue curve, and the marginal cost curve. For the linear example, this latter area is always smaller than the former.

The optimal solution involves a higher value to information than the monopolist calculates. The monopolist underinvests in information relative to the social optimum, but overinvests relative to the competitive outcome. This is a general result that will tend to occur so long as the marginal revenue curve shifts less than the demand curve in response to each new piece of information.[19] The variance of price in the socially optimal solution is lower than in the monopoly solution (whose price variance is lower than in the competitive solution). The variance of quantity in the socially optimal solution is higher than in the monopoly solution (whose quantity variance is higher than in the competitive solution).

2.5 Comparison of Monopoly and Competition

Which is worse, having a monopolist who does some information processing or having competitors who do none? To obtain some insight into this question, let us compare the competitive solution with no planning to the monopoly solution under the extreme assumption that the monopolist plans perfectly and that we ignore the costs of information gathering. This comparison will provide us with the most favorable case[20] to monopoly and will allow us to draw conclusions about the maximum trade-off between planning efficiency and deadweight loss.

If the demand curve is $q = a - p + \epsilon$ with ϵ a normal random variable with mean 0 and variance σ^2, and constant marginal production costs are c, then (from section 2.2) in equilibrium under competition no planning occurs and the amount supplied will equal $a - c$, the expected price will equal c, the actual price will equal $c + \epsilon$, and the variance of price will equal σ^2. In comparison to the ideal world of perfect planning, we can calculate the expected deadweight loss that comes from not planning. For each realization of ϵ, we can regard the competitive equilibrium as resulting from an imposition of a (random) tax equal to the discrepancy between actual price and the constant marginal cost c. This discrepancy equals ϵ. Since the demand curve has slope -1, the expected value of the resulting deadweight loss equals $\frac{1}{2}\sigma^2$, where σ^2 is the variance of ϵ.

If we calculate the deadweight loss of a monopolist who plans relative to the ideal world of marginal cost pricing and planning, we see from section 2.3 that the discrepancy between price and marginal cost for any realization ϵ equals $((a-c)/2) + (\epsilon/2)$ so that the expected deadweight loss equals $((a-c)^2/8) + (\sigma^2/8)$. The deadweight loss of monopoly that results from nonmarginal cost pricing rises slower as σ^2 increases than does the deadweight loss from (unplanned) competition (that also results in [ex post] nonmarginal cost pricing). For very large values of σ^2, the deadweight loss from monopoly power is swamped by the deadweight loss that results from not planning, while exactly the opposite is the case for small values of σ^2.

How large does σ^2 have to be before monopoly is better than competition? The answer is when $\sigma = (a-c)/\sqrt{3}$. The average level of demand at the competitive price equals $a-c$. Therefore, the implied coefficient of variation necessary for monopoly to be preferred to competition is about .58. This strikes me as a fairly high value. For example, in many manufacturing markets a conservative estimate (95 percent confidence interval) of demand would be, say, ± 20 percent of the previous year's level (correcting for trend). Using the normal distribution as an approximation, this would approximately imply a coefficient of variation of only .1. Only if one felt that an interval slightly larger than 0 to twice the level of average demand represented a 95 percent confidence interval would the coefficient of variation rise to .58.

In order to see whether the above results were robust to a different specification of demand, I redid the calculations for demand curves of the form $A_0 v/p^\eta$, where A_0 is a constant, η is the price elasticity, and v is assumed to be lognormally distributed with mean 0 and variance σ^2. Table 2.1 reports the threshold value for σ beyond which monopoly with planning is superior to unplanned competition.

The standard deviation σ gives an idea of the proportional variation in demand. For example, a $\sigma = \ln 2$ (.69) would imply that a 95 percent confidence interval would include demands that were approximately between ¼ and 4 times the average level. Even the lowest threshold value of .82 in table 2.1 suggests that a 95 percent confidence region would have to be larger than ¼ to 4 times the average demand level. Again, the levels of demand variation that are required before monopoly deadweight

Table 2.1 **Threshold Values of σ beyond Which Monopoly Dominates Competition**

Elasticity η	Threshold Values of σ
1.5	1.25
2	1.07
3	.95
4	.91
10	.82

losses are exceeded by planning losses seems so high as not to be applicable to most industries.

The above numerical calculations suggest that it is unlikely that the planning benefit that accompanies monopoly will exceed the deadweight inefficiency loss that also accompanies monopoly. However, there are two very good reasons to believe that the above (standard) framework for calculating deadweight losses may be inappropriate in this instance. Unfortunately, the quantitative significance of these effects are difficult to assess.

The first qualification relates to a point made by Stigler (1939) in regard to a cost function and adjustment costs. If the output of a firm must vary, then the cost of producing might well depend on how adaptable the technology is. If adjustment costs are an increasing convex function of the adjustment (e.g., Lucas 1967), then the implied variability of output in the social optimum will be lower than that implied by the above framework, where constant returns to scale are postulated. This suggests that the difference between the socially optimal output and the competitive output will diminish relative to that between the socially optimal output and the monopoly output. The position of competition relative to monopoly would then improve from that portrayed in table 2.1.

A second qualification is that it is inappropriate to use the same demand curve to calculate the monopoly deadweight loss and the competitive price fluctuations that will prevail in response to demand shifts. Demand curves, like supply curves, have a time dimension associated with them that depends on adjustment costs. In the very short run most demand curves are probably very inelastic because it takes consumers time to adapt to any price change. Although it would take us too far afield to discuss how the formation of expectations of future prices is affected by current price, it seems clear that the monopoly price markup is based not on the "short-run" elasticity of demand but on a "long-run" elasticity of demand, provided the firm wishes to continue in business.[21] However, when calculating how price will fluctuate in the unplanned competitive world, the short-run demand curve is the appropriate one to use since no one firm has an incentive to concern itself with the effect of its actions on future price expectations. Although applying Stigler's (1939) reasoning to input price fluctuations leads us to expect the short-run demand curve to be more elastic the more variable prices are (i.e., demander firms pay to have a technology with lots of substitutability),[22] it still seems plausible to expect that the relevant short-run demand elasticity determining price fluctuations under (unplanned) competition could be lower than the elasticity determining the monopoly markup. When this is the case, the results of table 2.1 will understate the deadweight losses under competition that arise from not planning relative to those that arise from monopoly power with planning.

