Innovation, Market Structure, and Welfare

By PANKAJ TANDON*

Many writers subscribe to Joseph Schumpeter's view that, while perfectly competitive firms allocate resources efficiently in a static sense, they perform poorly when it comes to innovation.[1] From this point of view, the optimal form of market structure is unlikely to be perfect competition, but some other type of dynamic competition which includes significant elements of monopoly. Recently, considerable effort has been focused on modelling Schumpeter's notion of competition. Perhaps best exemplified by the 1980 work of Partha Dasgupta and Joseph Stiglitz (hereafter D-S),[2] this approach views free entry to the *R&D* game, rather than to production, as the relevant notion of dynamic competition.[3] Thus the market structure in production activities is endogenous in the model.

This paper extends the D-S approach to discuss the tradeoff between static and dynamic efficiency. The question asked is: what is the optimal market structure or optimal degree of concentration? The purpose is to compare the modified notion of competition (what D-S call a "free-entry oligopoly") with other types of blocked-entry oligopoly. A different way of stating the question then is: *are barriers to entry, in addition to those created by R&D, desirable?*

I show that the D-S approach will answer this question in the affirmative. However, a careful examination of the tradeoffs reveals a rather stronger result. It can be argued that, at the level of entry characteristic of the free-entry oligopoly, there may be no tradeoff at all! Purely static considerations are shown to lead a social welfare maximizer to argue for *increased* concentration. The fundamental reason is still the tendency towards scale economies that *R&D* results create.[4] By entering the industry, the marginal firm will inhibit the reaping of these scale benefits by inframarginal firms. Thus the marginal firm will in general make a net negative contribution to social welfare, even when we disregard the further dynamic effect on *R&D* incentives. Of course, once the industry is more concentrated than the free-entry outcome, this "perverse" static effect may begin to disappear. The result is similar in some respects to that of Stiglitz (1981) for the case of potential competition, although the driving force is different.

To demonstrate the point, an illustrative model of the D-S type is developed. It is found that the free-entry outcome performs relatively worse for industries that are characterized by high levels of technological opportunity.[5] Some simple numerical calcu-

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[1]The "Schumpeterian tradeoff" is referred to repeatedly. See, for example, Paolo Sylos-Labini (1969), F. M. Scherer (1980), C. C. von Weizsacker (1980), Richard Nelson and Sidney Winter (1982), and Morton Kamien and Nancy Schwartz (1982).

[2]There is a large and growing literature in this area. See, for example, Kamien and Schwartz (1972, 1976), Glenn Loury (1979), Carl Futia (1980), and my 1983 article. For a first attempt at empirical work in this area, see Richard Levin (1981). An alternative approach involves the use of simulation models; see Nelson and Winter (1977).

[3]Readers will recognize a similarity of this approach with the notion of contestable markets discussed most recently by William Baumol (1982) and by Baumol, John Panzar, and Robert Willig (1982). For an interesting comparison of the Schumpeterian with the Marxian notion of competition, see John Elliott (1980).

[4]This was noted, for example, by Robert Wilson (1975).

[5]In such industries, the long-term gains from dynamically efficient innovation become of paramount importance; consequently, the optimal market structure would consist of a small number of firms. The driving force behind such a result is what Scherer (1972) has called the "Lebensraum effect." Firms performing *R&D* must at least break even. They derive their profits from

lations carried out in Section II correspondingly suggest that the optimal degree of concentration rises as technological opportunities improve. It is found, however, that except for very high values of the technological opportunity parameter, the optimal degree of concentration will typically involve more than one firm. Thus although the free-entry outcome results in *excessive* duplication, it is seen that not *all* duplication is entirely wasteful. The reason is that the duplication of research in this second best world can indicate reduced static deadweight losses in the industry.[6]

