THE INFLUENCES OF FIRM SIZE AND MARKET STRUCTURE ON THE RESEARCH EFFORTS OF LARGE MULTIPLE-PRODUCT FIRMS

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PREFACE

This dissertation examines empirically the separate influences of several structural variables on the innovative activity of large multimarket firms. In particular, a multiple regression model is formulated to explain the variance in the proportion of resources allocated toward research and development among a sample of large firms by variations in their size, market share, diversification, the concentration of their markets, the average growth of their markets, and the broad scientific base and technological opportunity associated with their primary operations.

The preparation of this study owes much to the assistance and guidance given me by the members of the thesis committee: Dr. Larkin Warner, the chairman, Dr. Frank Steindl, and Dr. Luther Tweeten, all from Oklahoma State University. Dr. Warner, especially, has given considerable counsel on its content and organization.

Dr. Willard Mueller (Director of the Bureau of Economics) and Dr. Arthur Andersen (Chief of the Division of Industry Analysis) were instrumental in enabling me to prepare the study as a staff member of the Federal Trade Commission. I am particularly indebted to Dr. Mueller who originally suggested the topic and has offered a number of helpful comments on its content. Without the material support and, particularly, the use of unpublished data gathered by the Federal Trade Commission, this thesis would not have been possible.

I also want to thank F. M. Scherer of the University of Michigan and Edwin Mansfield of the Warton School of Finance and Commerce of the University of Pennsylvania who read the first draft and offered several constructive comments on its content. Thomas Hogarty and William Kelly have given useful advice on the statistical measures and techniques used.

Needless to say, none of the above persons are responsible for any errors or omissions in the study.

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CHAPTER I

INTRODUCTION

This is an empirical study. Its purpose is to present additional evidence on the relationship between the size and market structure of an industrial firm and its emphasis on technological innovation. More specifically, multiple regression techniques are used to test a number of related hypotheses which attribute a causal influence on a firm's research and development (R&D) effort to its size, market share, diversification, and the concentration of its markets.

The Problem

The writer's interest in the study was stimulated by the increasing public debate over the position, originating with Schumpeter[1] but advanced most recently by Galbraith,[2] that the costs and risks of modern technology compel firms to become large and to achieve a high degree of market

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[1] Joseph A. Schumpter, *Capitalism, Socialism, and Democracy* (New York: Harper and Bros., 1942).

[2] John K. Galbraith, *The New Industrial State* (Boston: Houghton Mifflin Company, 1967).

power if they are to be technically progressive.[3] Advocates of this position share the view that large firms operating in highly concentrated industries are the principal contributors to technological change by virtue of the new or improved products and processes which flow from their research and development laboratories.[4] Only large firms, so the argument goes, are able to afford the expensive equipment and the teams of trained specialists necessary for contemporary innovation. Furthermore, it is asserted, for several reasons, that the willingness and ability to invest in costly and risky research increase with the size and market power of industrial firms. First, greater restrictions against the competitive forcing of prices toward short-run marginal costs provide protection against the rapid erosion of the gains from research while increasing the supply of internal funds. Second, a greater number of simultaneous R&D projects enables a larger firm to

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[3]The relationship between invention, innovation, and concentration has been the subject of U.S. Congressional hearings during which most of the arguments examined by this study were discussed and some empirical evidence presented. U.S., Congress, Senate, Subcommittee on Antitrust and Monopoly, Hearings, Concentration, Invention, and Innovation, 89th Cong., 1st Sess., 1965.

[4]Others who have given this thesis added emphasis are David Lilienthal in Big Business: A New Era (New York: Harper & Bros., 1952); A. D. H. Kaplan in Big Enterprise in a Competitive System (Washington: Brookings Institution, 1954); Henry H. Villard in "Competition, Oligopoly, and Research," Journal of Political Economy, LXVI (December, 1958), 483-97; and John K. Galbraith in American Capitalism: The Concept of Countervailing Power (Boston: Houghton Mifflin Co., 1952).

balance its successes against failures and, thereby, to receive a more predictable return on its investment. Third, the greater experience and more heterogeneous resources of a larger, more diversified firm enable it to increase its expected returns from research, particularly basic research, by increasing the probability that unexpected discoveries can be put to commercial use. Fourth, the typically higher market share of a larger firm provides it with the stability of income necessary for planning long-range research projects.[5] Finally, it is argued that there is no reason to fear a lack of competitive pressure to innovate for such pressure abounds in oligopolistic industries. Hence, firms may avoid price competition in highly concentrated markets where mutual interdependence is recognized, but more subtle forms of nonprice competition, including the development of new or improved products or processes, will flourish.

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[5]These four arguments are based on the theory of capital investment under the assumption that the firm is a risk averter, that is, it not only seeks greater expected returns from its investments, but it also places a premium on the reduction of uncertainty. Other things equal, therefore, larger firms with greater market power find investment in costly and risky R&D more attractive because they can expect (1) higher net future investment returns, (2) lower variability in these returns, and/or (3) a longer time period over which future investment returns can be discounted to the present. Risk aversion has been a basic assumption in several theoretical works. See, for example, H. M. Markowitz, Portfolio Selection (New York: John Wiley and Sons, 1959). Galbraith in the New Industrial State places extreme emphasis on the compelling need for firms to become large in order to eliminate uncertainty.

The important issue facing antitrust policymakers is not the defense of an industrial system of only small firms, but whether or not technological progress requires very large corporate complexes and levels of concentration approaching complete market dominance by a few leading firms.[6] Would the combination of firms that are already large enough to perform organized research into fewer, extremely large conglomerate firms with economic power autonomous from the discipline of market forces increase the technical progressiveness of the industrial system? If such is the case, then antitrust policy traditionally concerned with limiting the market power of dominant producers by discouraging excessive levels of industrial concentration may act as an impediment to technological progress. Merger policy concerned with the concentration of aggregate economic power into the hands of a relatively few large conglomerate firms may need reshaping in the light of its influence on innovative performance. However, if among firms already engaged in research, increased firm size, diversification, and market power beyond moderate levels do not increase the intensity of their research

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[6]This point was emphasized by the then Attorney General, Nicholas Katzenbach. Speaking on the subject of "Business Size and National Economic Growth," he points out that ". . . the crucial question is not whether large firms conduct more or better research than small firms, but how large firms compare with giants and with super-giants." An address before the 50th World Convention of the National Industrial Conference Board, September 20, 1966, p. 5. (Mimeographed)

efforts, then the evidence does not support the argument that antitrust policy which seeks to discourage high levels of aggregate and market concentration will also reduce the level of research and development.

Scope and Objectives of the Study

In examining this issue two specific questions are asked. First, among firms performing research can differences in research and development efforts be explained by differences in size, market share, diversification, and/or market concentration; and, if so, what are the separate influences of each of these variables? Second, if any of the structural variables do have a positive influence, does it follow that an <u>unlimited</u> increase in the variables leads to greater research and development? In other words, does some optimal industrial structure for innovative effort exist, and, if so, does it require extremely large, conglomerate firms and/or very high levels of market concentration?