2.6 Dominant Firm and Competitive Fringe

In this section the behavior of an industry structure with a dominant firm and a competitive fringe is examined. There are at least two reasons to justify such a market structure in the model being examined. First, suppose that only one firm (or a few firms which decide to collude) has access to an *information acquisition* technology. Then this firm would become a dominant firm which would use information on demand to determine its output, which the firm realizes affects price. Free entry and access to the *production* technology would ensure that a nonplanning competitive fringe would continue to enter as long as expected price exceeded constant marginal production costs.

The second reason justifying a market structure with a dominant firm that plans and a competitive fringe that does not plan is based on the earlier discussion where we argued that firms would have an incentive to merge for information reasons.[23] The merged firm would have to acquire some market power if it were to continue to have an incentive to acquire information. But how, with free entry, could the merged firm maintain its market power? There are at least two possible answers. Once the merged firm is created and it collects information and earns above-normal profits, it would be necessary for another firm to enter and do whatever the merged firm was doing in order to erode the monopoly profits. The second firm to enter realizes that its profitability will depend on the initial firm's behavior in response to its entry. When such interdependence arrangements are necessary to determine the profitability of entry, entry is thought to be more difficult than when entry can occur on a small scale with market conditions taken as given. In *Barriers to New Competition*, Bain (1956) labeled such a condition an economy-of-scale barrier to entry. A second possible explanation of why the large merged firm with market power can persist utilizes Stigler's (1964) theory of oligopoly. Suppose that all firms which acquire information collude but that there is a cost to enforcing the collusive agreements.[24] These costs rise as the number of firms taking part in the collusive arrangement increases.[25] Equilibrium will require that firms be indifferent between joining the collusive arrangement or remaining outside the arrangement and not collecting information. In terms of the assumptions of the model, this would require that the competitive fringe (which does not plan) earn zero profits and that the number of firms which belong to the cartel be such that enforcement costs dissipate the profits of the cartel. The cartel would have market power in the sense that they take into account their effect on price.

Regardless of which reason is responsible for the existence of a market structure with a dominant firm (or colluding firms) and a competitive fringe, the interesting feature of this market structure is that the dominant firm will take into account how its production strategy influences the size of the competitive fringe. The competitive fringe will affect but not eliminate the market power of the dominant firm. The reason is that, as before, production decisions must be made before demand is observed. The competitive fringe which does not invest in information will therefore base its output decisions on expected price, which in equilibrium must equal the constant marginal production cost. The dominant firm, on the other hand, is in the position of having invested in information to obtain an advance reading on demand before it produces. The dominant firm will produce little in low realizations of demand and a lot in high realizations of demand. The competitive fringe remains finite despite constant returns to scale precisely because of its inability to forecast demand as accurately as the dominant firm. The size of the competitive fringe will be endogenously determined by the price distribution, which itself is endogenously influenced by the dominant firm's production strategy.[26]

Let us now examine the equilibrium conditions in the industry. Let $\tilde{Q}(p)$ be the random distribution of demand at price p. Let $C(F)$ be the cost of learning for certain the demands of F percent of the population, with $C'(F) > 0$. Let S be the amount that is supplied by the fringe. The value of S will be unchanged over time because ex ante the world always looks the same to the competitive fringe (i.e., the dominant firm is able to keep secret its future production plans from the competitive fringe). Because of the assumption of constant returns to scale, the expected price must equal the constant cost of production c in equilibrium. The dominant firm will use the residual demand curve to determine its optimal investment in information and its production response to that information. Let $m(\gamma, F)$ be the amount the dominant firm supplies when it observes random state of demand γ after it has sampled F percent of total demand.[27] Price will be determined by the condition

$$\tilde{Q}(p) = m(\gamma, F) + S. \tag{2}$$

For a fixed F, S, and strategy $\{m(\gamma, F)\}$ and for a random γ and $\tilde{Q}$, (2) induces a distribution on price p. Call this distribution $f_1(p; F, S, m(\gamma, F))$, which we abbreviate as $f_1(p)$. It is this distribution that will determine whether there is an incentive for the competitive fringe to expand or contract. In equilibrium it must be the case that the size of the competitive fringe S is such that the expected value of price equals c, the constant marginal production cost, or

$$\int p f_1(p) dp = c. \tag{3}$$

The dominant firm will realize how S is determined and will take (3) into account in determining its optimal supply strategy. We can think of (3) as establishing a relation between S and the strategy $\{m(\gamma,F)\}$ of the dominant firm. In other words, since the dominant firm's supply strategy affects the price distribution, which affects the size of the competitive fringe, the dominant firm will act like a Stackelberg competitor taking (3) as determining the competitive fringe's response to his *strategy*.

How is $m(\gamma, F)$ determined? For the moment let us hold F constant and ignore information acquisition costs $C(F)$. For *fixed* S, F, γ, and $m(\gamma, F)$, (2) induces a distribution on p. Call this distribution $f_2(p)$.[28] (If $F = 1$, no residual randomness is left after the information acquisition takes place and $f_2(p)$ is degenerate. Remember that the dominant firm only observes the random demand of F percent of the market. The observed γ refers only to the first F percent of the market.) Expected profits, π_1, conditional on S, F, γ, and $m(\gamma, F)$ equal

$$\pi_1(m(\gamma, F)) = \int \pi_0(m(\gamma,F),p) f_2(p) dp,$$

where

$$\pi_0(m(\gamma, F),p) = [p-c]\, m(\gamma, F).$$

The monopolist wants to choose a strategy that maximizes the expectation of $\pi_1(m(\gamma, F))$ when γ is regarded as random. The monopolist therefore maximizes $\pi(F) = E(\pi_1(m(\gamma, F)))$ with expectations taken with respect to γ. Finally, the monopolist chooses the optimal amount of investment in information by maximizing $\pi(F) - C(F)$ or equivalently by choosing F such that

$$\pi'(F) = C'(F). \tag{4}$$

Throughout the maximization, the relation between S and $m(\gamma, F)$ as summarized in (3) is taken into account.