I. A Simple Illustrative Model

The model used here is a modified version of the one proposed by Dasgupta and Stiglitz.[7] Consider the market for some well-defined new product. Consider the linear approximation to the market demand for this product:

$$p(Q) = a - bQ.$$

Let the average cost of production be c, a function of the amount of research, x, done on the product, but independent of output Q. For convenience, call the difference $(a - c)$ the "cost reduction" and represent it by B. Since c is a function of x, and a is a constant, B is also a function of x. Assume that this function is of a constant elasticity form,[8] so that

$$B(x) = \beta x^{\alpha}. \tag{1}$$

The strategy of this section will be to look at the equilibrium outcomes under free entry and blocked entry, and to compare them to the socially optimal outcomes. In this manner, the value of a welfare index can be compared for different levels of entry and the optimal number of firms computed.

A. *The Social Problem*

Suppose society wishes to maximize net social benefit. The usual notion of consumer's surplus will be used to measure consumption benefits. If society can produce this product at a cost c, the optimum price to charge for it would be c. The quantity demanded at this price would be B/b. The consumer's surplus generated by reducing the cost of production to c would then be $B^2/2b$. If this represents a per annum benefit that extends indefinitely into the future, we may aggregate these future returns using the social discount rate, r. In this case, net social welfare may be written

$$W = (B^2/2rb) - x. \tag{2}$$

The social problem then is to choose x in order to maximize W. Note that, since there is no uncertainty in this model, it is optimal

the market power with which research results endow them. In industries where it is socially desirable that large amounts of research be done— because research is highly productive—firms must be allowed a commensurate degree of market power. In industries where *R&D* is not particularly effective, more attention can be paid to static efficiency, and the free-entry outcome is comparatively better.

[6] Note that this defense of duplicative research is different from the argument I advanced in my 1983 paper. The argument there was that duplication is not always wasteful since, in the presence of uncertainty, it is a reasonable way to raise the probability of success in research.

[7] The main difference is that, whereas D-S assume the demand curve to have constant elasticity, the demand curve is taken here to be linear. The two assumptions seem in some sense to be equally arbitrary. On theoretical grounds, the constant elasticity assumption is superior, since it yields a consistent welfare index. On practical grounds, however, it is impossible to use. When the elasticity of demand is less than one, the index is negative. This obviously makes it impossible to make cardinal welfare comparisons of the kind attempted here. Further, it is well known that, if the elasticity of demand is less than unity, no monopoly equilibrium will exist. This would eliminate the possibility of a complete set of comparisons. The present framework has been used to analyze optimal patents (see my 1982a article) and has the virtue of permitting all the necessary comparisons. It should be noted, however, that the use of consumer's surplus as a welfare index has not been shown to be appropriate in general, so that the results below must be interpreted with great caution.

[8] Note that this formulation is different from that of D-S, who consider the case where $c(x) = \beta x^{-\alpha}$. Again, the two assumptions seem equally arbitrary and differ only by a constant term. I make mine for the convenience of computations presented in the next section.

for society to have only one firm. This is the sense in which this is a natural monopoly problem.

Using the functional form (1) for $B(x)$, it can be shown that the solution to the social problem involves

$$(3)\quad x_s = \left(\alpha\beta^2/rb\right)^{1/(1-2\alpha)},$$

$$(4)\quad B_s = \beta\left(\alpha\beta^2/rb\right)^{\alpha(1-2\alpha)},$$

$$(5)\quad Q_s = (\beta/b)\left(\alpha\beta^2/rb\right)^{\alpha/(1-2\alpha)},$$

$$(6)\quad W_s = ((1-2\alpha)/2\alpha)\left(\alpha\beta^2/rb\right)^{1/(1-2\alpha)}.$$

This set of results is consistent with those of Dasgupta and Stiglitz. Given a value of the demand choke point, a, the demand slope parameter may be interpreted as indicating the size of the market, with a higher absolute slope indicating a smaller market. Equations (3)–(6) show that the optimal levels of $R\&D$ and output both rise as the market expands (b falls). Further, more productive research (characterized by higher β) also calls for higher $R\&D$ and output. This is all in accord with intuition.