Since the hypotheses examined in this study represent important structure-performance relationships which may be influenced by antitrust policy, it is not surprising that such relationships have undergone considerable empirical scrutiny in recent years.[7] Attempts to estimate the

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[7]See Daniel Hamberg, "Size of Firm, Oligopoly, and Research: The Evidence," <u>Canadian Journal of Economics and Political Science</u> XXX (Feb., 1964), 62-75; I. Horowitz, "Firm Size and Research Activity," <u>Southern Economic Journal</u> XXVIII (January, 1962), 298-301; Edwin Mansfield,

influence of market structural variables on the innovative performance of large firms have been frustrated, however, by the lack of refined data. Not only must measurements of firm innovative performance be interpreted carefully, but meaningful measures of market structural variables for large multi-market firms cannot be determined from published sources. The difficulty exists because firms generally report their sales on consolidated income statements, so that the relative importance of each of the firm's markets to its total operation cannot be measured.[8] Previous empirical studies based on a cross section of large firms have generally grouped them into broad two-digit or, in some cases, three-digit SIC categories. While this allows for estimates of the importance of firm size for research in technically related areas, it is extremely hazardous to draw conclusions concerning the importance of industry

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"Size of Firm, Market Structure, and Innovation," Journal of Political Economy (December, 1963), 556-76; F. M. Scherer, "Firm Size, Market Structure, Opportunity, and the Output of Patented Invention," American Economic Review, LV (December, 1965), 1097-1125; James S. Worley, "Industrial Research and the New Competition," Journal of Political Economy, LXIX (April, 1961), 183-86; and Henry G. Grabowski, "Determinants of Industrial Research and Development: A Study of the Chemical, Drug, and Petroleum Industries," Journal of Political Economy LXI, No. 2 (March-April, 1968), 292-306.

[8]The requirement that a conglomerate firm publish data for each of its industries is now under consideration by the Securities and Exchange Commission. This issue is discussed more fully in U.S., Congress, Senate, Subcommittee on Antitrust and Monopoly, Hearings, Concentration and Divisional Reporting, 89th Cong., 2nd Sess., 1966.

concentration from such broad industry groups. Although there have been attempts to relate four-firm concentration ratios to indices of technological innovation for a cross section of more narrowly defined industries, these studies have faced the same difficulty. Since each company's total research effort and total sales are classified into an industry according to its primary product, narrowly defined industry aggregates of consolidated firm data fail to reflect the importance of other industries, both for the company's total sales and for its research outlays. The more narrow the industry category is defined the more acute this problem becomes.[9]

Despite the limitations of published data, it is helpful to examine evidence based on their use. First, if the relationships found are in general agreement, then there is some assurance that the regression estimates, though crude, do not reflect systematic estimation errors. The influence of absolute firm size, in particular, may be estimated from consolidated company data; however, precise estimates of the separate influences of variables, such as market share and diversification, which are assumed to be positively correlated with firm size cannot be determined

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[9]Scherer, American Economic Review, LV, 1097-1125, and in a more recent article, "Market Structure and the Employment of Scientists and Engineers," American Economic Review, LVII (June, 1967), 524-31, attempts to determine the influence of market concentration ratios on innovation from more narrowly defined industries.

from such data. Second, and perhaps more important for interpreting the results of this study, the examination of previous results provides a basis of comparison among alternative indices of innovative performance. Particularly the relation between R&D input and innovative output is important in interpreting R&D intensity as an index of innovative performance.

The major contributions of this work, presented in Chapters III and IV, stem from a comprehensive body of unpublished data gathered by the Federal Trade Commission. From these data more meaningful measures of market structural variables have been derived for a sample of large multi-industry firms that perform organized research and development. The raw data from which these variables are determined consist of the dollar value of shipments in each of the firm's five-digit SIC product classes for the 1,000 largest manufacturers in 1950.[10] For a sample of corporations performing research during the same year, these data are used to derive measures of each firm's weighted average market share, the weighted average concentration of it markets, its diversification, and, finally, the weighted average rate of growth of its markets. The weights assigned in each of the averages depend on the relative importance

[10]They are the data underlying the Federal Trade Commission's Report on Industrial Concentration in the 1,000 Largest Manufacturing Companies: 1950 (Washington: U.S. Government Printing Office, 1957).

of each of the firm's five-digit product markets to the firm's total value of shipments. The exact procedures used to derive each market structural variable are described in detail in Chapter III. In Chapter IV multiple regression techniques are used to "explain" the variation among the firms' R&D laboratory employment per 1,000 total employees by the variation in the firms' size, market share, diversification, market concentration, market growth, and broad level of technological opportunity associated with the same primary two-digit SIC industry category. The separate influences of each of these independent variables on a firm's innovative effort are estimated from the partial regression coefficients.

Results and Their Significance

The regression estimates summarized in Chapter IV indicate that among firms already performing organized research, differences in their market structures have, at most, only a modest influence on their R&D efforts. Furthermore, of those variables which do exhibit a positive influence, there appear to be upper limits on their importance for research.

Firm size, for example, is found to be an important determinant of R&D effort among all firms; however, among large firms engaged in organized research, there is no general tendency for the proportion of a firm's resources allocated toward research to increase with its size.

Among the market structural variables, diversification is found to have a positive influence on a firm's research effort; however, the degree of market heterogeneity necessary for maximum research effort is not great. Diversification is more important for research within technically related areas which are within the realm of operation of moderately large firms. The other market structural variables are found to have no significant influence on a firm's research effort, although there is some evidence that a quadratic relation exists between market concentration and research. More specifically, markets with extremely low concentration ratios may be less conducive to research than moderately concentrated markets; however, when market concentration becomes too high, both price and nonprice competition (including technical rivalry) may decline. A "suggested" optimal market concentration ratio may exist when the leading four firms share between 50 and 60 percent of the market.

These results suggest that antitrust policies to limit the growth of large conglomerates and to prevent high levels of market concentration have no detrimental effect on the allocation of resources toward organized research and development and, indeed, may contribute toward greater research effort by industrial firms.

CHAPTER II

FIRM SIZE, MARKET STRUCTURE AND INNOVATION: THE EXISTING EVIDENCE

Although precise measures of market structural variables for large multimarket firms cannot be determined from the consolidated sales data which they report in their income statements, conclusions concerning the influence of firm size on technological innovation can be reached with some degree of certainty. Conclusions reached by previous studies on the influence of market concentration and diversification on innovation must be considered tentative due to data shortcomings. Nevertheless, it is of interest to review the studies' results as a basis of comparison with this study. This chapter examines empirical evidence from several published sources and reviews the results of several previous studies which estimate the influence of firm size, market concentration, and diversification on the innovative performance of industrial firms.

The Influence of Firm Size

Industry data published annually by the National Science Foundation have been referred to by several writers, notably Villard,[1] as empirical evidence supporting the hypothesis that dominance by large firms provides an industrial environment most conducive to innovation. Several characteristics in this body of data are evident. First, firms with over 5,000 employees are more likely to engage in organized research and development than are smaller firms. Second, among firms performing organized R&D, those employing more than 5,000 persons spend a greater amount on R&D in the aggregate than do smaller firms. Third, for the entire industrial sector firms with 5,000 or more employees exhibit higher ratios of R&D expenditures to net sales, on the average, than do firms employing fewer than 5,000 persons. In 1965 companies employing 5,000 or more spent $12,362 million, or 87 percent of the total funds spent on R&D in industry. In the same year companies employing from 1,000 to 4,999 spent $1,102 million or 8 percent of total industrial funds spent on R&D, and companies employing less than 1,000 spent $734 million or 5 percent of the total.[2] Also in 1965, companies employing greater than 5,000 spent 5.2 percent of net sales on R&D, while companies in the 1,000 to 4,999 size category

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[1]Henry H. Villard, "Competition, Oligopoly, and Research," Journal of Political Economy, LXVI (December 1958), 486.