The above formulation can be used to determine the optimal F, optimal strategy, $m(\gamma,F)$, and resulting S that characterize equilibrium in the model. One interesting feature of this model is that the dominant firm will find it optimal to produce positive output even when the expected price is below the constant costs of production. In other words, even if the dominant firm knows in advance that demand is so low relative to the amount supplied by the competitive fringe that price will be below the constant production costs, the dominant firm may still choose to produce. This strategy is profit maximizing for the firm because although the firm loses money when it produces when price is below constant production costs, if it did not produce in those demand states then the price distribution would be affected in such a way as to encourage entry. This resulting entry would reduce profits of the dominant firm in all states of demand. The dominant firm follows a conscious policy of trying to keep price low in some states to discourage entry so that when demand is high, the dominant firm can reap high monopoly profits.

There is one inessential indeterminacy in the problem that becomes obvious on reflection. Suppose that the monopolist's optimal output m as a function of the observed state of nature γ is $m(\gamma)$.[29] Let

$$\min_{\gamma} m(\gamma) > 0.$$

Suppose the competitive output is S. Notice that the price distribution, output produced, and monopoly profits are unchanged if we consider the equilibrium monopoly output $m^*(\gamma) = m(\gamma) + \Delta$, and equilibrium competitive supply $S^* = S - \Delta$ for

$$0 < \Delta < \min_{\gamma} m(\gamma).$$

Since on any fixed amount of output Δ expected profits are zero, we see that the relevant issue is not the size of the monopolist's output relative to the competitive fringe, but rather the variation in the monopolist's output above some fixed level. As long as a firm produces a fixed amount of output, it makes no difference whether we regard the firm as part of the competitive fringe or as a division of the dominant firm. For expositional ease, in the example to follow I will make S as large as possible so that

$$\min_{\gamma} m(\gamma) = 0.$$

However, the reader should bear in mind that this assumption has no effect on the market equilibrium.

A simple example is the easiest way to illustrate the above points and show how the dominant firm can solve for its optimal strategy. In the example, we will for simplicity initially suppress the decision of the firm to optimally acquire information.

Assume that some dominant firm either has perfect information about demand or has determined that it is optimal for it to be perfectly informed. Let the market demand curve be

$$D(p) = a - p + \epsilon,$$

where ϵ is a random variable with mean 0 and variance σ^2, p is price, and a is a constant. (For purposes of this section, the probability distribution of ϵ need not be specified.) Let S stand for the output of the competitive fringe. Production by the competitive fringe must occur before price is observed. Competitive entry will occur until expected price equals constant production cost c. Since ex ante the world always looks the same to the competition fringe, S will be a constant. The residual demand curve facing the dominant firm is

$$D^R(p) = a - p - S + \epsilon.$$

By assumption, the dominant firm has invested in information and knows ϵ before production decisions are made. Let $m(\epsilon)$ represent the optimal output of the dominant firm when ϵ is observed. Then price is a random variable that varies as ϵ varies. Price is determined by the condition (analogous to (2)) that supply equals demand or

$$S + m(\epsilon) = a - p + \epsilon$$

or

$$p = a - S - m(\epsilon) + \epsilon. \tag{5}$$

The above equation determines the distribution of price. In particular, the expected value of price is

$$E(p) = a - S - E[m(\epsilon)].$$

Expansion of the competitive fringe will continue until $E(p) = c$ or until

$$c = a - S - E(m(\epsilon)),$$

so

$$S = a - c - E(m(\epsilon)). \tag{6}$$

This last condition determines S as a function of the entire output strategy of the dominant firm. The dominant firm recognizes this interdependence and takes it into account in determining its optimal strategy. We can now write down the dominant firm's optimization problem.[30] The dominant firm wishes to choose the function $m(\epsilon)$ to maximize the expected value of profits with price being determined by (5) and the size of the competitive fringe being determined by (6).

Mathematically, the dominant firm wants to

$$\max_{m(\epsilon)} \int [p(\epsilon) - c]\, m(\epsilon)\, dG(\epsilon)$$

subject to $p(\epsilon) = a - S - m(\epsilon) + \epsilon$, and $S = a - c - \int m(\epsilon)\, dG(\epsilon)$, where $G(\epsilon)$ is the cumulative density of the random variable ϵ.

Substituting $p(\epsilon)$ and S into the profit expression, we obtain the following calculus of variations problem:

$$\max_{m(\epsilon)} \int [\bar{m} - m(\epsilon) + \epsilon]\, m(\epsilon)\, dG(\epsilon),$$

where $\bar{m} = E(m(\epsilon))$.

Consider the variation $\delta s(\epsilon)$ around the optimal policy $m(\epsilon)$. Let $m^*(\epsilon) = m(\epsilon) + \delta s(\epsilon)$, and therefore $\bar{m}^*(\epsilon) = \bar{m}(\epsilon) + \delta \bar{s}(\epsilon)$, where a bar stands for expected value. Substitute $m^*(\epsilon)$ into the objective function and set the derivative with respect to δ equal to 0 when δ is zero. This derivative with respect to δ must[31] equal 0 if $m(\epsilon)$ is the optimal policy. Performing these calculations, one finds that the solution is

$$m(\epsilon) = \frac{\epsilon}{2} + K, \quad S = a - c - K,$$

$$m(\epsilon) + S = a - c + \epsilon/2, \quad \text{and} \quad p = c + \epsilon/2, \tag{7}$$

where K is a constant.

To avoid the indeterminacy of K and in view of the previous discussion, we let $\epsilon_{\min} = \min \epsilon$ and set $K_{\min} = \epsilon_{\min}/2$. Setting $K = K_{\min}$ in (7) ensures that

$$\min_{\epsilon} m(\epsilon) = 0$$

so that $m(\epsilon) \geq 0$ for all ϵ.[32]

Notice that when $\epsilon < 0$, $p(\epsilon) - c < 0$, yet the dominant firm still produces a positive quantity. Price being below marginal cost does not imply that marginal revenue is below marginal cost for the dominant firm. As discussed earlier, the feedback of the output strategy on the size of the competitive fringe explains this result. The dominant firm's strategy then is to produce in all states—but to produce the most when demand and price are the highest. This profit maximizing behavior can be viewed as a sophisticated form of "predatory" or "limit" pricing in which the dominant firm occasionally chooses to produce and sell at prices below marginal cost in an effort to control the size of the competitive fringe.

