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MARKET STRUCTURE AND INNOVATION: A NEW PERSPECTIVE*

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INTRODUCTION

THE hypothesis that the large enterprise possessing some degree of market power is best suited for the introduction of new products and new methods of production has been the subject of a multitude of empirical investigations since it was suggested by Joseph A. Schumpeter in 1942 [15, pp. 105–6]. Elaborations on the original Schumpeterian thesis, referred to as 'neo-Schumpeterian' theories, have also been the subject of numerous empirical research efforts.[1]

It is useful to categorize the Schumpeterian and neo-Schumpeterian hypotheses under two headings: (1) aspects of firm size affecting the profitability of innovative activity, and (2) effects of market power on innovative activity.

This paper attempts to shed further light on the validity of the 'market power' aspect of the Schumpeterian thesis.[2] Conclusions drawn by authors of previous empirical studies in this area have been mixed. Findings reported by two researchers are especially worth noting, as they have strongly influenced the direction of the present effort.

In one of the most definitive attempts to measure the relationship between innovative effort and market power (as measured by concentration ratios), Scherer reported that 'inventive output does not appear to be systematically related to variations in market power . . .' [12, p. 1121]. The same author, using somewhat different empirical methodology, later concluded that there might be 'modest' support of Schumpeter, but that the relationship between innovative effort and concentration is complex, '. . . since high concentration and rich technological opportunity tend to coincide'.[3] Scherer first noted

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[1] For a comprehensive summary, see Scherer [14, Chapter 15], and Markham [8].

[2] The relationship between firm size and innovative activity, while discussed peripherally herein, has been explored rather extensively through empirical efforts (see Worley [19], Hamberg [5], Comanor [2], and Shrieves [16]) and theoretically (Fisher and Temin [4]).

[3] Scherer [13, p. 530], Scherer used dummy variables for distinguishing among broad technological categories such as chemicals, electrical, general and mechanical and 'traditional' technologies. Scherer found that two of his technology dummy variables were statistically significant determinants of interindustry differences in R & D intensity, as measured by the ratio of industry R & D employment to total industry employment. In the same study, he utilized durable goods and consumer goods dummy variables to distinguish among basic product categories, but found no statistically significant relationship between these product-market characteristics and R & D intensity.

that once technology dummy variables were introduced in regressions designed to explain interindustry differentials in R & D intensity, the explanatory power of concentration ratios declined substantially. Secondly, when his 56 industry sample was stratified according to technology class, simple regressions of R & D intensity on concentration levels resulted in varying estimates of the direction and significance of the effect of concentration.

An implication of still greater complexity in the relationship between concentration and innovative effort is suggested in an insightful study by Comanor, who noted an 'interaction between concentration and product differentiation in their influence on research spending' [2, p. 651]. His conclusion was based on an analysis of a sample of firms in 33 SIC three-digit industries which he classified into two sectors: those producing investment goods and consumer durables, and those producing material inputs and consumer non-durables. The former group was designated as being conducive to the achievement of differentiation based on product design, whereas for the latter group, Comanor reasoned that research is less likely to result in product differentiation. Comanor found that although average research levels tended to be higher in both sectors where eight-firm concentration levels were above 70%, the relationship was far stronger in industries producing consumer non-durables and material inputs than in those producing investment goods and consumer durables.[4]

Thus two researchers have noted differences in the role of market power as a determinant of innovative effort among *classes* of firms; in one case the classes were formed on the basis of technological characterization of industries, and in the other case on what might be called a product-market characterization. Neither author offered a clear theoretical rationale of the differential role of concentration across industrial sectors. Furthermore, it should be of interest to note any correspondence between the respective classification schemes employed by Scherer and Comanor; i.e. to what extent do the technological categories in which Scherer noted a significant relationship between concentration and innovative effort coincide with Comanor's material inputs and consumer non-durables sectors?

The next section of this paper will discuss aspects of existing opposing theories relating to the innovation/market structure controversy which may serve to provide a useful perspective from which to view the empirical conclusions reported above. Subsequently, the paper offers an empirical analysis which simultaneously incorporates the suggestions of Scherer and Comanor, resulting in a more definitive view of the dichotomous nature of the relationship between market structure and the intensity of innovative effort. The final section of the paper offers a new, though admittedly speculative, interpretation of the empirical findings of this and previous studies.

[4] Comanor's empirical conclusions were significant at alpha levels of 25–30%.

EFFECTS OF MARKET POWER ON INNOVATIVE ACTIVITY: OPPOSING THEORIES

The essence of the theories relating market structure to innovative activity is a comparison of the relative incentives for innovation under the alternative regimes of competition and monopoloy or oligopoly. The literature holds two basic theories which are in opposition to each other, i.e. one theory supports the monopolistic organizational form as superior for innovation, while the other supports a competitive structure of industry. In contrasting these opposing theories, it appears that the crucial difference lies in respective assumptions regarding the ability and speed with which an innovator's rivals can imitate or duplicate new technology.

If there are no effective property rights in new technology, i.e. if its benefits are not appropriable, then it becomes available *freely* to an innovator's competitors or potential competitors—it is a public good in the sense that its marginal production cost is zero (or negligible). Therefore the long-run cost function for firms utilizing new technology does not incorporate any cost for the technology except for the firm from which the technology originates.

Consider the extreme case in which new technology is instantaneously available to an innovator's rivals. Economic theory predicts that under conditions of purely competitive market structure and free entry, the original innovator will not be able to recoup the investment required to produce the technology embodied in the innovation, since equilibrium product prices will *not* reflect any costs for new technology.

Now consider an oligopolist innovator whose market position is protected by entry barriers.[5] If a product innovation increases industry demand, some portion of the increase will be reflected in the demand curve faced by the individual oligopolist innovator, even with immediate imitation by his rivals. Thus, sufficient incentive for innovation *may* exist. If a process innovation reduces marginal production costs for an oligopolist, the resulting reduction in product price will be less than the fall in marginal costs (e.g., with a linear demand curve, and constant pre- and post-innovation marginal costs, fall in price will be one-half the reduction in marginal costs), even with immediate imitation by rivals. Again, sufficient incentive for innovation *may* exist for the oligopolist.[6]

The foregoing arguments, which constitute an important part of the Schumpeterian theory of the advantages of oligopolistic or monopolistic market structure for promoting technological progress, depend crucially on the condition of instantaneous and costless imitation by rivals.