[2]National Science Foundation, Basic Research, Applied Research, and Development in Industry, NSF 67-12, (Washington, D.C.: U.S. Government Printing Office, 1965), p. 22. NSF data is available on a comparable basis since 1957.

spent 2.3 percent and companies employing less than 1,000 spent 1.8 percent.[3]

A further examination of NSF data reveals two other characteristics. First, as shown in Table 1, within the same industry group the tendency for dollar expenditures on R&D as a percent of net sales to rise with the three employment size categories is much less evident than in the aggregate. Second, company-financed R&D expenditure as a percent of net sales is much less dependent on firm size than is total R&D expenditure as a percent of net sales. In 1965 the category of companies employing 5,000 or more spent 2.1 percent of net sales on company-financed R&D, while the 1,000 to 4,999 category spent 1.9 percent, and the less than 1,000 category spent an average of 1.4 percent.[4] The reduced importance of firm size when only company-financed R&D is examined is explained, of course, by the fact that Federal funded R&D is heavily concentrated among the largest firms.

Industry data published by the National Science Foundation suggest, therefore, that while firm size is an important determinant of organized R&D effort, the extent

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[3]Ibid., p. 68.

[4]Ibid., p. 78. Although the same industry categories exhibit a higher ratio of company-financed R&D to net sales among firms in the largest sized categories as for total R&D to net sales in Table 1, the differences between the ratio of expenditure to net sales among the size categories for firms in the same industry groups are drastically reduced when Federal funded R&D is excluded.

TABLE I

FUNDS FOR R&D AS A PERCENT OF SALES BY INDUSTRY AND SIZE OF COMPANY, 1965

Industry	Total	Companies with total employment of		
		Less than 1,000	1,000 to 4,999	5,000 or more
Total	4.3	1.8	2.3	5.0
Food and kindred products	.4	(a)	.4	.4
Textiles and apparel	.4	(a)	.5	.5
Lumber, wood prod., and furniture	.5	(a)	.5	.3
Paper and allied products	.7	(a)	.9	.6
Chemicals and allied products	4.2	(a)	4.3	4.4
Industrial chemicals	4.6	(a)	4.1	4.9
Drugs and medicines	5.9	3.9	6.8	5.9
Other chemicals	2.3	2.1	2.6	2.2
Petroleum refining and extraction	1.2	(a)	.9	1.2
Rubber products	1.9	1.3	1.0	2.2
Stone, clay, and glass products	1.6	(a)	.7	2.0
Primary metals	.8	(a)	1.0	.7
Ferrous products	.7	(a)	.4	.7
Nonferrous products	.9	(a)	1.3	.8
Fabricated metal products	1.4	1.1	1.0	1.7
Machinery	4.1	1.7	2.4	5.4
Electrical equipment	9.4	5.8	4.6	10.6
Communication and electronics	12.2	11.5	7.6	12.8
Other electrical equip.	7.0	2.9	2.7	8.5
Motor vehicles and other transp. equipment	3.1	1.8	1.0	3.2
Aircraft and missiles	28.0	8.0	16.1	29.3
Professional and Scientific instruments	6.2	4.9	5.0	7.2
Measuring instruments	3.9	5.6	3.4	3.3
Optical, surgical, and photographic instruments	7.2	4.2	6.2	8.1
Other mfg.	.7	(a)	.9	.4

(a) Not available separately but in total.

Source: National Science Foundation, Basic Research, Applied Research, and Development in Industry. (Washington, D.C.: U.S. Government Printing Office, 1965), p. 72.

to which larger firms are likely to allocate a higher proportion of resources to R&D is dependent, to a large extent, on the firm's primary activity. Furthermore, since NSF data do not give a breakdown of average R&D performance among larger firms (employing more than 5,000), it cannot be determined from such data if limits exist on the importance of firm size for innovative performance in all areas of the industrial sector.

There is considerable variation in R&D performance among larger firms in a number of industries that NSF data miss because there is no breakdown of firm size beyond 5,000 employed. Thus, when faced with the evidence of the National Science Foundation, Worley[5] and Hamberg[6] argue that the case for bigness would be strengthened if among only larger firms performing organized research in an industry, R&D increases more than proportional to firm size. Using a regression equation of the form $Y=AX^b$, where Y is the number of persons employed in R&D by each company and X is total company employment, both Worley and Hamberg estimated the parameter b among large firms.[7] For R&D

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[5] James S. Worley, "Industrial Research and the New Competition," Journal of Political Economy, LXIX (April, 1961), 183-86.

[6] Daniel Hamberg, R&D: Essays on the Economics of Research and Development (New York: Random House, 1966), p. 47.

[7] R&D employment data are taken from National Academy of Sciences, National Research Council, Industrial Research Laboratories of the United States, 10th and 11th editions (1956 and 1961).

to increase more than proportional to size, b would, of course, have to be significantly greater than one. For the eight industry groups both Worley and Hamberg sampled, they found the following results:

TABLE II

COMPUTED VALUE FOR b FOR EIGHT INDUSTRY GROUPS SAMPLED BY HAMBERG IN 1960 AND WORLEY IN 1955

Industry	b (Hamberg) 1960	b (Worley) 1955
Food and kindred products	0.767	0.638
Chemicals and allied products	1.156	1.071
Petroleum and products	*1.397	**1.229
Stone, clay, and glass products	*1.842	1.317
Primary metals	**0.665	0.885
Machinery (except electrical)	1.249	1.226
Electrical machinery	1.291	1.285
Transportation equipment	1.304	1.011

* Significant at .01 level.

** Significant at .05 level.

Hamberg finds b greater than one at the 5 percent level only for the petroleum, the primary metals, and the stone, clay, and glass industries, while Worley finds b significantly greater than one only in petroleum. Although both researchers conclude from this evidence that research intensity does not increase with firm size, F. M. Scherer has pointed out that the statistical methodology and data used lead to significant biases which render their results questionable.[8] In particular, the use of the logarithmic transformation of the independent and dependent variable places too much weight on the smaller-sized firms when the relation is not monotonic. Measurement error in the scale variable also has the effect of biasing the research elasticity consistently downward. It is also important to note that the analyses of Hamberg and Worley apply only to firms actually performing research and, hence, their results do not describe the relationship between firm size and the decision to undertake research.

The influence of firm size on research intensity is also likely to depend on the homogeneity of the sample of firms with respect to their technologies. Hence, when William Comanor estimated the research elasticities of twenty-one more homogeneous three-digit SIC industries or two-digit SIC industries with dummy variables to separate three-digits within the two-digit category, he generally found the coefficients of b in the exponential equation to decline. The elasticities found by Comanor exceed unity in only six cases of the twenty-one when the dependent variable includes only professional research personnel and in only ten cases of the twenty-one when total R&D employment is used.[9] Although none of the elasticities are found

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[8] F. M. Scherer, "Size of Firm, Oligopoly, and Research: A Comment," The Canadian Journal of Economics and Political Science, XXXI, no. 2 (May, 1965), 256-66.

[9] William S. Comanor, "Market Structure, Product Differentiation, and Industrial Research," The Quarterly Journal of Economics, LXXXI (November, 1967), 639-57.

to be significantly greater than one, seven of the twenty-one regression coefficients are found to be significantly less than one at the 5 percent level. In contrast, Hamberg found elasticities greater than one in twelve out of the seventeen broader industries he examined.[10]

If the relationship between research intensity and firm size has a point of inflection, then the exponential equation assumed in the methodology first used by Worley is clearly inappropriate. Scherer has estimated the relationship between R&D employment and firm sales for selected two-digit SIC industry groups using polynomials of the form

$$RD_i = a_0 + a_1 S_i + a_2 S_i^2 + a_3 S_i^3 + e_i \quad \text{and}$$

$$RD_i + b_0 + b_1 \log S_i + b_2(\log S_i)^2 + b_3(\log S_i)^3 + u_i$$

where RD_i is 1955 R&D employment and S_i is 1955 sales for the ith firm.[11] He finds that the relationship between R&D employment and firm size has a point of inflection in most industry categories sampled. For the total sample he finds that research intensity increases with size among

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[10]The stone, clay, and glass products industry is particularly heterogeneous. Hence, when dummy variables are added for each three-digit SIC category, the research elasticity estimated by Comanor is 0.80 which is significantly negative. Hamberg found the research elasticity on a two-digit basis to be 1.84 which is significantly positive.