The expected profits of the optimally behaving dominant firm equal

$$\int [\bar{p} - c]\, m(\epsilon)\, dG(\epsilon) = \int (\bar{m} - m(\epsilon) + \epsilon)\, m(\epsilon)\, dG(\epsilon) = \int \left(\frac{\epsilon}{2}\right)^2 dG(\epsilon) = \frac{1}{4}\sigma^2,$$

where σ^2 is the var ϵ. This result is intuitively appealing. The advantage of the dominant firm is its ability to detect changes in demand. The level of demand will only influence the size of the competitive fringe. Therefore, profits of the dominant firm will depend on the changes (variability) in demand and not on the average level of demand.

The deviation of price from marginal cost equals $\epsilon/2$ so that the expected deadweight loss to society from the dominant firm equals $\frac{1}{8}\sigma^2$. Even though the competitive output derived in section 2.2 and the *expected* market output in this case[33] are identical, because output of the dominant firm varies in response to ϵ, the deadweight loss is *lower* in a market structure with a dominant firm and competitive fringe than in a purely competitive market.[34] The intuitive reason for this result is that the competitive fringe removes any persistent expected distortions between price and marginal cost, while the dominant firm, even though it follows a "predatory" policy, makes sure that industry output responds to shifts in demand. Any laws limiting the ability of the dominant firm to respond to demand fluctuations (such as one prohibiting production if price is below c) will tend to increase deadweight loss.

In the preceding example, the optimal choice of information investment was suppressed and for expositional simplicity was taken to be complete (the fraction $F = 1$ of the population was surveyed by the dominant firm). The level of F will of course determine the type of uncertainty in demand that the dominant firm and competitive fringe face. The marginal cost of information will influence the optimal F, which will in turn influence the size of the competitive fringe. If no information is collected by the monopolist, then all market power vanishes and we approach the (unplanned) competitive equilibrium discussed in section 2.2. If complete investment ($F = 1$) takes place, then we approach the market equilibrium just presented.

To examine these points more concretely, consider the more general demand curve used earlier:

$$D(p) = a - p + \sqrt{F}\, V_1 + \sqrt{1-F}\, V_2,$$

where $0 < F < 1$, V_1 and V_2 are independent random variables with mean 0 and variance σ^2 (for purposes of this section, the probability distributions of V_1 and V_2 need not be specified), the realization of $\sqrt{F}\, V_1$ can be observed at cost $C(F)$, and $\sqrt{1-F}\, V_2$ is unobservable at the time production must occur. Following the steps presented earlier in this section for determining the optimal policy, it follows that, for fixed F, the optimal strategy of the dominant firm as a function of the observed V_1 and the resulting equilibrium are given by

$$m(V_1) = \sqrt{F}\frac{V_1}{2} + K, \quad S = a - c - K, \quad S + m(V_1) = a - c + \frac{\sqrt{F}}{2}V_1,$$

$$p(V_1, V_2) = c + \frac{\sqrt{F}}{2}V_1 + \sqrt{1-F}\, V_2$$

$$\pi(F) = F\frac{\sigma^2}{4} \text{ (ignoring information acquisition costs),}$$

where K is the arbitrary constant discussed earlier. If $C(F)$ is the cost of finding out about F percent of the population, the optimal F (assuming an interior solution) satisfies $\pi'(F) = \sigma^2/4 = C'(F)$. Recalling the results of section 2.3, we see that although the profits of the dominant firm are lower than those of the monopolist, the incentives to invest in information are unchanged. This result is not of course general. The differences in information investment will in general depend on the differences in behavior of the marginal revenue schedule to new information in the regions of the monopoly and dominant firm output (see the discussion in the appendix).

If we measure the size of the competitive fringe by the minimum output that is always produced,[35] then it is clear from the solution just presented that the size of the competitive fringe shrinks as investment in information (i.e., F) increases. The optimal F increases as the variance of demand increases and as the marginal cost of information falls. Therefore, it follows that the larger the variance of demand and the lower the marginal cost of information, the smaller the size of the competitive fringe. It also follows that under the same conditions, the profits of the dominant firm rise.[36]

2.7 Summary and Conclusions

We have examined market structure in markets where knowledge of the next period's demand is socially beneficial to suppliers since it enables suppliers to better plan their production. When demand is random, the purely competitive market does not generate the correct incentives for collection of the information about the demand uncertainty. Although private institutions might develop to collect such information, because of the usual problems with appropriability of information, there is no reason to believe that the socially optimal amount of information will be collected. Examination of the monopoly case showed that although the monopoly firm does have an incentive to invest resources in planning and thereby does adjust its output to demand fluctuations, the deadweight losses from the monopoly are likely to swamp any losses that arise from not planning in the purely competitive case.

We next examined a market structure with a dominant firm(s) and competitive fringe. This market structure could arise if one or a few colluding firms had sole access to information acquisition or if, as a result of the natural incentives to merge, one or a few colluding firms emerge that are able to maintain and exercise market power. Analysis of this market structure showed that the size of the competitive fringe would be positively related to the marginal cost of information and negatively related to the variance of demand. The profits of the dominant firm would be positively related to the variability in demand and negatively related to the total and marginal cost of information. The dominant firm follows a "predatory" policy designed to limit the size of the competitive fringe. The dominant firm produces even when price is below marginal cost in order to keep the competitive fringe small and thereby increase its monopoly returns when demand is high. The dominant firm has an incentive to vary its output in response to demand fluctuations. The presence of the competitive fringe removes any persistent distortion between price and marginal cost. As a result, the deadweight loss to society from a market structure consisting of a dominant firm with a competitive fringe is lower than the deadweight loss from a market structure of either pure competition (with no planning) or pure monopoly (with planning).

The links between information, planning market structure, and behavior seem to be sufficiently strong to warrant further research. Understanding these links could improve our understanding of differences in market behavior. For example, in markets with little planning the variation of prices should be greater than in markets with much planning, while just the reverse should be true for quantity variation. In markets with planning, contracts may be the mechanism by which demanders convey information to suppliers and which suppliers use to make sure that what demanders predict for their demands turns out to be their demands. A contract[37] specifying a quantity to be bought at tomorrow's prevailing price plus a discount equal to the demander's information cost of predicting demand could emerge as the most efficient mechanism for suppliers to acquire information.