B. *Free-Entry Oligopoly*

Following Dasgupta-Stiglitz and other recent work in this area, the competitive situation will be taken to be one where there is free entry, but not necessarily a large number of infinitesimal firms. Because $R\&D$ is something like a fixed cost of entry, firms must earn quasi rents in equilibrium that cover this cost. Thus in the product market there will be an oligopoly. This approach is similar to the familiar monopolistic competition model, and has been used recently in several different contexts (see, for example, Steven Salop, 1979).

The usual type of Cournot-Nash outcome will be treated as the equilibrium concept. Thus any firm that enters will choose its $R\&D$ spending and its output level to maximize profits, assuming other firms will not alter their behavior. Entry occurs as long as there are positive profits. The net present value of the ith firms' profits will be given by

$$(7)\quad \pi_i = (1/r)\left[a - b\left(Q_i + \sum_{j\neq i} Q_j\right) - a + B(x_i)\right]Q_i - x_i.$$

Concentrating on symmetric equilibria,[9] the first-order conditions for (7) to reach a maximum are

$$(8)\quad (1/r)Q_iB'(x_i) = 1,$$

$$(9)\quad (n+1)bQ_i = B(x_i),$$

where n is the number of firms that have entered. A third condition that characterizes the market equilibrium is that no further entry is profitable. For the sake of analytical convenience, take this to imply $\pi_i = 0$ for all i. This ignores the integer problem, but really does not cause the model to become unrealistic. Thus

$$(10)\quad (1/r)\left(B(x_i) - nbQ_i\right)Q_i = x_i.$$

Combining (8), (9), and (10) yields the interesting result that the equilibrium number of firms n^* will be given by

$$(11)\quad n^* = (1-\alpha)/\alpha,$$

where $\alpha = (dB/B)/(dx_i/x_i)$, the elasticity of the cost reduction function. Note that the result (11) does not depend on any particular functional form for $B(x_i)$.

We may interpret α as a measure of technological opportunity. High α indicates that research is productive in producing cost reductions. Condition (11) says that the number of firms that will enter in competitive equilibrium is inversely related to technological opportunity. This is in line with the re-

[9] In general, the equilibrium may not be symmetric. An asymmetric outcome is obtained, for example, by M. Therese Flaherty (1980). Dasgupta and Stiglitz did assume a symmetric outcome. For the basic argument here, symmetry is not necessary but only a desirable simplification.

sults of D-S, although still somewhat surprising. One might expect that high possible payoffs to *R&D* might tempt many firms to enter. The factor dominant in this model, however, is that *R&D* serves as a barrier to entry. We will see in (18) below that, in industries marked by high levels of technological opportunity, *R&D* per firm will be high; thus such industries are characterized by higher entry barriers, and greater concentration.

Two other points about (11) deserve mention. First, and somewhat surprisingly, note that n^* does not depend upon the discount rate. Interestingly, this result persists in the constant elasticity demand case. A reduction in the discount rate might be expected to encourage entry since the value of a fixed revenue stream would rise. However, the cost of entry also would rise since firms would increase their *R&D* spending. Second, note that (11) does not contain any demand parameter. This result is akin to the D-S finding that the number of entrants did not depend on the size of the market, but is not robust with respect to different cost or demand conditions.[10]

To complete the discussion of this section, the outcome of equations (8)–(10), assuming the functional form (1), should be presented. In free-entry equilibrium, the level of *R&D* spending per firm, the "cost reduction" and the industry output level are computed to be

$$(12)\quad x^* = \left(\alpha^2\beta^2/rb\right)^{1/(1-2\alpha)},$$

$$(13)\quad B^* = \beta\left(\alpha^2\beta^2/rb\right)^{\alpha/(1-2\alpha)},$$

$$(14)\quad Q^* = ((1-\alpha)\beta/b)\left(\alpha^2\beta^2/rb\right)^{\alpha/(1-2\alpha)}.$$