[5] Stigler's interpretation of *free entry* as entry by firms suffering no cost differentials is intended here. This assures a horizontal long-run industry supply curve. *Entry barriers* imply the absence of free entry in the Stigler sense (see Stigler [17, p. 70]), in which case the industry supply curve is not horizontal.

[6] The logic of the foregoing paragraphs is presented in more detailed form in the author's Ph.D. dissertation. The analysis in the case of a pure product innovation (one which shifts the industry demand curve without affecting production costs) parallels Stigler's analysis of advertising. See Stigler [17, pp. 23–6].

Another approach proceeds with the assumption that an inventor (firm) may fully appropriate the benefits of knowledge resulting from innovative efforts. Thus an innovator's rivals cannot gain access to new technology without incurring costs, which are in turn reflected in their cost functions and in equilibrium product prices. Under such an assumption, Arrow [1] has shown that, in the case of process innovation, the 'competitive' organizational form for a given industry will lead to a greater incentive for the allocation of resources to inventive activity than would monopolistic structure of the industry. Arrow's conclusions follow from the fact that an inventor-innovator has the ability to internalize the benefits flowing from an innovation and from the fact that the net benefits to invention are lower under monopoly since the preinvention profits of the monopolist represent an (opportunity) cost of invention which is not present in the instance of competitive market structure.[7]

The opposing theoretical conclusions as to the relationship between market structure and innovation thus indicate a need of empirical tests for considering the speed and ability (i.e. costs) of rivals in imitating innovation. Unfortunately, no measures for capturing this 'degree of technological appropriability' for various firms or industries are available. However, it is plausible that the speed and ability with which industrial rivals can imitate innovation is related systematically to the technological and product-market characteristics found to be empirically related to innovative effort by Scherer and Comanor. Thus, while direct control for appropriability may not be feasible, the kind of classification schemes suggested by Scherer and Comanor permit such control by proxy to the extent that the classes defined have interpretation in terms of differential appropriability.

OTHER FACTORS RELEVANT TO INTERINDUSTRY DIFFERENTIALS IN INNOVATIVE EFFORT

Of course, there are other reasons why technological and product-market factors affect the intensity of innovative effort. The demand by a firm or industry for resources to be used in innovation is derived from demand by buyers of that firm's or industry's products for new or improved products or

[7] Demsetz [3] has demonstrated that if an adjustment is made for the 'normally restrictive' behavior of a monopolist in the level of output and utilization of inputs, then the absolute incentive for allocating resources to inventive activity is greater for a monopolist than for a competitively organized industry. Both Arrow and Demsetz neglected to carry their arguments through for a ratio of incentive to innovate to sales levels, which is unfortunate, since much of the empirical research in this area uses a ratio of R & D to some size variable in analyzing interindustry differentials in innovative efforts. The author has followed through in this respect on the Arrow and Demsetz contributions and found that while the Demsetz adjustment does alter the Arrow conclusion with respect to absolute dollar incentive to invent, the conclusion as far as relative incentive which would follow from Arrow's work is not altered. Kamien and Schwartz [6] extend and generalize Demsetz's analysis, but still fail to point out the implications for size relative levels of incentive to invent.

from potential buyers' demands for existing products at lower prices.[8] Furthermore, the costs of altering technology in either product or production process must be weighed against the strength of demand in assessing the profitability of innovation.

An additional factor which might affect innovative effort warrants discussion. As a very substantial portion (generally in excess of 50%) of industrial R & D expenditures is financed by the federal government, it is possible that the allocation of private funds to R & D is thereby affected. It might be argued that R & D performed under government contract is a substitute for R & D which is privately financed, and therefore that private spending on R & D would be inversely related to government financed R & D within an industry. On the other hand, government participation and results in an area of research might result in developments which favorably alter the risk-return patterns of privately financed ventures into that area.[9] A further possibility is that government contracts for R & D enable firms to reach some minimally efficient level of R & D activity beyond which there are significant economies of scale to be exploited by the application of privately financed expenditures. Thus, there are potentially offsetting determinants of the effects of government spending on industrial R & D, the net effect of which will determine the empirically observable relationship between private and public research efforts.[10]

METHODOLOGY

The methodology employed herein analyzing the 'market power' aspect or element of the Schumpeterian thesis involves multiple regression analysis for estimating the empirical relationship between innovative effort (measured by research and development employment) and concentration levels across industries. Product-market characteristics, technological characteristics, and government involvement in generating technology will be accounted for in the analysis.

First, the relationship between innovative effort and the concentration aspect of market structure is estimated across industry groups without regard to the potential dichotomous nature of the relationship suggested by the alternative theories summarized earlier.

While similar in some respects to interindustry approaches using industry averages on R & D and size variables, the approach herein has the advantage

[8] Kamien and Schwartz [6] have shown rigorously that, *ceteris paribus*, industries having greater price elasticity of demand will have greater incentive to pursue process innovation.

[9] Cf. Terleckyj [18, pp. 47–8]; Nelson [9, pp. 289–91].

[10] Related to arguments in the previous section on the importance of appropriability of new technology, there is another reason for suspecting that this variable is important to our objectives. For industries which deal substantially with the government as a purchaser of their products, such as aircraft and communications equipment industries, the appropriability of the benefits of innovation is determined primarily by the winning of a contract from some agency of the Federal Government. Thus, in those industries we might suspect that Arrow's arguments prevail.

of utilizing more information by virtue of using company level data on R & D, firm size, technological characteristics, and government support of R & D. Furthermore, while primarily addressing the market power aspect of the Schumpeterian thesis, a by-product of the interfirm specification utilized is a cross-industry estimate of the relationship between R & D effort and firm size.