Knowledge of the link between market behavior and structure and planning and information could also be useful in the formulation of a coherent public policy toward market structure. When the purely competitive outcome is not the socially desirable one, one must treat proposals to break up industries into atomistic competitors very cautiously. On the one hand, if entry barriers in *production* exist, then the analysis of the pure monopoly case in section 2.5 suggests that in most instances the argument that planning would be harmed by deconcentration should not be considered a valid defense. On the other hand, if no production advantages are present and a competitive fringe exists, then the analysis of section 2.6 suggests that the planning argument, if true, should indeed be considered a reasonable defense.

Appendix: Investment in Information: Monopolist versus Social Planner

In this appendix we discuss the conditions under which a monopolist will tend to underinvest in information relative to the social optimum. The conditions required seem sufficiently plausible to make the underinvestment result the most likely case. However, to dispel any notion that the underinvestment result must occur, we offer the following counterexample.

Suppose that there are only two possible states of demand as represented by the two demand curves shown in figure 2.1.

Let marginal cost equal $5. The social planner will maximize expected consumer surplus by producing any quantity in excess of 200. The social planner has absolutely no incentive to invest in information to find out which state of demand will prevail. The monopolist, on the other hand, has an incentive to invest in information to determine whether he should produce slightly less than 100 units and earn profits of about $500 or whether he should produce slightly less than 200 and earn profits of about $1,000. The fact that the change in revenue for the monopolist can be

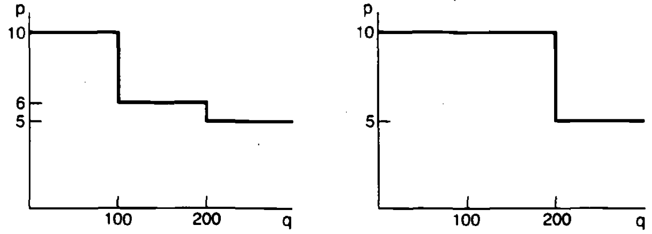

Fig. 2.1

much greater than the change in demand price is what generates the incentive for the monopolist to overinvest.

If we rule out very different behavior in the response of the marginal revenue (MR) and inverse demand (P) function to new information in the region of the monopoly solution and social optimum, respectively, then we will tend to see the monopolist underinvesting in information. The reason is simple—and is easiest to explain when (using the notation of section 2.3) the effect of the random demand component V_1 is symmetric on $\partial P/\partial F$ and $\partial MR/\partial F$ (i.e., $(\partial P/\partial F)(-V_1) = -(\partial P/\partial F)(V_1)$) and the error distribution V_1 is symmetric. Assume that $\partial P/\partial F$ and $\partial MR/\partial F$ are approximately equal on the relevant ranges so that new information does not shift the MR curve by more than it shifts the P curve.[38]

Using the notation of section 2.4, we have

$$\mathrm{SUR}(F) = \int d\psi_1 \int d\psi_2 \left[\int_0^{S(V_1,F)} P(q, V_1, V_2, F)dq - c\,S(V_1, F)\right],$$

where ψ_i is the cumulative density of V_i and $S(V_1, F)$ has been chosen optimally (i.e., $S(V_1, F)$ maximizes $\int d\psi_2 \int_0^S P(q, V_1, V_2, F)dq - cS$). By the envelope theorem,

$$\text{(A1)} \qquad \frac{\partial \mathrm{SUR}(F)}{\partial F} = \int d\psi_1 \int d\psi_2 \int_0^{S(V_1,F)} \frac{\partial P}{\partial F}(q, V_1, V_2, F)dq.$$

The monopolist's profits equal

$$\pi(F) = \int d\psi_1 \int d\psi_2 \int_0^{S^*(V_1,F)} [\mathrm{MR}(q) - c]dq,$$

where MR(q) is marginal revenue at output q and S^* is chosen optimally (i.e., $S^*(V_1, F)$ maximizes $\int d\psi_2 \int_0^S [\mathrm{MR}(q, V_1, V_2, F) - c]dq$). The envelope theorem allows us to calculate $\pi'(F)$ as

$$\text{(A2)} \qquad \pi'(F) = \int d\psi_1 \int d\psi_2 S^* \frac{\partial P}{\partial F} = \int d\psi_1 \int d\psi_2 \int_0^{S^*(V_1,F)} \frac{\partial \mathrm{MR}}{\partial F} dq.$$

From the symmetry assumption, it follows that $\mathrm{SUR}'(F) > \pi'(F)$, provided that

$$\int_{S(-V_1,F)}^{S(V_1,F)} \left|\frac{\partial P}{\partial F}\right| dq \text{ exceeds} \int_{S^*(-V_1,F)}^{S^*(V_1,F)} \left|\frac{\partial \mathrm{MR}}{\partial F}\right| dq.$$

In general, the range $[S(V_1, F), S(-V_1, F)]$ will tend to be wider than the range $[S^*(V_1, F), S^*(-V_1, F)]$. This follows directly from our assumptions since it can be shown that $\partial S^*/\partial V_1$ exceeds $\partial S/\partial V_1$,[39] so that a monopolist will tend to respond less to demand fluctuations than a social planner. Hence, under the stated assumptions, the quantity

$$\int_{S(-V_1,F)}^{S(V_1,F)} \left|\frac{\partial P}{\partial F}\right| dq$$

will tend to exceed

$$\int_{S^*(-V_1,F)}^{S(V_1,F)} \left|\frac{\partial \mathrm{MR}}{\partial F}\right| dq.$$

We expect then that provided the behavior of MR and P to new information in the relevant ranges is not too dissimilar, the monopolist will tend to underinvest in information.

Notes

1. This paragraph makes rigorous the ideas of the previous paragraph. This paragraph can be omitted if the reader is willing to accept that a demand curve like equation (1) is consistent with the ideas of the previous paragraph.

2. For simplicity, throughout this paper we ignore the nonnegativity constraint on price and quantity. The probability of negative values can be made arbitrarily small by appropriate choice of a and σ^2.