[11]Scherer, <u>The Canadian Journal of Economics and Political Science</u>, XXXI, no. 2, 261-66. The logarithm is a technique used to suppress the values of extremely large firms.

firms with sales of less than roughly $500 million but decreases with firm size for firms with greater than $500 million in sales in 1955.[12] He does find several important exceptions, however, among the industries he examined. The chemicals industry as a whole and the giant leaders of the automobile and steel industries displayed increasing R&D intensity with sales.

Economies of Scale in R&D

Of particular importance for this study is the relation between innovative output per unit of R&D input and firm size. Since the hypotheses examined by this study are specifically concerned with the willingness and ability of firms to invest in research and development, R&D input is used as the dependent variable. However, if economies of scale in R&D are important among research-performing firms, then larger firms contribute more to the nation's technological progress than their research and development efforts would suggest.

Scherer has examined the relationship between not only firm size, measured by 1955 sales, and R&D input, measured by the number of R&D employment in the firm's R&D laboratories, but also the relation between firm size, measured by the same size variable, and innovative output, measured by the number of patents issued to the firm in

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[12]Ibid., pp. 264-5.

1959. Estimating nonlinear polynomials of the form

$$Y_i = a_0 + a_1 X_1 + a_2 X_2^2 + a_3 X_i^3$$

for 448 of Fortune's list of the 500 largest corporations in 1955, he found nonlinear regressions of R&D employment on sales which generally paralleled those estimated for patents on sales, although the regressions of patents on sales generally exhibited less pronounced nonlinearities than the corresponding R&D on sales equations. He did, however, find some evidence of diminishing returns to R&D input intensity. The more R&D employees per million dollars of sales a firm retained, the more patents per million dollars of sales it received, but at a decreasing rate.[13]

Jacob Schmookler measured patent output per R&D input for firms of different size classes in several research intensive industries, and concluded that, for the industries sampled, the largest firms are less efficient in their innovative output per R&D input than are the somewhat smaller firms.[14]

Although the number of patents is the only practical output measure for a large sample of firms, Edwin Mansfield measures inventive output by the number of significant

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[13] F. M. Scherer, "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions," The American Economic Review, LV (December, 1965), 1097-125. R&D employment includes professionals and supporting personnel.

[14] U.S., Congress, Senate, Subcommittee on Antitrust and Monopoly, Hearings, Invention, Innovation, and Concentration, 89th Cong., 1st Sess., 1965, pp. 1257-69.

inventions by a small sample of firms in the chemical, petroleum, and steel industries. Holding firm size fixed, he finds a strong positive relation between R&D expenditures and the output of significant inventions, but innovative output increases more than proportional to R&D input only for the chemical industry. In petroleum and steel the number of significant inventions increases in proportion to the amount of R&D effort. Hence, economies of scale are not important in two of three industries he studied.[15]

Perhaps the most reasonable conclusion concerning the importance of scale economies is that it varies according to the nature of the R&D activity of the firm. If the firm is engaged in the development of highly technical systems, such as ballistic missile or communication systems, then scale economies may be quite large. However, for the development of such items as electrical components, instruments, or drugs, the firm with only one gifted scientist and a small staff of supporting personnel may be all that is necessary to perform efficiently. Among large firms primarily in industries in which R&D projects are generally financed by company funds, the minimum size necessary for an efficient R&D program does not appear to be a significant

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[15] Edwin Mansfield, "Industrial Research and Development Expenditures Determinants, Prospects, and Relation of Size of Firm and Inventive Output," Journal of Political Economy, LXXII, No. 4 (August, 1964), 334-37.

barrier to innovation. Indeed, the greater difficulty in communication and coordination of larger scale R&D programs has been cited as a cause of diseconomies of scale in research and development.[16]

The Influence of Market Concentration

Empirical studies concerned with a direct structure-performance relationship between market concentration and innovation have related aggregate industry indices of innovation with four-firm industry concentration ratios. In several of these studies, 20 or fewer two- and three-digit SIC categories are used. Hamberg, for example, computed least squares and rank correlation coefficients between (1) industry aggregates of company-financed R&D expenditures and four-firm concentration ratios and (2) average industry company-financed R&D to sales ratios and the same measure of industry concentration, all data for the year 1958. He found coefficients of .56 and .46, respectively, for the first relation and .54 and .36, respectively, for the second. All coefficients except the last are significant at the .05 level.[17]

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[16]See, for example, the testimony of Arnold C. Cooper in the U.S., Congress, Senate, Hearings on Invention, Innovation, and Concentration, 89th Cong., 1st Sess., 1965, pp. 1293-307.

[17]Hamberg, R&D: Essays on the Economics of Research and Development, pp. 63-65. I. Harowitz in "Firm Size and Research Activity," Southern Economic Journal, XXVIII (January, 1962), 298-301 finds a similar positive relation between research and concentration.

Although broad industry groups generally include the majority of sales by large multimarket firms, it is improbable that any two such firms classified in the same broad category according to their primary product market would operate in the same markets in the same proportion with each other or with the group average. Hence, as Scherer observes, it is impossible to determine precisely "what has been cooked in the stew" in such a procedure.[18] To hold some of the other variables besides concentration constant while narrowing the boundaries of the industries he observes, Scherer utilizes a selected sample of industries from an FTC report for 1950.[19] From those industries in the FTC report he draws a sample of 48 which meet the following criteria: (1) The industry can be meaningfully defined in terms of economic analysis. (2) Bureau of Census coverage ratios are at least 75 percent for industries with concentration ratios less than 50 percent and 85 percent for industries with higher concentration ratios. (3) Primary product sales are at least 75 percent of industry sales. (4) The broad parent industry (two-digit SIC category) is suitable for making and patenting inventions. (5) Industry technology is such that patents can

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[18] Scherer, American Economic Review, LV, 1118.

[19] U.S. Federal Trade Commission, Report on Industrial Concentration and Product Diversification in the 1,000 Largest Manufacturing Companies: 1950 (Washington: U.S. Government Printing Office, 1957).

be meaningfully classified. (6) Among industries meeting the above conditions, those exhibiting a wide variation in technologies, concentration ratios, and total sales are chosen. Scherer uses a multiplicative regression model to "explain" the variation in the number of patents issued in 1954 to the four leading firms in each industry by the variation in the firms' sales in 1950, their share of total industry sales in 1950, and two slope dummy variables to differentiate industries in chemicals and in electricals. The regression coefficient for the market share variable suggests that structural market power, if it has any influence, is extremely modest.[20]

More recently from another sample of industries, however, Scherer finds market concentration to have a positive influence on the employment of scientists and engineers in an industry.[21] Furthermore, Scherer finds empirical support for the neo-Schumpeterian hypothesis that a quadratic relation exists between market concentration and research intensity. As concentration rises the employment of R&D personnel per 1,000 total employees in an industry increases up to a point and then decreases.

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[20] Scherer, American Economic Review, LV, 1118-21.

[21] Scherer's latter sample is taken from the U.S. Department of Commerce, Bureau of Census, Census of Population: 1960, "Occupation by Industry," (Washington: U.S. Government Printing Office, 1963). His results are published in "Market Structure and the Employment of Scientists and Engineers," American Economic Review, LVII, No. 3 (June, 1967), 524-31.