After considering the role of concentration without concern for how that role may differ among classes or 'sectors' of industries, the sample of firms is partitioned according to product-market characteristics (which will be described later) and the role of concentration is then re-evaluated accordingly. The degree of association between product-market characteristics and technological characteristics is discussed.

THE SAMPLE AND VARIABLES

A sample of 411 firms fulfilling the following criteria was selected: (1) the firm is included in the 1965 edition of *Industrial Research Laboratories of the United States* and the data on the firm from that source is complete with respect to the variables used herein, (2) the firm is included on the Standard and Poor's COMPUSTAT tapes, and (3) the firm is assigned to a three-digit (Enterprise Standard Industrial Classification) manufacturing industry by the *Directory of Companies Filing Annual Reports With the Securities and Exchange Commission, 1970*. Fifty-six three-digit industries are represented by firms in the sample.

R & D employment is utilized as the measure of innovative effort.[11] Sales revenues are utilized to account for differences in firm size.[12] The *Industrial Research Laboratories* data on employment of scientists by various disciplines offer a more elaborate and objective means of classifying firms according to their technological characteristics than heretofore used.[13] For each firm in the sample, the ratio of the number of R & D scientists or engineers employed in various scientific disciplines to the total R & D employment of the firm was computed to yield an index of the *relative* extent to which the firm was involved in each of 14 disciplines.

For indicating product-market characteristics, the Census Bureau's input–output ratios on sales of consumption goods, investment goods, materials and sales to local and federal government were computed for all three-digit

[11] Includes professional, scientific, and supporting personnel. Unfortunately, no reliable measure of innovative *output* is available at the relevant level of analysis. See Scherer [12] for a discussion of the use of R & D employment data *vis-à-vis* patents data as measures of innovative activity. R & D expenditures would be preferred to employment but such data are not available at the firm level. Statistical analyses not shown here indicate that total R & D employment is a better proxy for R & D expenditures than is employment of R & D scientists and engineers.

[12] See Scherer [11] for a discussion of the use of sales rather than assets or employment as a measure of firm size.

[13] See footnote 3.

industries represented by firms in the sample.[14] In addition, the durable goods dummy variable is available for each of the three-digit industries.

In view of the eventual desirability of (1) partitioning the firms into classes for analysis, and (2) analyzing the correspondence between product-market and technological classification of firms, there is an inherent disadvantage due to the number of descriptors involved.[15] In addition, there is a likelihood of confounding of meaning of various descriptors due to significant collinearities.[16] One way to deal with these difficulties is subjectively to reduce the number of descriptors to what would be considered a manageable level. This could be done by using simple 'dummy' categories, for both product-market and technological classes;[17] however, such an approach ignores the multi-dimensional nature of some firms in either the product-market or technology sense, or both. Instead, this study utilizes the technique of factor analysis to (1) reduce the dimensionality of the product-market and technology characterizations, and (2) to establish descriptors which are statistically independent (within each of the two areas of interest) so as to minimize the confounding problems.[18]

The following equation was estimated using company-level data for all 411 firms in the sample:[19]

$$(1) \quad \ln(\text{R \& D}) = a + b\ln(\text{Sales}) + \sum_{j=1}^{2} c_j P_j + \sum_{j=1}^{5} d_j T_j + e(\text{GOV}) + f(\text{CR4}) + \epsilon$$

[14] The ratios for the enterprise SIC industry definitions used herein were computed as weighted averages of the ratios for corresponding establishment SIC industries.

[15] For example, with five variables representing product-market characteristics, if the observations are stratified according to 'high' or 'low' values on each variable, there are $2^5 = 32$ subgroups to be analyzed (of course, some may be empty), whereas if there were only two variables to contend with, there would be only $2^2 = 4$ subgroups. Bounded rationality dictates that the former situation should be avoided in favor of the latter.

[16] For example, the correlation between the materials to total output and the consumer goods to total output ratios among the 56 industries was −0·76, and between the investment goods ratio and the durable goods dummy variable, 0·50.

[17] For example, Scherer used four classes of 'scientific and technological opportunity' whose origin is somewhat obscure (Scherer [13, p. 525]). Comanor partitioned his data according to economic sectors (as defined in Kaysen and Turner [7]) which he then asserted had significance in terms of whether or not product differentiation was founded on product design (Comanor [2, p. 648]).

[18] See Rummel [10, p. 31]. Orthogonal factor rotation techniques were utilized for analysis of the input–output ratios and the durable goods dummy variable (Appendix) yielding two product-market factors, hereafter referred to as $P1$ and $P2$. The $P1$ factor is interpreted as representing the relative involvement of an industry in the production of material inputs for other industries. The $P2$ factor is interpreted as representing the relative involvement in the production of durable equipment. Similarly, the data on relative involvement in various scientific disciplines, along with capital–output ratios, were factored, yielding five technology factors (Appendix), hereafter referred to as $T1$ through $T5$. These measures represent a technological profile of each firm in the sample, where the components have the following interpretations: $T1$, life sciences technologies; $T2$, electronic and aerospace technologies; $T3$, degree of process orientation in production technology; $T4$, mechanical and electro-mechanical technologies; $T5$, chemical technology.

[19] Note that equation (1) focuses implicitly on R & D intensity, or R & D relative to sales, since it is equivalent, logically and statistically, to

$$\ln(\text{R \& D/Sales}) = a + (b-1)\ln(\text{Sales}) + \ldots$$

This 'size relative' formulation is consistent with the objective of distinguishing empirically between the opposing views as stated by Schumpeter and Arrow, yet does not run afoul of Demsetz's qualification of Arrow's conclusions. See footnote 7.

where

R & D is 1965 privately financed R & D employment
Sales is 1965 revenues
P_j is the jth product-market factor
T_j is the jth technology factor
GOV is the percentage of the firm's 1965 R & D activity financed by the federal government
CR4 is the four firm shipments concentration ratio for the industry into which the firm is classified.

FINDINGS

The regression results for equation (1) are presented in Table I. Before discussing the empirical role of the concentration ratio, consider the coefficients of the other variables.