From equation (2), recall that the present value of the potential gross social welfare gain is given by $B^2/2rb$. From this must be subtracted the triangle of deadweight loss due to the static inefficiency of price exceeding marginal cost, and of course the cost of research. Now in the linear demand case, a Cournot oligopoly produces $n/(n+1)$ times the competitive output. Thus

$$Q^* = n/(n+1)(B/b).$$

The welfare index in this case is given by

$$(15)\quad W = B^2/2rb - B^2/2rb(n+1)^2 - nx.$$

Using equations (11)–(14) and simplifying yields

$$(16)\quad W^* = (1/2)((1-\alpha)/\alpha)^2\left(\alpha^2\beta^2/rb\right)^{1/(1-2\alpha)}.$$

A comparison between these results and the social optimum, represented by equations (3)–(6) will be shown in the next section. However, a couple of observations are in order at this point. First, consider the relationship between *R&D* spending per firm and market structure. As argued earlier, we should observe high *R&D* per firm associated with concentration. Differentiating (11) we have

$$(17)\quad dn^*/d\alpha = -1/\alpha^2 < 0.$$

Increased concentration is associated with high α, that is, high technological opportunity. From (12) we have

$$(18)\quad dx^*/d\alpha = (2x^*/(1-2\alpha)) \times (1/\alpha + \ln x^*) > 0,$$

assuming $\alpha < 1/2$, which is certainly a reasonable assumption.[11] Thus high *R&D* spending per firm is associated with high technological opportunity. Combining (17) and (18) we get the result that high *R&D* per

[10]Although the parameter b cannot truly be interpreted as a "market size" parameter, it is curious that n^* does not depend on it. The parameter a in the inverse-demand curve may be thought of as indicating size. However, the model here implicitly normalizes with respect to a, rendering it difficult to analyze the effects of changing size on n^*.

[11]See Zvi Griliches (1973) for a discussion of the problems associated with estimating α and of some of the estimates that have been made. A reasonable estimate is 0.1; the highest estimate has been 0.12 by Edwin Mansfield (1965).

firm is associated with greater concentration. An obvious collary is that greater cost reductions are associated with greater concentration, which was Schumpeter's basic point, and matches the result of Dasgupta and Stiglitz. Also parallel to D-S, note from (3) and (12) that $x^* < x_s$; the free-entry oligopoly will always result in cost reductions that are too small relative to the socially managed industry.

Second, what about total $R\&D$ spending? Define $X^* = n^*x^*$. It is not immediately obvious how this varies with α, since $dn^*/d\alpha$ and $dx^*/d\alpha$ have opposite signs. However, it can be shown that $dX^*/d\alpha$ is positive.[12] Thus total $R\&D$ spending also rises with technological opportunity and concentration. If we compare X^* with x_s, we find from (3), (11), and (12) that $X^* < x_s$ always. Here, unlike the D-S model, even aggregate $R\&D$ spending remains smaller than the socially optimal level for one firm.

C. *Blocked-Entry Oligopoly*

A Cournot-Nash equilibrium for an industry with blocked entry is now examined. Suppose the fixed number of firms in the industry is n. Then (8) and (9) will be the typical firm's first-order conditions if we concentrate on symmetric equilibria. Solving these equations yields the equilibrium levels of $R\&D$ per firm, cost reduction, and industry output.

$$(19)\quad x_b = \left(\alpha\beta^2/rb(n+1)\right)^{1/(1-2\alpha)},$$

$$(20)\quad B_b = \beta\left(\alpha\beta^2/rb(n+1)\right)^{\alpha/(1-2\alpha)},$$

$$(21)\quad Q_b = \left(n\beta/(n+1)b\right) \times \left(\alpha\beta^2/rb(n+1)\right)^{\alpha/(1-2\alpha)}.$$

[12]Using (17) and (18) we may write

$$dX^*/d\alpha = -x^*/\alpha^2 + ((1-\alpha)/\alpha) \times [(2x^*/(1-2\alpha))(1/\alpha + \ln x^*)].$$

This may be simplified to

$$dX^*/d\alpha = -\left(x^*/\alpha^2(1-2\alpha)\right)[1 + 2\alpha(1-\alpha)\ln x^*]$$

which is positive for $\alpha < 1/2$.