He concludes from this empirical evidence that higher concentration beyond very low levels may have a favorable influence on research; but if industries become too highly concentrated, the implicit collusion that often occurs against price competition in oligopolistic markets may be extended to other forms of nonprice competition, such as rivalry in research. For his sample of industries Scherer finds an "optimal" range of concentration for research when the four leading firms share between 50 to 55 percent of the total industry's value of shipments.

According to William Comanor, concentration may be considered to have two distinguishable effects on the level of research in an industry. The first is the firm size effect which arises from the obvious relationship between concentration and the relative size of the leading firms in an industry. The second effect is the market power effect which refers to the relation between concentration and market power and the latter's effect on research. In an empirical study on the relation between concentration and research, Comanor attempts to estimate the separate influences of each of these two effects.[22] His results suggest that while simply increasing the size among larger firms in an industry is unlikely to lead to greater R&D,

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[22]Comanor, The Quarterly Journal of Economics, LXXXI, 645-52. The multiple regression model employed in Chapter IV of this study will allow for similar estimates of these separate influences; however, it will approach the question at the level of the individual firm.

there is evidence that in some market situations higher concentration, holding firm size constant, is associated with increased research. In particular, in markets where prospects for achieving product differentiation are limited (consumer nondurables and material inputs) there is evidence of a positive relationship between industry concentration and research. However, in markets where product differentiation possibilities are high and, as a result, competition in research is likely to be important, there is no evidence that increased concentration leads to more research.

The Influence of Diversification

One of the difficulties in estimating the influence of the size distribution of firms in an industry on technological innovation from industry aggregates is that data are generally compiled on a basis of the company as the reporting unit. Large diversified firms which are classified into an industry by their primary product may, in fact, operate across many product markets. Since a diversified firm may not restrict its innovative efforts to products or processes closely related to its primary activity, its innovative performance may not be influenced entirely by the level of concentration in its primary industry.[23]

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[23]In Scherer's analysis of the difference in patent output among industries mentioned above, he attempts to

A measure frequently used to measure diversification is the complement of the specialization ratio, that is, one minus the ratio of primary industry shipments to total shipments of all firms in an industry. Hence, the lower the specialization ratio, the higher the degree of diversification. The specialization ratio can, of course, be applied to any measure of firm output. During the hearings before the Senate Subcommittee on Antitrust and Monopoly, Richard Nelson presented specialization ratios for R&D outlays, equal to the percent of R&D expenditures by firms in an industry directed toward the industry's primary products.[24] Table 3 summarizes his results and compares them with the average of the 1958 and 1963 employment specialization ratios derived from the Bureau of the Census' Enterprise Statistics.[25] A comparison between R&D and

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mitigate this problem by selecting industries with relatively specialized firms and by counting only those patents which pertain to the primary activity of the four leading firms in each industry. American Economic Review, LV, 1118-21.

[24]U.S. Congress, Senate, Subcommittee on Antitrust and Monopoly, Hearings, Invention, Innovation, and Concentration, 89th Cong., 1st Sess., 1965, p. 1141.

[25]Employment specialization ratios rather than shipment specialization ratios were used because the 1958 and 1963 Enterprise Statistics provide a matrix of employment by Enterprise category. Since employment in the primary industry was determined for a broad two-digit level of aggregation, the off-diagonal elements within the same broader category were also included. An average of specialization ratios by narrower classification understates the employment of the primary industry.

TABLE III

COEFFICIENTS OF SPECIALIZATION FOR R&D EXPENDITURE AND TOTAL EMPLOYMENT BY INDUSTRY

Industry	Specialization ratios	
	1960 R&D[a]	Employ-ment[b]
Aircraft and missiles	67.9	77.2
Chemicals	80.3	77.4
Electrical equipment and communication	58.7	63.6
Fabricated metals	32.4	80.3
Food and kindred products	78.1	88.9
Machinery	51.4	75.0
Motor vehicles and other transport equipment	58.1	91.0
Petroleum	52.6	88.5
Primary metals	58.8	73.8
Professional and scientific instruments	32.0	80.9
Rubber products	33.9	87.5

[a]Computed by Richard Nelson from National Science Foundation, Research and Development in Industry, 1960 (Washington: U.S. Government Printing Office, 1963), pp. 80-81.

[b]Average of employment specialization ratios computed from U.S., Bureau of the Census, Enterprise Statistics (Washington: U.S. Government Printing Office, 1962 and 1968), Table 6.

employment specialization ratios indicates that, except for chemicals, R&D expenditure is less specialized within the primary industry of the firm than is total employment.

Although R&D expenditures are diversified, it has not led to a diversification of R&D over product fields for the entire manufacturing sector. Table 4 presents an array of R&D expenditures on applied research and development by product field in 1960. If R&D expenditures are ranked

TABLE IV

PRODUCT FIELD ORIENTATION OF INDUSTRY RESEARCH AND DEVELOPMENT, 1960

Product field	Cost of R&D ($ millions)	Percent of total R&D
Applied Research and Development, total	$10,121	96.3
Guided missiles and spacecraft	2,192	21.7
Communication equipment and electronic components	2,184	21.6
Aircraft and parts	1,200	11.9
Chemicals	887	8.8
Machinery	755	7.5
Atomic Energy devices	613	6.1
Motor vehicles and other trans. equipment	553	5.5
All other product fields	1,737	13.2

Source: National Science Foundation, Basic Research, Applied Research, and Development in Industry, 1965 (Washington: U.S. Government Printing Office, 1967), p. 89.

according to their product field or their primary industry, the same familiar names head the list, namely, aircraft and missiles, electronics, chemicals, and machinery. It follows, therefore, that diversified firms primarily operating in research oriented industries seek out other research oriented industries into which they diversify their R&D activities. Firms in research intensive industries with a well defined scientific base, such as chemicals or aircraft and missiles, on the other hand, appear to find their greatest immediate payoff in fields in which they already operate. Therefore, firms in these industries tend to specialize their R&D programs within a relatively narrow range of product fields.[26]

Several researchers have related indices of diversification to innovative performance at the firm level to test the hypothesis of Nelson that a diversified firm is likely to be more research intensive, since it is better able to exploit unexpected research outputs than a more specialized firm and, therefore, can expect higher future returns from R&D.[27] Since company sales for multimarket firms are published on a consolidated basis, the measures introduced by these researchers are based upon a numerical count of the existing product markets of the firm.

Scherer measures firm diversification by the number of "technologically meaningful" industries in which the company operates.[28] Introducing this variable into regressions of patents on sales, patent intensity on sales, R&D on sales, and patents on R&D for 448 large corporations,

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[26]Table 3 shows that in chemicals especially, firms tend to specialize their R&D outlays.

[27]Richard Nelson, "The Simple Economics of Basic Scientific Research," Journal of Political Economy, LXVII (June, 1959), 297-306. Although Nelson argues in terms of more risky basic research, uncertainty is an important component of all R&D, and, therefore, the diversification hypothesis is worth testing.

[28]He derives roughly 200 "technological meaningful" industries by consolidating the 447 SIC four-digit manufacturing industries.

he finds a significant reduction in unexplained variance in every case.[29]

When, however, Scherer regressed patents on sales and diversification in 14 two- and three-digit industry groups, allowing each subsample to assume its own best-fitting sales and diversification coefficients, he found a total reduction in unexplained variance of only 1.05 percentage points beyond the contribution of simple linear regressions of patents on sales. Although this increment was significant at the 1 percent level in an F-ratio test, there was a decline in explanatory power of approximately 12 percentage points for his index of diversification. This decline in explanatory power suggests that Scherer's diversification index acted partly as a surrogate dummy variable to separate industry groups.[30]

An alternative measure of firm diversification is used by Grabowski. For companies primarily in the petroleum, chemical, and drug industries, he measures diversification by the number of separate five-digit SIC product classifications which have some potential relevance to R&D activity. Holding interfirm differences in internal availability of funds and research productivity constant,

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[29]When his index of diversification is added to a regression of patents on sales the variance in patenting is reduced by 13 percent. Similar results were found in each of the other regressions with a t-ratio of its regression coefficient of 5.0 or more. Scherer, American Economic Review, LV, 1115.