Both product-market factors had positive and significant regression coefficients, a result which is in contrast to the lack of significance of variables representing product or market characteristics in Scherer's [13] study. Thus, if our interpretation of the $P1$ factor's meaning is correct, the evidence indicates that firms heavily involved in the production of material inputs will, *ceteris paribus*, devote more resources to research and development than firms ranking low on this factor. Similarly, if we can interpret the $P2$ factor as indicating the extent of involvement in the production of durable equipment, then the evidence would indicate that, *ceteris paribus*, firms in such industries perform more R & D. Accordingly, the industries with low scores on both $P1$ and $P2$, which are primarily engaged in the production of consumer goods, can be expected to allocate relatively little of their resources to R & D activity.

The life sciences technological factor ($T1$) was significantly (0·05) directly related to innovative effort, and the mechanical and electromechanical factor significantly (0·05) inversely related, while the other technological factors exhibited weak inverse relationships with the dependent variable. A suggested interpretation is that the areas encompassed by life sciences are relatively 'fertile' in terms of technological opportunity.[20]

The coefficient of the variable GOV, the percentage of R & D financed by the government, was negative, and significant (0·05), indicating an inverse relationship between government financed innovative effort and privately financed effort at the firm level.

The concentration ratio had a positive regression coefficient which was significant at the 0·025 level.

[20] This conclusion is admittedly tenuous for two reasons. First, we do not know to what extent these 'technological' factors also convey information about product characteristics not embodied in the product-market factors. Secondly, the regression coefficients for the 'T' factors undoubtedly reflect differences in costs of various types of engineering and scientific skills as well as a pure technological 'fertility'.

TABLE I

INTERFIRM REGRESSIONS

Dependent variable: ln (R & D)

Figures in parentheses are *t*-statistics

Equation number	Constant	ln (*Sales*)	P_1	P_2	T_1	T_2	T_3	T_4	T_5	*GOV*	CR_4	*d.f.*	R^2	*F*
		Variable												
(1)	1·24	0·604	0·183	0·273	0·341	−0·075	−0·021	−0·130	−0·079	−0·525	0·008	10/400	0·555	49·97
		(17·80)	(2·44)	(3·86)	(4·91)	(−0·89)	(−0·25)	(−1·77)	(−0·99)	(−2·05)	(2·06)			
(1·1)	−5·13	0·571	4·89	3·56	0·134	0·065	−0·256	0·017	0·108	−0·894	0·059	10/39	0·683	8·40
		(6·08)	(0·74)	(0·94)	(0·49)	(0·45)	(−0·66)	(0·11)	(0·43)	(−1·77	(0·85)			
(1·2)	1·97	0·679	−0·467	1·83	0·398	−0·180	−0·143	0·138	0·201	1·26	0·010	10/138	0·588	19·72
		(10·95)	(1·84)	(3·64)	(1·58)	(−0·79)	(−1·33)	(0·95)	(1·99)	(1·63)	(1·62)			
(1·3)	2·77	0·648	1·38	−0·121	−0·022	−0·139	−0·033	−0·100	−0·674	−1·02	−0·008	10/118	0·563	15·22
		(9·82)	(2·28)	(0·71)	(−0·08)	(−0·96)	(−0·10)	(−0·78)	(−2·80)	(−2·61)	(−0·88)			
(1·4)	2·15	0·565	−0·088	2·47	0·174	−0·143	0·208	−0·106	−0·139	−0·782	0·025	10/72	0·773	24·52
		(9·16)	(−0·23)	(3·04)	(1·74)	(−0·58)	(1·41)	(−0·56)	(−0·90)	(−1·08)	(3·34)			
(1·5)	1·96	0·604	−0·028	−0·013	0·218	−0·056	−0·082	−0·118	−0·475	−0·815	−0·003	10/168	0·546	20·18
		(11·21)	(−0·10)	(−0·08)	(0·99)	(−0·50)	(−0·32)	(−1·13)	(−2·52)	(−2·62)	(−0·37)			
(1·6)	2·00	0·651	−0·257	2·64	0·149	−0·222	0·026	−0·076	0·084	0·103	0·013	10/221	0·636	38·66
		(14·70)	(−2·38)	(6·86)	(1·94)	(−1·40)	(0·32)	(−0·68)	(1·01)	(0·2)	(2·75)			

The coefficient of the ln (Sales) term of equation (1) was estimated to be 0·604, significantly less than unity at the 0·01 level, implying that smaller firms performing R & D allocate proportionately (to sales) more resources to R & D than do larger firms. Thus, the results for a sample of 411 firms are consistent with conclusions drawn from prior intraindustry studies with respect to distribution of R & D effort by firm size.[21] On the other hand, the results for the concentration variable appear to offer support for the thesis that firms in more concentrated industries will be more vigorous innovators than firms in less concentrated industries.

THE ROLE OF CONCENTRATION RECONSIDERED

Comanor's findings, as summarized in the introduction, suggest that the relationship between concentration and the level of R & D varies according to the product-market characteristics of industries, and that the equation used for empirical analysis in the preceding section may have been misspecified in that it assumed a constant coefficient for the concentration measure regardless of product-market characteristics. However, even if we accept Comanor's suggestion that the importance of product differentiation is the appropriate basis for distinction between the industries of his two sectors, we should not foreclose the possibility that there exist other bases for distinction which may be relevant to the observed differences in the role of concentration as it relates to R & D activity.

In particular, we should investigate (*à la* Scherer) the role of classification by technological characteristics for the market structure/innovation relationship, and the possibility of a correspondence between the product-market and technological classification schemes. Furthermore, there are several shortcomings in the methodology employed by Comanor in testing for an 'interaction' between concentration levels and what he interpreted as the importance of product differentiation. First, Comanor's designation of concentration classes based upon a 70% eight-firm concentration level was arbitrary. Second, as Comanor himself noted, his analysis did not account for interindustry technological or product-market differences *within* the sectors defined. Third, he did not account for variation in the level of government involvement in research and development activity; indeed, his R & D employment data did not distinguish between private and government financing of R & D.