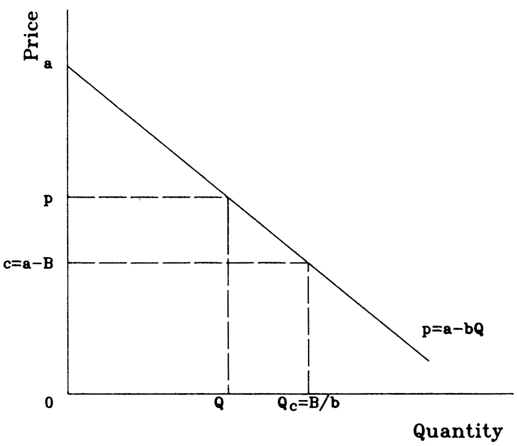

FIGURE 1

It is possible to show that, if n were given by (11) (i.e., were the free-entry number of firms), (19)–(21) would reduce to (12)–(14).

To construct the welfare index for this case, it is useful to examine Figure 1. In equilibrium, the cost of production is $c = a - B(x)$, and output is Q. Recall that in the linear demand case $Q = nQ_c/(n+1)$, where Q_c, the competitive output, is given by $Q_c = B/b$. This can be rearranged to yield $Q_c - Q = Q_c/(n+1)$. The welfare index can then be written as

$$(22)\quad W_b = B^2/2rb - (p-c)Q_c/2r(n+1) - nx_b.$$

It is now possible to take up the question of whether the free-entry outcome could be improved upon by greater concentration, solely on grounds of static efficiency. To examine the static efficiency effect[13] of there

[13]Note that I have not explicitly analyzed here the dynamic effect. It is clear that the remaining firms will have increased incentives to perform $R\&D$. The cost of production will decline, price will fall, and industry output will increase. On the face of it, this constitutes a welfare improvement. In general, I believe it will be so. However, I wish to offer an interesting alternative possibility. It *may* be that the dynamic effect could actually work in the other direction, i.e., that it could lead to a decline in welfare relative to the static $(n-1)$-firm equilibrium. The reason is the traditional rent-seeking or common pool argument. In the $(n-1)$-firm static equilibrium, each firm will be making some extra-normal profit above its $R\&D$ spending. This profit of course

being one less firm at the free-entry level of concentration, we must rewrite W_b for $(n-1)$ firms, holding x_b (the *R&D* spending level per firm) and hence Q_c, c, and B constant. Keeping in mind that price will be higher by $(p-c)/n$, we find the change in welfare is

$$(23)\quad \Delta W_b = x_b(1+2n-2n^2)/2n^2.$$

Now note that for $n \geq 2$ the right-hand side of (23) is always negative. Thus we may state the basic proposition:

PROPOSITION 1: *At the free-entry level of concentration, static efficiency improves with concentration.*[14]

For purposes of further comparison, it is useful at this point to rewrite (22) in terms of the parameters of the model. Using (19)–(21), we obtain

$$(24)\quad W_b = [n(n+2)/2\alpha(n+1)-n] \times \left(\alpha\beta^2/rb(n+1)\right)^{1/(1-2\alpha)}.$$

The optimal degree of concentration, taking into account static and dynamic effects, would be the value of n that maximizes (24). This is not easy to do analytically, but can be done numerically as the following section shows.

belongs in our measure of social welfare. It is possible that this profit will entirely be dissipated in rivalry over relatively unproductive research lines as has been argued by Yoram Barzel (1968), Jack Hirshleifer (1971), and others. In my 1983 article, I constructed a specific example to demonstrate this possibility in a model where the results of research are uncertain. I do believe, however, that in general the dynamic effect will argue for increased concentration.