[30]Ibid.

he finds that diversification exerts a positive influence on research and development expenditures as a percent of sales.[31]

Although the empirical results of Scherer and Grabowski suggest that structural diversification has a favorable influence on R&D investment, such an interpretation should be made with caution due to the limitations of measures of diversification based upon the number of existing product markets of the firm.[32] One limitation in such measures is that a numerical count fails to give relative weight to the firm's primary markets versus other markets which are less important to the firm's total sales. A second limitation, which is particularly important in testing Nelson's hypothesis, is that such indices fail to measure the degree of heterogeneity of the firm's factors of production and marketing channels of distribution. For example, a firm may operate in six product markets all in chemicals and

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[31]Henry Grabowski, "The Determinants of Industrial Research and Development: A Study of the Chemical, Drug, and Petroleum Industries," Journal of Political Economy, LXXVI, no. 2 (March-April, 1968), 292-306. The data for the number of 5-digit product classes are taken from the Fortune Plant and Product Directory, 1961. Availability of internal funds is measured by last year's cash flow, deflated by current sales. R&D productivity is measured by the number of patents per R&D employee.

[32]This is not a criticism of their approaches to measuring diversification; however, it does point out the problem of measuring structural diversification for conglomerate firms reporting consolidated sales data.

exhibit more homogeneous factors of production and more closely related, functionally, products than another firm operating in only two product markets, but one each in chemicals and food products. Finally, the structural effect of diversification is more meaningful if rates of market growth in demand among firms are held constant. Hence, diversification may have a greater influence on a firm's R&D investment behavior if the primary markets of the firm offer few opportunities for its homogeneous growth.[33]

Summary

The empirical evidence reviewed in this chapter leads to several general conclusions concerning the influence of firm size and market structure on innovation. First, while large firms are more likely to undertake organized research than smaller firms, the tendency for larger firms already performing organized R&D to allocate a higher proportion of their resources to innovative activity depends, to a large extent, on the primary activity of the firm. In some industries larger firms are necessary to undertake extremely sophisticated research. Evidence on the performance of only the largest firms, however, indicates that upper limits exist on the importance of firm size for research

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[33]See Michael Gort, Diversification and Integration in American Industry (Princeton: Princeton University Press, 1962), pp. 104-5, for a discussion of the relationship among diversification, growth in market demand, and technological change.

in even the most technically oriented industries. Second, evidence from several sources suggests that economies of scale in R&D laboratories may be significant in certain industries. However, firms in these industries generally perform organized research which is heavily financed by Federal funds. Third, evidence on the structural influence of the size distribution of firms in an industry is mixed. Attempts to correlate the four-firm concentration ratio with measures of innovative performance have found no relation in some studies but have found a significant positive relation in others. The inconsistency of these results probably reflects the limitation of aggregate industry data for measuring the size distribution of markets for diversified firms reporting on a company basis. Fourth, there is evidence that diversification and technological research are positively related, and that diversified firms tend to seek out technically oriented industries in which to concentrate their R&D activities. This relationship can be more firmly established, however, if more meaningful measures of firm diversification are used.

CHAPTER III

MEASURING THE INFLUENCE OF MARKET STRUCTURE ON INNOVATIVE PERFORMANCE FROM UNCONSOLIDATED FIRM DATA

The methods and procedures of developing measures of the market structure and innovative performance of industrial firms determine to a large extent the usefulness of interpretations derived from their analysis. From the empirical results based on industry or consolidated firm data, it is apparent that policymakers need more precise information concerning the separate influences of market power and diversification on innovative performance. In the empirical analysis which comprises the balance of this study, more meaningful estimates of the influences of several market structural variables on innovative performance are determined based upon unconsolidated firm data.

The Sample: Its Origin and Biases

Because of the time-consuming efforts necessary to develop each measure of market structure for the firm, certain limits are established on the selection of a cross section of firms in order to keep the study within reasonable bounds. First, only publicly-owned corporations among the largest 1,000 in sales in 1950 are examined, since smaller firms are not included in the FTC Corporate Pattern Survey.[1] The data gathered by the FTC for each firm consist of the dollar value of shipments in each five-digit SIC product class in which the firm operated in 1950. A copy of the form sent out to each company is in Appendix B.[2] Second, only firms whose primary product markets are in the following major industry categories are included: (1) food products, except beverages; (2) chemical and allied products; (3) petroleum products; (4) stone, clay, and glass products; (5) primary metal products; and (6) motor vehicles and equipment. These particular categories are chosen because they provide a cross section of the manufacturing sector and because they performed a small proportional amount of Federal financed R&D, according to a 1951 survey by the Department of Labor.[3] Third,

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[1]Only food manufacturers among the largest 500 in 1950 are examined in order to keep the number of such firms at a reasonable level compared to the other industries represented.

[2]In computing the measures of the independent variables based on the FTC Corporate Pattern Survey, only those product classes contributing as much as 1 percent to the total shipments of the firm are examined, so that the lengthy computational process can further be reduced. The exclusion of product classes which contribute less than 1 percent does not alter the measurements significantly. In the food products industries the same measures were computed using all product classes and in no case was the measure altered as much as 1 percent.

[3]U.S. Department of Labor, Scientific Research and Development in American Industry, Bulletin No. 1148 (Washington: U.S. Government Printing Office, 1953), pp. 76-77.

only those companies reporting the number of employees in their research laboratories for 1950 in the National Research Council's Industrial Research Laboratories of the United States[4] are included.

The sample satisfying these three conditions consists of a fairly large (181) collection of firms with a representative number from each of the major industry categories. A frequency distribution of the sample by industry category and size class is given in Table 5. The actual firms included in the sample are listed by industry in Appendix A.

This selection process leads to certain biases as a representative sample of all manufacturing firms. First, it excludes a number of important research-performing firms which operate primarily in industry groups other than the six examined. For example, firms in the aircraft and parts or electrical equipment industries employed 42.8 percent of all R&D personnel in manufacturing in 1952, but they are deliberately excluded from the sample because 85.1 and 57.0 percent of their R&D, respectively, was financed by the Federal Government.[5] Second, the sample includes only relatively large firms which reported their R&D employment in 1950. Hence, conclusions reached from this sample are

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[4]National Academy of Sciences, National Research Council, Industrial Research Laboratories of the United States, 9th ed. (Washington, D.C., 1956).

[5]U.S. Department of Labor, Scientific Research and Development in American Industry, pp. 59 & 78.

TABLE V

FREQUENCY DISTRIBUTION OF FIRM SAMPLE BY INDUSTRY AND ASSET SIZE CATEGORY,[a] 1950

Industry	Total number	Firms with assets in $ millions: Less than 50	50 – 100	100 – 200	200 or above
Food and kindred products	42	17	13	7	5
Chemicals and allied products	49	25	13	6	5
Petroleum extraction and refining	27	17	4	5	1
Stone, clay, and glass products	19	8	7	3	1
Primary metals	24	10	4	2	8
Motor vehicles and transp. equipment	20	7	4	5	4
Total	181	84	45	28	24

[a]The range of asset size is from $11.1 million for the smallest firm to $4,188.0 million for the largest firm.

concerned only with the influence of market structure and size on the R&D performance of firms performing organized research, and no conclusions can be reached concerning their influence on the decision to undertake organized research and development.