The empirical analyses herein will first follow Comanor's example by partitioning the IRL sample of firms according to product-market characteristics (while not singling out the importance of product differentiation as the basis for partitioning), and will endeavor to correct for the shortcomings noted.

[21] See footnote 2.

The two product-market factors discussed earlier (and in the Appendix) essentially allow a four-way classification of industries. (A summary of the categorization of the 56 SIC industries represented by firms in the sample is presented in Appendix Table II.) Since the $P1$ and $P2$ factors are approximately standardized normal in their frequency distribution as a result of the manner in which they were constructed, we have for convenience assigned the value zero as the cut-off between 'high' and 'low' rankings on these factors.

To test for an 'interaction' between concentration and the two product-market factors, the sample was stratified according to the scheme mentioned above, and for each of the four resulting subsamples, equation (1) was re-estimated. Table II contains the means and standard deviations for variables appearing in equation (1) for each subsample of firms. The regression results are given in Table I. The equations for the subsamples are identified as follows:[22]

(1.1) $P1 > 0$, $P2 > 0$—non-specialized producers' durable goods

(1.2) $P1 > 0$, $P2 < 0$—materials

(1.3) $P1 < 0$, $P2 > 0$—specialized durable equipment

(1.4) $P1 < 0$, $P2 < 0$—consumer goods.

The noteworthy result of the four regressions (1.1) to (1.4) was that the coefficient for the four-firm concentration ratio was negative and significant at the 0.20 level in equation (1.3), but was positive and significant at the 0.10 and 0.01 levels, respectively, in equations (1.2) and (1.4), where $P2$ was negative. The coefficient was positive, and significant at the 0·20 level in equation (1.1). These results suggest that there is an interaction between $P2$ and the concentration measure. To test this effect more directly, the sample of 411 firms was divided according to whether $P2$ was positive or negative, and equation (1) was again estimated; the results are given as equations (1.5) and (1.6), respectively, in Table I.

Before discussing the results of these two regressions, consider the 'profiles' of the two subsamples given by the last two columns of Table II. The firms for which $P2$ is greater than zero, as stated earlier, tend to be heavily involved in producing durable equipment. Their research technology is heavily

[22] While these sectoral definitions may appear at first glance to resemble those employed by Comanor, there are several differences worth noting. First, the consumer goods industries are not split on the basis of durability, but on whether or not a substantial portion of their output is purchased as investment goods (see Appendix Table II). Also note that those industries traditionally grouped together as investment goods are divided on the basis of whether or not they are 'specialized' or 'general purpose' products (see Appendix footnote 3). This interpretation arose in part from the observation that, while both the first and third groups have substantial and roughly equal proportions of their output classified as investment goods, the first group ($P1 > 0$, $P2 > 0$) typically has high material ratios and low consumer goods ratios, whereas the third group ($P1 < 0$, $P2 > 0$) has many industries with only moderate materials ratios and several with substantial consumer goods ratios.

TABLE II

MEANS AND STANDARD DEVIATIONS OF VARIABLES IN SUBSAMPLE ANALYSIS[a]

	Subsample					
Variable	$P1>0$, $P2>0$	$P1>0$, $P2<0$	$P1<0$, $P2>0$	$P1<0$, $P2<0$	$P2>0$	$P2<0$
PROD1	0·38 (0·13)	0·95 (0·32)	−0·38 (0·19)	−0·99 (0·54)	−0·16 (0·39)	0·26 (1·02)
PROD2	0·82 (0·22)	−0·36 (0·17)	1·36 (0·74)	−0·67 (0·28)	1·21 (0·68)	−0·47 (0·26)
TECH1	−0·15 (0·45)	−0·18 (0·32)	−0·16 (0·39)	0·66 (1·51)	−0·16 (0·41)	0·12 (1·02)
TECH2	0·34 (0·90)	−0·32 (0·36)	0·38 (0·88)	−0·23 (0·54)	0·37 (0·88)	−0·28 (0·44)
TECH3	−0·46 (0·38)	0·40 (0·83)	−0·40 (0·45)	0·19 (0·95)	−0·42 (0·44)	0·32 (0·88)
TECH4	0·32 (0·82)	−0·25 (0·55)	0·30 (0·93)	−0·21 (0·66)	0·31 (0·89)	−0·24 (0·59)
TECH5	−0·25 (0·48)	0·02 (0·85)	−0·27 (0·51)	0·53 (0·77)	−0·26 (0·50)	0·20 (0·86)
GOV	0·17 (0·26)	0·04 (0·11)	0·29 (0·32)	0·04 (0·16)	0·26 (0·31)	0·04 (0·13)
CR4 (%)	35·6 (11·7)	37·6 (12·9)	47·0 (14·6)	37·7 (14·1)	43·8 (14·8)	37·6 (13·3)
Sales ($\times 10^6$)	70·1 (124·8)	291·1 (386·0)	211·3 (393·3)	735·5 (1467·0)	171·9 (345·8)	450·1 (951·3)
R & D/Sales ($\times 10^6$)	3·1 (4·6)	1·5 (3·0)	4·4 (31·1)	1·1 (1·8	4·1 (11·4)	1·3 (2·6)
No. of firms	50	149	129	83	179	232

[a] Figures in parentheses are standard deviations.

oriented to electronics, aerospace, mechanical, and electromechanical fields. They perform a relatively high percentage of their total R & D effort for the federal government.[23] These firms tend to be in more highly concentrated industries, on average, than firms in the other group, although they are typically much smaller firms, and less process-oriented.

On the other hand, the firms for which $P2$ is less than zero encompass the consumer products category ($P1<0$, $P2<0$), as well as the predominately material inputs group ($P1>0$, $P2<0$). Their technology is more involved in life sciences and chemistry. They are much larger firms than in the first subsample, but are in less concentrated industries, and perform far less R & D on government contract. The firms in this subsample area are also relatively process-oriented in terms of production technology.

The differences between the means of all variables listed in Table II for the $P2>0$ and $P2<0$ subsamples are statistically significant at the 0·01 level in one-tailed t-tests.