[14]The sharpness of the result here does depend a bit on the restrictive functional forms assumed. However, I believe the basic point is quite general. In my 1982b article, I argued the point more generally and also considered the case of constant elasticity demand. In this case, the result continues to hold unambiguously even when the free-entry equilibrium sustains only three firms. The result also has parallels in the literature on spatial competition. See Curtis Eaton and Richard Lipsey (1978, 1979), Scherer (1979), and Salop.

II. Welfare Comparisons

There are three sets of equations derived above. Equations (3)–(6) represent the outcomes of social management; they will be taken as the ideal values of the different variables. Equations (12)–(14) and (16) represent the outcomes in a free-entry oligopoly, which is the case nearest to a competitive equilibrium that has been discussed. Finally, equations (19), (21), and (24) represent the outcomes in an industry with blocked entry.

This section makes comparisons between the socially optimum outcomes on the one hand and the free-entry and blocked-entry outcomes on the other. Comparisons are also possible between the blocked-entry outcomes for different values of n, so that it is possible to speak then of the "optimal" market structure.

Dividing the respective free-entry outcomes by equations (3)–(6) yields the following ratios:

$$(25)\quad x^*/x_s = \alpha^{1/(1-2\alpha)}$$

$$(26)\quad B^*/B_s = \alpha^{\alpha/(1-2\alpha)}$$

$$(27)\quad Q^*/Q_s = (1-\alpha)\alpha^{\alpha/(1-2\alpha)}$$

$$(28)\quad W^*/W_s = (1-a)^2\alpha^{1/(1-2\alpha)}/\alpha(1-2\alpha).$$

We see that the relative performance of the free-entry outcomes to the social optima is determined entirely by the technological opportunity parameter α. Table 1 lists the values of these ratios for different values of α, which is taken to range in value from 0.2 to 0.01. A value of 0.2 would indicate a dynamic industry characterized by high technological opportunity. It is seen from the table that, although the level of *R&D* spending as a proportion of the ideal declines as α falls, the welfare index rises. There are two significant reasons for this. First the size of the output distortion falls as the number of firms increases, that is, as α falls. This effect is clearly captured in the fifth column of Table 1, which shows the free-entry output level getting closer to the ideal level as α falls. In principle, the effect ought to be counteracted by the increased dynamic efficiency losses. The second point, however, is

TABLE 1—COMPARISON OF R&D, COST REDUCTION, OUTPUT, AND WELFARE UNDER FREE-ENTRY OLIGOPOLY WITH THE SOCIAL OPTIMUM

n^*	α	$\frac{x^*}{x_s}$	$\frac{B^*}{B_s}$	$\frac{Q^*}{Q_s}$	$\frac{W^*}{W_s}$
4	.200	.068	.585	.468	.365
6	.143	.066	.678	.581	.472
9	.100	.056	.750	.675	.570
12	.077	.048	.792	.731	.632
15	.063	.042	.820	.769	.676
20	.048	.035	.852	.811	.728
25	.038	.029	.873	.839	.763
30	.032	.025	.888	.860	.790
40	.024	.020	.909	.887	.827
50	.120	.017	.923	.905	.852
100	.010	.009	.954	.945	.911

Note: n^* is the number of firms that enter under free entry.

that, although the *R&D* ratio does decline with α, the size of the cost reduction as a proportion of the ideal *rises* as α falls. This is entirely plausible with a concave cost-reduction function.