An alternative to speaking of a biased sample is to say that the selection process enumerates very nearly a specific universe. In this universe the typical firm is a fairly large firm that is engaged in organized research and development financed primarily by company funds and operates in several, at least moderately concentrated, markets. Although the sample is not representative of all manufacturing firms, it is representative of the industrial giants referred to by Galbraith as essential for technological innovation.

Although dated, the year 1950 is relevant to the time period when most of the arguments favoring larger firms and more concentrated markets for research were formalized.[6] Empirical evidence from several sources suggests that the importance of the size distribution of firms in an industry to the level of research and development performed in that industry may not have changed appreciably since 1950. Hence, research elasticities estimated by Hamberg in 1960 are in close agreement with those estimated by Worley in 1955.[7] Mansfield's estimates of the elasticities of research expenditures with respect to firm sales among large firms in the chemical, petroleum, drug, steel, and glass industries during the period 1945 to 1959 revealed no systematic change in the research elasticities among firms in these industries over time.[8] Furthermore, National Science

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[6]The Schumpeterian thesis was first published in 1942, and the arguments of Galbraith, Lilienthal, Kaplan, and Villard appeared in the literature during the 1950's. See supra, ch. I, pp. 1-2.

[7]See supra, p. 14.

[8]Edwin Mansfield, "Industrial Research and Development Expenditures: Determinants, Prospects, and Relation to Size of Firm and Inventive Output," The Journal of Political Economy, LXXII, no. 4 (August, 1964), 327-37.

Foundation data available on a comparable basis from 1958 to 1965 reveal similar patterns of company-financed R&D expenditures as a percent of net sales across three employment size categories, less than 1,000 employees, 1,000 to 4,999 employees, and 5,000 employees or more.[9] However, the influence of market structure on a firm's research intensity may have changed over time, but more conclusive evidence will not be forthcoming until unconsolidated sales data for multiple product firms, similar to that used in this study, are made available for a more recent time period.

Although recent conglomerate merger trends have increased industrial diversification, many of the large firms in the sample were considerably diversified in 1950. However, while such firms often operated across several two-digit SIC industry categories in 1950, the sample cannot be taken as representative of so-called "pure" conglomerates that operate in many markets which are neither technically nor functionally related. Nevertheless, 1950 estimates of the influence of diversification probably represent more than mere historical evidence of its importance for R&D investment.

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[9]National Science Foundation, Basic Research, Applied Research, and Development in Industry, 1965 (Washington: U.S. Government Printing Office, 1967), p. 69.

The Dependent Variable

Although there is no completely accurate measure of innovative performance available for a large sample of firms, the measure used in this study is the number of R&D employees in the firm's R&D laboratory or laboratories per 1,000 total company employees in 1950. R&D employment is the most frequently used measure of R&D performance by the firm. R&D expenditures are not readily available from published sources at the firm level.[10]

The only practical alternative measure of innovative performance available from published sources for a large sample of firms is the number of patents issued to the firm during a representative period of time. For several reasons, however, R&D employment rather than patents was chosen as the dependent variable. First, since the Schumpeterian thesis is concerned specifically with the influence of firm size and market power on a firm's willingness and ability to invest in costly and risky research, it is theoretically more correct to use a measure of R&D input rather than innovative output. Second, since the

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[10] R&D employment data for each firm are taken from the National Research Council's, Industrial Research Laboratories of the United States (1950). Since the hypotheses are concerned with the decision to allocate a higher proportion of resources to R&D, the dependent variable is expressed as a measure of intensity rather than the absolute level of R&D employment. R&D employment includes both professionals and supporting personnel.

number of patents a firm seeks is more variable over time than is R&D employment, patent data may not be as desirable in cross-section analysis that estimates structural influences in the underlying relationships which are relatively stable over time.[11] Third, comparisons of patents among firms may be misleading due to different "propensities to patent," that is, differences in the number of patents a firm seeks relative to the number of inventions or innovations it makes. The very fact that a firm possesses monopoly power may lower the number of patents it seeks, since the more a firm approaches industrial domination, the less it needs patents to give it monopoly control over the inventions used. Although large firms may avoid patents to maintain secrecy, the short-run marginal cost of patenting may be lower for large firms with a staff of in-house patent attorneys. To use patent counts to measure innovative performance, therefore, may lead to differences among firms of different market structures that are not a reflection of differences in their innovative activity.[12]

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[11]For cross-section studies patent data should be averaged over, at least, a 3-5 year period. See Dennis C. Mueller, "Patents, Research and Development, and the Measure of Inventive Activity." The Journal of Industrial Economics, XV, no. 1 (November, 1966), 26-37 for a discussion of this problem as well as a comparison between patent and R&D figures to measure inventive activity. His conclusion is that "both patents and R&D data, if employed with caution, may provide the researcher with satisfactory indexes of inventive activity."

[12]F. M. Scherer recognizes the problem of interfirm and interindustry differences in the propensity to patent.

The Definition of Research and Development

In interpreting the intensity of R&D employment as an index of innovative performance, the nature of the innovative output likely to result from resources allocated to organized research and development should be considered. The definition of R&D used by the National Science Foundation for classifying statistical measurement is as follows:

> Research and development includes basic and applied research in the sciences and engineering, and design and development of prototypes and processes. . . . It excludes quality control, routine product testing, market research, sales promotion, sales service, research in the social sciences or psychology, or other nontechnological activities or technical services.[13]

Although the National Science Foundation has attempted to distinguish between R&D and more routine design improvements, there is little doubt that companies include as R&D the more or less routine work that goes into yearly changes in model design. An examination of Westinghouse's R&D activities, for example, revealed the following breakdown of expenditures: 2 percent was for "blue sky" research that was not connected in any way with current products,

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Accounting for differences among industries with dummy variables, he assumes interfirm differences in the same major industry category to be a random disturbance which, unless correlated with one of the independent variables, serves only to increase the unexplained variance in his regression equations. See "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions," American Economic Review, LV (December, 1965), 1258.

[13]National Science Foundation, p. 119.

3 percent for long-range major developments, 6 percent for continuations of promising past research, 10 percent for standard product development, and 79 percent for developments required for customer-tailored equipment.[14]

The Uncertainty of Research and Development Investment

An ideal classification of R&D performance would relate R&D activities to the possibilities of future application.[15] Certainly the risk of investment in activities with an uncertain future payoff is much greater than the risk associated with a customer-tailored development expenditure having a fairly certain application.

The breakdown by the National Science Foundation of R&D into the three categories of basic research, applied research, and development expenditures allows for some consideration of aggregate firm behavior regarding investment outlays with different possibilities of future application. The National Science Foundation defines basic research to "include the cost of research projects which represent original investigation for the advancement of scientific knowledge and which do not have specific commercial

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[14]U.S. Congress, Senate, Hearings before the Subcommittee on Antitrust and Monopoly, Concentration, Invention, and Innovation, 89th Cong., 1st Sess., 1965, pp. 1244-45.

[15]David Novick suggests such a classification in his testimony before the Subcommittee on Antitrust and Monopoly, Ibid., pp. 1241-56.

objectives, although they may be in the fields of present or potential interest to the reporting company." Applied research "includes the cost of research projects which represent investigation directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes." Note that this definition of applied research differs from the definition of basic research chiefly in terms of the objectives of the reporting company. Development "includes the cost of projects which represent technical activity concerned with nonroutine problems which are encountered in translating research finding or other general scientific knowledge into products or processes."[16] Table 6 is a percentage distribution of R&D investment into these three components. For all industries only 4 percent of R&D was for basic research while 77 percent was for development. Basic research appears to be most promising when firms are in industries having a scientific base, such as chemicals, drugs, and petroleum. Development expenditures appear more significant in industries based upon mechanical devices such as machinery, electrical equipment, and aircraft and missiles.