The results for regressions (1·5) and (1·6) in Table I indicate that the

[23] The arithmetic average of 0·26 of GOV is substantially less than the *weighted* average percentage of R & D performed for the government in these industries.

coefficient for the four-firm concentration ratio is positive and highly significant (0·005 level) for the $P2 < 0$ subsample of industries, but negative, though not significant for the $P2 > 0$ subsample.

The literal interpretation of the significance of concentration in equations (1.2), (1.4) and (1.6) is that, for the groups of industries classified as producing consumer goods or material inputs, firms in more concentrated industries devote a greater proportion of their resources to formal innovative effort than firms in less concentrated industries, whereas the coefficients for the concentration measure in equations (1.1), (1.3) and (1.5) would appear to offer some support to the opposite argument for the respective industry groupings.[24]

INTERPRETATION OF FINDINGS

The role of concentration appears to be ambiguous when the manufacturing industries represented by the sample were divided into 'sectors' according to the product-market factors developed in the Appendix. Concentration levels were significantly directly associated with R & D performance for the sets of industries identified as producers of material inputs and consumer goods. A positive but statistically weak relationship between concentration and research levels was found among industries identified as producers of non-specialized producers goods, and a marginally significant inverse relationship was found among producers of specialized durable equipment. Thus, it appears that the relationship between concentration and innovative activity depends upon the types of products sold and the kinds of markets served by an industry.

Furthermore, the evidence indicates that the distinction between industry sectors in which concentration has a direct empirical relationship with innovative activity and those in which it does not may be more subtle and complex than represented by prior empirical findings. The sector profiles in Table II suggest that systematic differences in technological characteristics and government involvement in financing R & D may also interact with the market structure variable in influencing innovation.[25]

It was argued earlier that oligopoly firms may have greater incentive to innovate when imitation was very rapid than did firms in a more atomistic structure. Thus, the relative likelihood of rapid imitation by rivals constitutes

[24] However, within those industries in which concentration appeared to be conducive to innovative effort, the larger firms performed proportionately less R & D than their smaller rivals. In this respect, the evidence is not so clearly in favour of the Schumpeterian notion that *large* firms are necessary to support the process of innovation. Of course it may be that the small firms in highly concentrated industries for which innovation is relatively important are responding to competitive pressure to innovate in order to carve their 'niche' in the market.

[25] Indeed, regression results not shown indicate that stratification of the sample on the basis of whether government financing accounted for more or less than 20% of the industry's R & D effort also resulted in concentration coefficients of opposite sign; where govenment financing exceeded 20%, the coefficient was positive and significant, and negative, though not significant, where the ratio of government input was less than 20%. Various combinations of constraints on technology factors also produced subsamples for which the concentration coefficients were of opposite sign.

an explanation for the observed duality of relationships between concentration and innovative effort.

The role of the rate of imitation of innovation is very difficult to assess, due to the lack of quantitative measures for this variable. However, it seems plausible that the rate of imitation of innovations would be greater in the non-durable consumer goods and material inputs industries than in non-specialized producer goods or specialized equipment industries for two reasons: (1) technological complexity is probably less for the former classes of products and (2) the incentive to imitate is probably greater in consumer goods and material inputs due to the repetitive nature of purchase of those types of goods, implying that realization of the full market potential for innovation in these areas is of a very temporary nature. On the other hand, where durable producers' equipment is concerned, a buyer will make very infrequent purchases even in the face of moderate technological developments in production technology, since in order to induce replacement of equipment already purchased, average total cost of production utilizing new equipment must be less than average variable cost when employing existing equipment. In such a situation, particularly if there are only a few prospective buyers, the innovator may have a long term advantage over rivals by virtue of being first.

Even with the possibility of rapid imitation of innovation, in industries where successful R & D effort is virtually assured of resulting in a significant government production contract, we would not expect to observe a positive relationship between concentration and innovative activity, since the production contract may provide the necessary degree of appropriability.

Relative to the important findings reported by Scherer and Comanor, as summarized earlier, three important conclusions emerge from this research. First, the finding of a dual nature of the role of concentration as it relates to innovative effort is sustained with even greater confidence than was possible given earlier findings. Secondly, and contrary to Comanor's evidence, high concentration levels may have an adverse effect on innovative effort in some industries, as suggested by the negative (though not significant) coefficient of the concentration variable in two of the regressions. This finding admits the possibility that the theoretical view which opposes Schumpeter's is the more relevant theory for some industries or technologies. Thirdly, whereas Comanor emphasized the nature of product differentiation as the relevant distinction between sectors in which concentration had a differential role in promoting innovation, the correspondence among product-market and technological characteristics found herein, in light of the discussion of the crucial role of conditions of appropriability of new technology, suggests alternative explanations for the dichotomous nature of the relationship between innovation and market structure.

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APPENDIX

PRODUCT-MARKET AND TECHNOLOGY FACTORS

Product-market Characteristics

For the 411 firms in the IRL sample, three of the input–output variables (CTO, ITO, MTO) and the durable goods dummy variable (DUR) were factored using orthogonal rotation techniques so that the resulting factors are statistically independent.[1] (Since the sum of the four input–output variables for a given industry is unity, one had to be omitted from the analysis. GTO was omitted.) The loadings of each of the four variables on the two resulting factors are given in Table I. Since the four variables (CTO, ITO, MTO and DUR) for each firm are determined solely by the three-digit industry into which the firm falls, the factor scores used later for firms within an industry are identical.

TABLE I

FACTOR LOADINGS ON PRODUCT-MARKET FACTORS FOR 56 INDUSTRIES

*P*1		*P*2	
MTO	(0·98)	ITO	(0·93)
DUR	(0·21)	DUR	(0·58)
ITO	(−0·17)	MTO	(−0·18)
CTO	(−0·87)	CTO	(−0·49)

The factors which resulted from analysis of the input–output ratios and the durable goods dummy variable will be referred to hereafter as *product-market factors*, since the four variables from which they were derived contain information about the nature of the product (e.g. materials vs. investment goods or durable vs. non-durable) as well as some indication of the number and type of buyers in the market (e.g. investment goods vs. consumer goods).