It has already been shown that the number of entering firms varies inversely with α. High opportunity industries are characterized by concentration. From (16) it is possible to show that the welfare index W^* varies directly with α—this would indicate that industries characterized by greater concentration also have associated with them a higher value of the welfare index. However, this should not be taken as an argument in favor of concentration. The driving force behind these results is the technological opportunity parameter α. Industries characterized by high technological opportunities create more social welfare simply because technological opportunities are high. What Table 1 shows clearly is that, *relative to the ideal welfare level* W_s, the industries characterized by *less* concentration perform considerably better than those that are more highly concentrated, that is, less concentrated industries come closer to realizing the maximum possible social gains than do more concentrated industries. This is because they produce a closer-to-ideal output (fifth column, Table 1) and also generate cost reductions closer to the ideal (fourth column). It must be kept in mind that this discussion has applied only to the free-entry case.

Let us turn now to the case of blocked entry, in order that we may find the optimal level of concentration. Using equations (6) and (24), it is possible to construct for our special case the ratio of the welfare index under blocked entry to the ideal maximum:

$$W_b/W_s = [(n(n+2)-2\alpha n(n+1)) /(1-2\alpha)](1/(n+1))^{(2-2\alpha)/(1-2\alpha)}. \tag{29}$$

This is a complex equation that is not easy to interpret. It shows the welfare index ratio as a function only of α, the technological opportunity parameter, and n.

Table 2 shows the value of this welfare index ratio for different values of α and n. The first column shows the corresponding value of n^*, the number of firms that would enter under free entry. For any given value of α, the welfare index is single peaked across the number of firms, with the peak occurring at smaller values of n for higher values of α. The peak of course represents the optimal number of firms. It is seen that this optimal number tends to be rather low and is always less than n^*. Further, it falls as the industry becomes more dynamic (α rises). This is consistent with the traditional view of dynamic vs. static efficiency. The greater the technological opportunities in an industry, the greater is the social payoff to the increased *R&D* incentives generated by concentration.

TABLE 2—VALUES OF THE WELFARE INDEX W_b/W_s FOR DIFFERENT VALUES OF α AND n

		Number of Firms											
n^*	α	1	2	3	4	5	6	9	15	20	30	50	100
4	.200	.577	.498	.422	.365	.322	.290	.226	.163	.135	.103	.074	.046
6	.143	.644	.630	.581	.538	.502	.472	.408	.336	.301	.256	.209	.158
9	.100	.682	.718	.696	.669	.643	.621	.569	.505	.471	.427	.376	.316
12	.077	.701	.761	.755	.739	.720	.703	.662	.608	.578	.538	.491	.433
15	.063	.712	.787	.791	.781	.768	.753	.722	.676	.650	.614	.572	.518
20	.048	.722	.813	.828	.825	.817	.807	.784	.749	.728	.698	.662	.616
25	.038	.728	.828	.849	.851	.847	.843	.823	.794	.777	.752	.721	.681
30	.032	.731	.839	.864	.869	.868	.865	.850	.826	.811	.790	.763	.728
40	.024	.736	.851	.882	.892	.893	.892	.884	.867	.855	.839	.818	.790
50	.020	.739	.859	.893	.905	.909	.909	.905	.892	.883	.869	.852	.829
100	.010	.745	.873	.915	.932	.940	.944	.947	.943	.939	.933	.924	.911

Note: See Table 1. The underlined values point out the optimal number of firms, n_b^*.

TABLE 3—COMPARISON OF THE FREE-ENTRY AND OPTIMAL OUTCOMES

α (1)	n^* (2)	n_b^* (3)	W^*/W_s (4)	W_b^*/W_s (5)	W^*/W_b (6)	x^*/x_b^* (7)	$\frac{n^*x^*}{n_b^*x_b^*}$ (8)
.200	4	1	.365	.577	.633	.216	.864
.143	6	1	.472	.644	.733	.174	1.044
.100	9	2	.570	.718	.794	.221	.995
.077	12	2	.632	.761	.830	.176	1.056
.063	15	3	.676	791	.855	.205	1.025
.048	20	3	.728	.828	.879	.162	1.080
.038	25	4	.763	.851	.897	.166	1.038
.032	30	4	.790	.869	.909	.140	1.050
.024	40	5	.827	.893	.926	132	1.056
.020	50	6	.852	.909	.937	.129	1.075
.010	100	9	.911	.947	.962	.095	1.056