3. Alternatively, at a cost, it is possible to reduce the prediction error of total demand below σ^2.

4. F will be a number between 0 and 1. However, for expositional simplicity we will talk about the first F percent of the market, rather than the first 100 F percent of the market.

5. Alternatively, the information investment of $C(F)$ has lowered the prediction error of demand from σ^2 to $(1 - F)\sigma^2$.

An alternative, perhaps more readable and less rigorous, derivation goes as follows: Imagine that there are N demanders each of whom has a demand curve $f(p) + \epsilon_i$, $i = 1,\ldots,N$, where ϵ_i are independent normal random variables with mean 0 and variance σ^2. Total mean demand is $Nf(p)$, while the variance of demand is $N\sigma^2$. We want to let the number of demanders become large and the demand curve change so that (a) each demander becomes an infinitesimally small part of the market and (b) the mean and variance of total industry demand remain bounded and approach some finite values. One way to do this is to let N approach ∞ at the same rate that expected demand per agent approaches zero and at the same rate that the variance of ϵ_i goes to zero. For example, if agents in any interval $[Z_0 + dZ, Z_0]$ demand $(a - p)dZ + \eta\sqrt{dZ}$, where η has mean zero and variance σ^2, then the total demand of agents in $[Z_0 + dZ, Z_0]$ is going to zero as is the variance. However, the total demand in the interval $Z \in [0,1]$ can be written as $a - p$ plus a normal random variable with mean 0 and variance σ^2. If demands of agents in the interval

$[0,F]$ are added to the (independent) demands of agents in the interval $[F,1]$, we obtain total demand; hence, total demand can be written as

$$a - p + W_1(F) + W_2(1 - F),$$

where $W_1(F)$ and $W_2(1 - F)$ are independent normal random variables with mean 0 and variances $F\sigma^2$ and $(1 - F)\sigma^2$, respectively. (See Cox and Miller 1970 for a more detailed discussion.)

6. Similar results emerge as long as suppliers must make some commitment to production before demand is known.

7. It is, of course, irrelevant whether the demander hires someone else to figure out his future demand or whether he does it himself.

8. Restrictions on the ability to borrow and to save to smooth income over time as well as ignorance of the relevant price distributions can sometimes alter the preference of demanders for variable versus fixed prices (see Hanoch 1974). These conditions seem unlikely to apply to firms. We ignore these conditions in the remainder of the paper.

9. The arguments in this paragraph can be restated precisely as follows: It can be shown that in competitive equilibrium with expected price equal to c, the marginal gain in a supplier's profits from knowing an agent's demand is of order dZ^2 while the marginal cost of acquiring the information is of order dZ. Therefore, no (infinitesimal) supplier has an incentive to acquire information. Only if suppliers are of finite measure and thereby have some market power to prevent expected price from equaling c can there be an incentive for a supplier to purchase information from a demander.

10. This point is similar to the one Arrow (1971) makes about incentives for discovery of new production techniques that will be widely copied immediately after their introduction. It is also related to the point that Green (1973), Grossman (1976, 1977), and Grossman and Stiglitz (1976, 1980) analyze in the context of efficient markets.

11. A trade association of demanders that reveals information to suppliers runs into the same problem.

12. With correlated demands and costs to information acquisition, a futures market among demanders cannot exist if price accurately aggregates demand information (Green 1973; Grossman and Stiglitz 1976). A "noisy" futures market (i.e., one where price does not reveal completely the knowledge of the informed traders [Grossman and Stiglitz 1980]) could provide an incentive for demanders to acquire information, earn a return on it, and thereby transmit "noisy" information to suppliers. Suppliers would then have an incentive to contact the knowledgeable demanders to get rid of the "noise" in the signal, and then would be back to the situation discussed above where firms have incentives to merge and where competitive firms adjust production until expected price equals marginal cost at which point incentives for information transmission vanish.

Ostroy's comments which criticize me for never having considered the case of correlated demands completely baffle me in light of the paragraph in the text above. Correlated demands do not eliminate the externality problem, contrary to Ostroy's comments. The externality problem persists under competition regardless of the stochastic demand structure.

Incidentally, Ostroy's criticism of the independent stochastic setup of demand is unfounded. Ostroy criticizes the assumption of the independence of individual demands because it implies that the fraction of individual demand that is explained by price becomes vanishingly small relative to the fraction of aggregate demand explained by price—and Ostroy knows of no justification for this result. Ostroy's "criticism" is equivalent to the "criticism" that the R^2 of an equation based on aggregate data is higher than the R^2 of an equation based on less aggregate data, and that the R^2 falls as the data become more disaggregated. Contrary to Ostroy's implication, such behavior of R^2 is indeed common (see, e.g., p. 181 of Theil 1971). This behavior provides an empirical confirmation of the applicability of the independent stochastic specification.

13. This expectation is with respect to the price distribution conditioned on the information.

14. An alternative interpretation is that investment can be undertaken to reduce the prediction error of demand next period by F percent.

15. Expectation is taken with respect to V_2.

16. Expectation is taken with respect to V_1.

17. The analysis assumes that expected consumer surplus is the appropriate indicator of welfare. See Carlton (1978) for an examination of this issue.

18. Expectation is taken with respect to V_2.

19. See appendix for more detailed discussion.

20. This comparison favors monopoly because it follows from the model that the deadweight loss of a monopolist falls as information acquisition costs decline to zero, and he acquires more information about demand to improve his planning.

21. In a continuous time model of demand with cost of adjustment, "long" and "short" run are not precise terms. The basic point is that in equilibrium, monopoly price can be a constant. Although raising price above this constant might initially lead to high profits, eventually, after demand has adjusted, total profits will fall. A monopolist may operate in the inelastic portion of his (very) "short-run" demand curve.

22. The fact that price variability can affect demand by influencing preferences for technologies with lots of substitution possibilities would also have to be taken into account in comparing monopoly to competition. Since the price variability of monopoly is closer to that of the social optimum than is the price variability of competition, we expect this effect to improve the position of monopoly relative to competition.

23. Earlier, we also briefly discussed incentives to merge among buyers. We henceforth ignore this possibility by making the implicit assumption that it is very costly to organize buyers, though not sellers. However, the reader should realize that the subsequent analysis could easily be redone with a dominant buyer (not seller) who gathers information, a non–information gathering group of buyers, and competitive sellers.