Interpretation of Product-market Factors

First, note that the bulk of the variation in the four original variables across 56 SIC three-digit industries is explained by only two factors, i.e. the dimensionality of the initial description of industries is reduced from four to two by using orthogonal factor rotation techniques. Thus, some degree of redundancy in the original measures of product-market characteristics has been eliminated. The loadings in Table I represent the correlation between the observed variables and the constructed factors.

The first factor has a high positive correlation with the materials to total output ratio (MTO) and a highly negative correlation with the consumption goods to total output ratio (CTO). The factor loadings for the investment goods to total output ratio (ITO) and the durable goods dummy variable (DUR) indicate that the first factor, hereafter referred to as product-market factor one, or *P*1 for short, is essentially neutral with respect to those variables. The *P*1 factor is therefore interpreted as representing the relative degree of involvement in the production of material inputs.

The second product-market factor, *P*2, has a very high correlation with the investment goods to output ratio and a somewhat weaker correlation with the durable goods dummy variable. The factor loading for the materials to output ratio is relatively low, and the consumer goods to output ratio has a fairly strong negative correlation with the second product-market factor. This factor will therefore be interpreted as representing the relative degree of involvement in the production of durable equipment.

[1] See Rummel [10 Chapter 16], for a discussion of alternative rotation techniques.

TABLE II

STRATIFICATION OF IRL INDUSTRIES BY PRODUCT-MARKET FACTORS

SIC	Industry description	CTO	ITO	MTO	GTO	SLGTO
1. $P1$ greater than zero; $P2$ greater than zero						
354.	Metalworking mach. and equip.	1·6	41·2	55·1	1·6	0·5
356.	General ind. mach. and equip.	0·0	23·6	72·2	3·5	0·7
369.	Misc. elec. mach. & equip.	7·1	22·4	65·1	4·4	1·1
381.	Engrg. and scientific equip.	0·6	26·3	60·7	10·7	1·7
2. $P1$ greater than zero; $P2$ less than zero						
204.	Grain mill products	21·8	5·4	71·8	0·7	0·3
206.	Sugar	26·2	3·8	69·8	0·1	0·1
221.	Textile mill products	4·7	2·3	92·7	0·2	0·1
241.	Lumber and wood products	1·8	2·2	95·9	0·1	0·0
262.	Pulp, paper and board	0·3	4·3	94·8	0·3	0·2
264.	Misc. converted paper prod.	24·6	1·9	72·4	0·5	0·6
271.	Newspapers, periodicals, books	27·8	2·2	67·2	0·1	2·7
275.	Printing and allied industries	6·0	0·5	90·0	1·3	2·1
281.	Basic chem., plastic, synthetic	0·9	7·5	86·0	5·1	0·6
285.	Paints and allied products	0·9	2·8	96·0	0·1	0·1
287.	Agricultural chemicals	2·4	7·0	86·4	0·5	3·8
289.	Misc. chemicals	7·4	9·0	79·3	3·8	0·5
299.	Misc. petroleum and coal prod.	14·3	2·4	81·5	1·2	0·6
309.	Misc. plastics and rubber prod.	10·3	4·0	82·7	1·9	1·0
321.	Glass products	8·0	5·6	84·9	0·4	1·1
324.	Cement	0·0	0·1	99·9	0·0	0·0
325.	Structural clay prod.	0·0	3·6	96·4	0·0	0·0
327.	Concrete, gypsum, plaster	2·7	2·0	94·8	0·3	0·1
331.	Iron and steel	0·0	2·4	97·3	0·2	0·0
335.	Non-ferrous metals	0·1	3·6	96·4	−0·2	0·0
341.	Metal cans	0·0	2·0	97·9	0·1	0·0
342.	Cutlery, hand tools, gen. hdw.	14·8	6·3	78·1	0·5	0·3
345.	Screw machine prod., etc.	1·2	2·2	95·8	0·8	0·0
349.	Misc. fab. metal products	2·1	7·7	89·6	0·6	0·0
399.	Misc. manufacturing	21·4	11·1	66·9	0·1	0·4
3. $P1$ less than zero; $P2$ greater than zero						
251.	Furniture and fixtures	50·9	20·9	23·8	0·9	3·5
352.	Farm, constr. and mining mach.	0·1	65·0	32·3	2·1	0·5
355.	Spec. ind. mach.	0·5	68·7	30·1	0·4	0·2
357.	Office and computing machines	2·8	49·8	33·2	11·0	3·2
358.	Service industry machines	9·5	41·4	45·4	1·4	2·2
366.	Radio, TV and comm. equipment	12·2	16·3	40·2	30·6	0·7
371.	Motor vehicles and equipment	38·3	19·0	39·4	1·6	1·6
372.	Aircraft and parts	0·4	11·1	39·2	49·3	0·0
374.	Railroad equipment	0·0	65·4	33·7	0·3	0·6
383.	Optical and photo instruments	24·0	18·7	48·9	5·8	2·6
384.	Surg., med. and dental instr.	12·3	31·0	46·8	4·4	5·5
393.	Musical instruments and parts	44·3	38·8	13·5	0·1	3·3
4. $P1$ less than zero; $P2$ less than zero						
201.	Meat products	74·1	2·4	22·2	0·5	0·9
202.	Dairy products	66·6	1·4	29·8	0·9	1·2
203.	Canned cured and frozen foods	61·6	4·8	32·7	0·3	0·5
205.	Bakery products	91·4	0·4	7·4	0·2	0·6
207.	Confectionery	79·0	1·8	19·1	0·0	0·0
208.	Beverages	78·0	1·1	20·6	0·1	0·1
211.	Cigarettes	93·9	2·6	3·4	0·0	0·0
239.	Misc. fabricated textile prod.	39·9	2·2	55·3	2·4	0·2
283.	Drugs	48·9	8·6	35·4	1·2	6·0
284.	Soap, cleaners and toilet foods	63·9	2·8	30·7	0·4	2·2
291.	Petroleum refining	39·5	4·0	51·7	3·4	1·5
301.	Tires and inner tubes	37·1	3·7	57·0	1·4	0·8
314.	Footwear, except rubber	99·5	−1·4	1·8	0·0	0·0
363.	Household appliances	59·0	9·9	30·7	0·2	0·3
391.	Jewellery, silverware, etc.	56·4	4·4	39·1	0·0	0·3