Another interesting point to note in Table 2 is that the drop in the welfare index moving from the peak to lower concentration is more dramatic at high levels of α than at low levels. Now it may be that society wishes relatively low levels of concentration for reasons other than those modeled in this paper. The point to be made here is that the cost of such antitrust action will be greater in dynamic industries characterized by high technological opportunity than in relatively "static" industries. But curiously, these are precisely the industries where concentration will tend to be more pronounced, as was seen in Table 1. Thus an interesting paradox is created for antitrust legislators.

The peaks in the welfare index for different values of α are underlined in Table 2. The number of firms at these peaks is the optimal number of firms. Of course this optimal number is a function of α. In Table 3, the optimal outcomes are compared with the free-entry outcomes. For example, n^* denotes the number of firms in free entry and n_b^* denotes the optimal number under blocked entry. For comparative purposes, the proportion of the ideal maximum welfare captured in the respective cases is presented in columns 4 and 5. This leads to column 6, which shows the proportion of the blocked-entry optimal welfare captured under free entry. It is seen that free entry does relatively better for low values of α. The desirability of additional barriers to entry is greater in dynamic industries. What drives this result is that restricting entry will lead to higher *R&D* spending per firm. Column 7 shows the *R&D* spending per firm in free entry as a proportion of the spending under the optimal outcome. I do not attach any particular significance to the specific numbers here; they are sufficient to indicate the basic effect of concentration on *R&D* incentives. Last, column 8 shows the ratio of total *R&D* spending in the two cases. Curiously, this ratio stays fairly close to unity. Again, this may not have much significance or importance. It does remind us of one particular assumption made in the model, namely that the *R&D* of different firms is purely duplicative. This is of course not realistic and needs to be modified in subsequent work.[15]

III. Concluding Remarks

This paper has examined the Schumpeterian tradeoff using a simple framework and the familiar technique of calculating consumer's surplus. In a sense, this is an extension of the approach of Oliver Williamson (1968) who pointed out that economies of scale could be used as a defense of monopoly and suggested a similar approach to its measurement.[16] I have shown here that free entry to the *R&D* game would lead to excessive entry, in the sense that an industry with fewer firms would be socially preferable. This was true even when free entry led to the entry of only a small number of firms. A simple model with specific functional forms indicated that the "optimal" market structure would in general involve few firms, particularly in industries characterized by high levels of technological opportunity. These results are also consistent with the Schumpeterian notion of competition.

The model used here is highly simplified, of course, and the conclusions accordingly limited. It was primarily my aim to examine the implications of the influential Dasgupta-Stiglitz approach to this problem. One important point that emerges is that it is not realistic to compare competition with monopoly—to use the usual characterization of the problem—in a model where all firms do the same research. Concentrated industries come out looking good in this paper since further entry adds no new knowledge. Of course, one of the key advantages of a more competitive environment is precisely that a greater diversity of ideas is allowed to flourish. Modelling this phenomenon is a key area of research in this field.

Let me note one other shortcoming of the model. The model has been essentially static, in that the technological opportunities are a one-shot deal. In fact, technological conditions in an industry are constantly changing. The model may be able to say something when the changes are exogenous. In this case, we might expect the industry structure to become less concentrated over time as technological opportunities are "used up." However, many of the changes may be endogenous, and intimately connected with market structure. The pyramiding of inventions is an important phenomenon that has received inadequate attention. Further research in this area is also of some importance in a proper understanding of the tradeoffs between competition and monopoly.

[15] For a model where firms do discover different things when doing the same amount of *R&D*, see my 1983 article.

[16] See also his update of the argument, Williamson (1977).

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