24. Recall that if firms which acquire information do not collude to restrict output, then it is impossible for there to exist an equilibrium that provides incentives for information acquisition in the model under examination.

25. This cost could be in the form of a price lower than the monopoly one. The point is that a useful theory of oligopoly may be one that postulates similar patterns of behavior to the oligopoly as a monopolist would exhibit but that allows the returns to the oligopoly to be below those of the monopoly because of the difficulty of colluding.

26. The reader who is not interested in the general solution to this problem can skip to the paragraph after equation (4).

27. The monopolist observes that γ is the value of a random parameter (a sufficient statistic) for the first F percent of total market demand. If no sufficient statistic exists, then γ can be regarded as the vector of random components for the first F percent of the market.

28. Recall that $f_1(p)$ was based on the assumption that $F, S, m(\gamma, p)$ were fixed but γ was random.

29. For notational simplicity, we henceforth will suppress F in writing $m(\gamma, F)$ and simply use $m(\gamma)$ to stand for the firm's optimal strategy.

30. Several nonnegativity constraints are being ignored for simplicity. We later give an example to show that there is a solution with these constraints satisfied.

31. Since the objective function is concave, this condition is necessary and sufficient for a maximum.

32. We must also require that $S \geqslant 0$ and $p(\epsilon) \geqslant 0$ for all ϵ. A numerical example satisfying all required nonnegativity constraints is $c = 2$, $a = 10$, and ϵ uniform on $[-1, 1]$. The optimal strategy is $m(\epsilon) = \epsilon/2 + 1/2$, the competitive fringe output is $S = 7\frac{1}{2}$, and the price is $p(\epsilon) = 2 + \epsilon/2$.

33. Recall that market output $S + m(\epsilon_1) = a - c + \frac{1}{2}\epsilon$.

34. Even if we assume the profits are dissipated by cartel enforcement costs and therefore include profits as part of the deadweight loss, the conclusion stated in the text is valid.

35. Whether the constant amount is produced by the dominant firm or a competitive firm is irrelevant. No monopoly profits can be made on this output.

36. More precisely, if we perturb the initial optimal solution by lowering the marginal cost of information and by not increasing the total cost of information at the initial optimum, then profits rise in the new optimal solution.

37. See Carlton (1979b) for further discussion about the information role of contracts.

38. If the (inverse) demand relation can be written as $P = g(q) + \sqrt{F}\,V_1 + \sqrt{1-F}\,V_2$ for some $g(\cdot)$ with V_1, V_2 independent, then these assumptions will be satisfied exactly.

39. If $\partial MR/\partial V_1 = \partial P/\partial V_1$ as assumed (this is the same assumption as $\partial MR/\partial F = \partial P/\partial F$), then the condition required for $\partial S/\partial V_1 > \partial S^*/\partial V_1$ is simply that the slope of the MR curve exceeds that of the P curve in the relevant ranges. This follows since by comparative statics we have

$$\frac{\partial S}{\partial V_1} = -\int d\psi_2 \frac{\partial P}{\partial V_1} \div \int d\psi_2 \frac{\partial P}{\partial S}.$$

and

$$\frac{\partial S^*}{\partial V_1} = -\int d\psi_2 \frac{\partial MR}{\partial V_1} \div \int d\psi_2 \frac{\partial MR}{\partial S^*}.$$

Again, we see that the underinvestment result depends on how different the behavior of MR and P are over different ranges of output.

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Comment Jean-Jacques Laffont

The message that Dennis Carlton wants to transmit is clear and interesting, but I will argue that he does not provide a totally convincing model and that he ignores a number of alternatives relevant for his problem.

Information about future demand conditions of a given commodity is in a world of a large number of buyers and sellers, a public good. There is a free rider problem in the financing of this public good from the point of view of sellers of the commodity, and demanders prefer random prices, that is to say, no production of public good. Consequently, it is argued that in a competitive situation no information will be bought and therefore that the outcome will be inefficient. Information here is some sort of public input for sellers. Hence, when the seller is a monopoly, it is in his interest to finance information gathering; indeed, the free rider problem disappears since he is the only one to use that information.

The author then compares the two inefficiencies, that associated with monopolistic behavior on one hand and that associated with the free rider problem on the other. The numerical values given in this comparison are not to be taken seriously, I think, but illustrate the trade-off.

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The basic assumption, which is implied by the use of a continuum, is that the search cost of information is, for an individual, infinitely larger than the use he can make out of it. It is not clear to me that in this problem such is necessarily the case.

First, if the seller faces a large number of stochastically independent buyers, a small random sample may be of great value in predicting the future demand conditions, suggesting that the modelization of the aggregate demand function is rather special (see also J. Ostroy's comment).

Second, it is implicitly assumed that the market will be unable to react to the inefficiency created by the lack of forecasting. Why does not a (competitive) industry appear in the production of this information? The success of DRI on the stock market suggests that selling information to a large number of users is not so difficult despite a real public good aspect to it.

Third, recent literature on incentives has shown that there are many ways in which the state can intervene to mitigate the free rider problem.

Therefore, the simple comparison between monopoly and competition is not really policy relevant.

In the last section the author suggests that the "most likely" market structure will be a monopoly with a fringe of competitors, but the reasons why this should be the case remain mysterious.

Comment Joseph M. Ostroy

The author asks, "How [well] does information get transmitted from demanders to suppliers in a competitive market?" The answer is, "We show that a competitive market is uniquely unsuited to the efficient transmission of this information." After examination of the competitive case, Carlton addresses the equilibrium and efficiency properties of monopoly and dominant firm models. I shall confine my remarks to the competitive market. My conclusion will be that the author's results can be attributed to a rather extreme assumption on the stochastic properties of individual demands. Once these assumptions are denied, the usual efficiency properties of competitive equilibrium reemerge and, unless there are scale economies in production (ruled out by the author), monopoly would not arise.

I shall focus on the demand side of the market which the author requires to have the following three properties:

(I) a large number of buyers,

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(II) random disturbances to individual demands are independently distributed, and
(III) aggregate demand, the average of individual demands, has a nonvanishing variance.