TABLE III

TECHNOLOGY FACTORS FOR 411 IRL FIRMS[a]

Factor loadings									
T_1		T_2		T_3		T_3		T_5	
BIOL	(0·75)	MATH	(0·60)	KO	(0·76)	MECH	(0·76)	CHEM	(0·66)
MD	(0·62)	PHYS	(0·55)	GEOL	(0·37)	AERO	(0·21)	BIOL	(0·18)
PHARM	(0·29)	ELEC	(0·37)	CHEMENG	(0·29	ELEC	(0·17)	CHEMENG	(0·16)
CHEM	(0·11)	MECH	(0·11)	CHEM	(0·21)	MATH	(0·12)	BACT	(0·13)
KO	(0·04)	GEOL	(0·03)	META	(0·07)	BACT	(−0·03)	PHARM	(0·03)
BACT	(0·02)	AERO	(−0·03)	MATH	(0·01)	MD	(−0·04)	MD	(0·02)
GEOL	(−0·03)	MD	(−0·03)	PHARM	(0·00)	PHARM	(−0·05)	MATH	(0·01)
AERO	(−0·04)	BACT	(−0·04)	MD	(−0·02)	GEOL	(−0·05)	AERO	(−0·03)
MATH	(−0·06)	PHARM	(−0·04)	PHYS	(−0·02)	CHEMENG	(−0·06)	GEOL	(−0·05)
PHYS	(−0·07)	META	(−0·06)	BIOL	(−0·04)	BIOL	(−0·08)	MECH	(−0·06)
CHEMENG	(−0·09)	BIOL	(−0·06)	BACT	(−0·06)	PHYS	(−0·14)	PHYS	(−0·10)
META	(−0·10)	KO	(−0·11)	AERO	(−0·07)	META	(−0·14)	KO	(−0·15)
ELEC	(−0·10)	CHEMENG	(−0·24)	MECH	(−0·07)	KO	(−0·18)	META	(−0·22)
MECH	(−0·12)	CHEM	(−0·30)	ELEC	(−0·30)	CHEM	(−0·37)	ELEC	(−0·24)

[a] Variable definitions:

BACT	Bacteriologists in R & D as a percentage of total R & D employment.
BIOL	Biological scientists in R & D as a percentage of total R & D employment.
CHEM	Chemists in R & D as a percentage of total R & D employment.
GEOL	Geologists in R & D as a percentage of total R & D employment.
MATH	Mathematicians in R & D as a percentage of total R & D employment.
MD	Medical doctors in R & D as a percentage of total R & D employment.
META	Metallurgists in R & D as a percentage of total R & D employment.
PHARM	Pharmacists in R & D as a percentage of total R & D employment.
PHYS	Physicists in R & D as a percentage of total R & D employment.
AERO	Aeronautical engineers in R & D as a percentage of total R & D employment.
CHEMENG	Chemical engineers in R & D as a percentage of total R & D employment.
ELEC	Electrical engineers in R & D as a percentage of total R & D employment.
MECH	Mechanical engineers in R & D as a percentage of total R & D employment.
KO	Ratio of net plant to sales.

By partitioning the sample of 56 industries according to whether a particular industry has positive or negative factor scores on $P1$ and $P2$, four subgroups emerge, as presented in Table II. The factor interpretations, along with the basic input–output ratios given for each industry in the table, suggest the following interpretations of the categories.[2]

Group 1 ($P1 > 0$, $P2 > 0$)—non-specialized producers durable equipment
Group 2 ($P1 > 0$, $P2 < 0$)—materials
Group 3 ($P1 < 0$, $P2 > 0$)—specialized[3] durable equipment
Group 4 ($P1 < 0$, $P2 < 0$)—consumer goods.

The two product-market factors thus provide a means of summarizing statistically the information on important dimensions of product and market characteristics which is embedded in the input–output ratios and the durable/non-durable goods dummy variable from which factor loadings and factor scores were obtained.

Technological Characteristics
Factor analysis was again employed to 'sort out' the interrelationships among the variables which might be related to the technological nature of each firm.

For the sample of 411 IRL firms, the variables factored were the capital–output ratio (KO) (from the 1971 COMPUSTAT tapes) and 13 variables describing the distribution of R & D scientists and engineers by discipline from the IRL data (see notes to Table III for variable definitions).

The results of the factor analysis of technology variables for the IRL sample is presented in Table III.

Interpretation of Technological Factors
The pattern which emerges from the analysis of technology variables is perhaps more obvious than that for the product-market variables. The patterns observed here relate to the product *and* process technology of industries, since the raw data did not provide distinction between these two categories of research activity.

Four of the factors, $T1$, $T2$, $T4$ and $T5$, describe patterns in the employment of scientists from various disciplines. They allow us to characterize firms according to their relative involvement in four broad areas of scientific endeavor. Inspection of the factor loadings (and industry rankings not shown here) suggests the following interpretations of the four technological factors:

$T1$—life sciences
$T2$—electronics and aerospace
$T4$—mechanical and electromechanical
T5—chemical.

The remaining factor, $T3$, is dominated in the factor loadings by the capital intensity variable (KO). This fact, along with the positive loadings for geologists, chemists, and metallurgists, suggest that this factor is an index of the degree of process orientation of the production technology employed by an industry, where process orientation refers to the physical continuity, or 'flow' characteristics of production.

[2] The author will provide elaboration on the logic of these interpretations upon request.
[3] In the context in which the word 'specialized' is used here, it is intended to imply that the equipment produced by the industry in question yields factor services which are of use only to a very limited number of production processes, e.g. farm machinery has little or no application outside the few industries producing agricultural products, whereas the products of the miscellaneous fabricated metals industry are utilized by the entire spectrum of manufacturing industries.

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