Condition (I) would be required for a competitive market even without stochastic elements. Coupled with (II) no buyer/seller has much of an incentive to reveal/discover the value of anyone's random component of demand because this will have little influence on market price, the medium through which rewards for such communication are obtained. For example, if price will not change as a result of its discoveries, why should a firm want to know the value of some one or a few individuals' random components of demand. Without (III), the market-clearing price will not fluctuate and the market will behave as if individual demands were perfectly certain.

An appeal to Laws of Large Numbers would appear to contradict the existence of (I), (II), and (III). We may have (I) and (III) if, for example, the random components of individual demands are perfectly correlated. We may have (II) and (III) if the number of buyers is small. And (I) and (II) are compatible if we rule out (III). How then can we achieve (I)–(III)? The answer is that we must require the variance of each individual's demand to overwhelm the price-determined, or nonrandom, component.

Let $\omega_n = (X_1^n, \ldots, X_n^n)$, where for each $i = 1, \ldots, n$, $X_i^n \in \{\sigma_n, -\sigma_n\}$, and let $\Omega_n = \{\omega_n\}$. It will also be convenient to define $\omega_n^0 = \Sigma_{i=1}^{i=n} X_i^n$.

The demand side of a market with n agents is denoted M_n and is defined by the n demand functions d_i: $R \times \Omega_n \rightarrow R$, $i = 1, \ldots, n$, where

$$d_i(p, \omega_n) = f(p) + X_i^n.$$

We are assuming that each agent's demand is composed of the sum of a deterministic term $f(p)$ that does not vary with the particular agent in M_n or the size of the market, and a random term X_i^n that varies with i and n.

Condition (II), independence, is obtained by assuming each $\omega_n \in \Omega_n$ has probability $(2^n)^{-1}$. Therefore, $E(X_i^n) = 0$ and var $(X_i^n) = \sigma_n^2$. Note that while the mean of individual random variables is independent of i and n, the variance of *individual* demand may depend on the number of agents in the market.

Because n will vary, normalize quantities so that aggregate demand $D_n(p, \omega_n)$ is average demand—i.e.,

$$D_n(p, \omega_n) = n^{-1} \Sigma d_i(p, \omega_n) = f(p) + n^{-1} \omega_n^0.$$

(This is in line with the author's analysis.)

The following result is a corollary of the Kolmogorov version of the Strong Law of Large Numbers (W. Feller, *Introduction to Probability Theory and Its Applications*, vol. 1, 2d ed. [New York: Wiley], pp.

243–44): If $(\sqrt{n})^{-1}\sigma_n \to 0$, then for any $\epsilon > 0$ and $\delta > 0$, there is an N such that for $n > N$,

$$\text{prob}\{|D_n(p,\omega_n) - f(p)| > \epsilon\} < \delta.$$

Therefore, if the standard deviation of individual demands σ_n is uniformly bounded, the stochastic component of aggregate demand vanishes. (This follows from the standard version of the Strong Law.) Further, even if $\sigma_n \to \infty$ but not as rapidly as $\sqrt{n}$, the same conclusion holds. Thus, the only possibility for achieving (I)–(III) is to add

(IV) $$\lim(\sqrt{n})^{-1}\sigma_n \neq 0.$$

The objection may be made that (IV) is needed simply because the definition of aggregate demand is average demand. This is certainly true, but as far as the implications for competitive analysis are concerned division by n is warranted. Let p^* be the competitive equilibrium price when there is no randomness ($\sigma_n = 0$)—i.e., p^* equals the constant marginal cost assumed in the paper. Assume for convenience that $f(p^*) = 1$. Now suppose sellers supply $nf(p^*) = n$ units each period and that the realized market-clearing price p fluctuates around p^* to compensate for the realized value of ω_n^0.

Realized price will be a function of ω_n^0 that solves the demand = supply equation

$$nf(p) + \omega_n^0 = nf(p^*) = n.$$

Dividing by n, p varies with ω_n^0 to satisfy

$$f(p) + n^{-1}\omega_n^0 = 1.$$

Again, we reach the conclusion that the distribution of realized prices collapses on p^*, unless we admit (IV).

These results indicate that if σ_n is uniformly bounded and n is large, the randomness can be ignored. However, there is a small difficulty. Let Φ_n be the distribution of prices in M_n when sellers supply $nf(p^*)$, and let $v(\Phi_n)$ be the value of the loss attributed by a typical buyer to Φ_n as compared with a distribution which has all its mass on p^*. The latter distribution might be achieved by permitting buyers to communicate the realizations of their random variables before supply decisions are made. There does not seem to be any guarantee that what might be called here the value of perfect information $nv(\Phi_n)$ goes to zero as n increases. However, such losses appear to be unavoidable.

Presumably, there is some cost c of communication of the realization of any buyer's random variable. By *independence*, total costs of communication vary directly with the number of buyers in the market, e.g., nc. When σ_n is uniformly bounded above, we may conclude that since Φ_n collapses to p^*, $\nu(\Phi_n) \rightarrow 0$. Therefore, the net benefits of communication to completely stable prices are

$$n[\nu(\Phi_n) - c],$$

which are negative when n is sufficiently large.

If the error terms were *dependent*, all of the above would change. Take the extreme case where the error terms are perfectly correlated: $X_i^n = \sigma_n$ implies $X_j^n = \sigma_n$ with probability one. Clearly, since ω_n^0 would take only the values $n\sigma_n$ or $-n\sigma_n$ with equal probability, the variance of individual and average demand would be identical and there would be no need to consider increasing σ_n. Now the question of communication becomes more interesting. Knowledge of one buyer's error term tells you everything. It would be redundant for all suppliers individually to discover the value of the random variable or for all buyers to communicate their identical information. But which buyer will reveal it, or how many sellers will try to discover it? Because he assumes independence, these problems cannot arise in the author's formulation of the problem.

Returning to the model under discussion, we have shown that (I)–(III) implies (IV). This means that *the proportion of an individual's demand that is explained by price becomes vanishingly small*—i.e.,

$$\lim_n \frac{f(p)}{f(p) + \sigma_n} = 0.$$

I know of no precedent, empirical or theoretical, to justify (IV). Perhaps it might be used as a mathematical expression of the idea that in some markets individual demands are simply not very much influenced by price even though aggregate demand appears to be! But this would be the starting point for a very different paper.