The degree of certainty involved in a particular type of R&D investment expenditure is also related to the length

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[16]National Science Foundation, p. 121.

TABLE VI

DISTRIBUTION OF R&D BY TYPE OF INVESTMENT, 1965

Industry	Percent of total industry R&D Basic	Applied	Development	Total
Food and kindred products	7	47	46	100
Textiles and apparel	5	44	51	100
Lumber, wood products, furniture	(a)	(a)	(a)	100
Paper and allied products	2	37	61	100
Chemicals	12	39	49	100
Petroleum extraction and refining	12	38	50	100
Rubber products	5	24	71	100
Stone, clay, and glass products	6	37	56	100
Primary metals	6	(a)	(a)	100
Fabricated metal products	2	22	75	100
Machinery, except electrical	2	13	85	100
Electrical equipment	5	14	82	100
Motor vehicles and transp. equipment	3	(a)	(a)	100
Aircraft and missiles	1	14	84	100
Instruments	(a)	(a)	(a)	100
All industries	4	19	77	100

(a) Not separately available but included in total.

Source: National Science Foundation, Basic Research, and Development, 1965 (Washington: U.S. Government Printing Office, 1967), p. 78.

of time expected for the investment to pay off. Table 7 shows the percent of companies in a number of industries which expect their R&D expenditures to pay off in 3 years or less, 4 to 5 years, or 6 years or more. For all manufacturing industries represented by the McGraw-Hill survey, 55 percent of the companies expected a payoff of 3 years or less from their R&D expenditures. In contrast, only 11 percent of the companies in all manufacturing expected a payoff of over 6 years from their R&D investment.

Both the emphasis on development expenditures and on a short expected payoff period lend support to the assumption that most firms are risk averters, that is, they prefer investments with a short payoff period and relatively certain future applicability to investments having a longer payoff period and more uncertain future applicability.

An evaluation of the risk involved in R&D investment must consider the source of funding. The use of Federal funding rather than company funding eliminates the market risks and incentives to which the Schumpeterian hypotheses are solely applicable. Table 8 reveals that Federal funds have accounted for over one-half of all expenditures for industrial research and development since 1956. Although the Federal Government finances over 50 percent of all R&D performed in manufacturing, it is largely concentrated in the electrical equipment and aircraft and missile industries. Table 9 presents the source of funding by industry in 1965. The trend toward a higher percentage of

TABLE VII

EXPECTED PAYOFF PERIOD OF R&D BY INDUSTRIES[a]

Industry	Percent of companies expecting payoff in		
	3 years or less	4 to 5 years	6 years or more
Iron & steel (ferrous)	38	50	12
Nonferrous metals	64	18	18
Machinery, not electrical	51	39	10
Electrical machinery	61	32	7
Autos, trucks, and parts	54	40	6
Transportation equipment	43	44	13
Fabricated metals and instruments	77	14	9
Chemicals	33	41	26
Paper and pulp	50	32	18
Rubber	38	38	24
Stone, glass, and clay	38	46	16
Petroleum and coal products	17	33	50
Food and beverages	54	43	3
Textiles	76	24	0
Misc. marketing	71	25	4
All manufacturing	55	34	11

[a]The McGraw-Hill survey usually consists of the larger firms. Together they employ about 40 percent of all workers in industry. The survey question was: "How soon do you expect your expenditures on research and development to pay off?"

Source: McGraw-Hill, Department of Economics, published in National Industrial Conference Board, Economic Almanac, 1967-1968 (New York: The MacMillan Company, 1967), p. 241.

TABLE VIII

TRENDS IN FUNDS FOR INDUSTRIAL R&D PERFORMANCE BY SOURCE, 1953-65

(Dollar amounts in millions)

Year	Total R&D	Federal		Company	
		Amount	Percent of total	Amount	Percent of total
1965	$14,197	$7,759	55	$6,438	45
1964	13,512	7,720	57	5,792	43
1963	12,630	7,270	58	5,360	42
1962	11,464	6,434	56	5,029	44
1961	10,908	6,240	57	4,668	43
1960	10,509	6,081	58	4,428	42
1959	9,618	5,635	59	3,983	41
1958	8,389	4,759	57	3,630	43
1957	7,731	4,335	56	3,396	44
1956	6,605	3,328	50	3,277	50
1955	4,640	2,180	47	2,460	53
1954	4,070	1,750	43	2,320	57
1953	3,630	1,430	39	2,200	61

Source: National Science Foundation, 67-12 (1965).

total industry R&D financed by the Federal Government reflects, to a large extent, the growing importance of publicly-supported R&D in these two industries which are growing rapidly relative to other manufacturing industries.

TABLE IX

PERCENT OF FUNDS FOR R&D BY INDUSTRY AND SOURCES OF FUNDING, 1965

Industry	Total	Company-financed (percent)	Federally financed (percent)
Food and kindred products	100	99	1
Textile mill products and apparel	100	(a)	(a)
Lumber, wood products, furniture	100	(a)	(a)
Paper and allied products	100	100	---
Chemicals and allied products	100	86	14
Petroleum extraction and refining	100	84	16
Rubber products	100	85	15
Stone, clay, and glass products	100	97	3
Primary metals	100	96	4
Fabricated metals	100	89	11
Machinery, except electrical	100	77	23
Electrical machinery	100	38	62
Motor vehicles and transp. equipment	100	74	26
Aircraft and missiles	100	12	88
Instruments	100	68	32
All manufacturing	100	45	55

(a) Not separately available but included in total.

Source: National Science Foundation, NSF 67-12 (1965).

The Relation Between R&D Employment and Expenditures

Table 10 shows that the cost per research scientist or engineer increases with the size of research-performing firms. There are two reasons for this relationship. First, larger companies typically employ a higher ratio of supporting personnel per scientist or engineer than do smaller companies. Second, larger firms are generally more capital intensive in their R&D activity than are smaller firms. The relatively low support ratios and less capital intensive R&D programs of smaller companies are attributed partly to the fact that such firms contract out much of their subprofessional work to drafting firms and machine shops because their work volume does not warrant the maintenance of staff and equipment to perform these functions. However, it is probably also true that the cost per R&D scientist or engineer depends upon the nature of the research program itself. Research is more labor intensive than is development. For example, in the transportation equipment and electrical equipment industries, two industries which performed a relatively high proportion of development relative to research activity, the cost per research scientist or engineer is relatively high. Among different sized companies in the same industry, smaller firms are probably more willing to undergo R&D work at its initial stage, when its unit costs are lower but the uncertainty of future payout is higher, than are larger firms.

TABLE X

AVERAGE COST PER RESEARCH ENGINEER OR SCIENTIST, BY INDUSTRY AND SIZE OF COMPANY, 1951[a]

Industry	All Companies	Less than 500 employees	500 to 4,999 employees	5,000 or more employees
Food and kindred products	$17.0	$10.6	$15.0	$18.2
Textiles and apparel	19.2	10.2	19.6	20.0
Paper and allied products	13.5	11.4	12.1	15.4
Chemicals and allied products	16.5	12.5	14.7	17.9
Industrial chemicals	18.2	12.2	12.9	19.6
Drugs	16.4	10.2	17.6	16.9
Petroleum extraction and refining	20.9	20.5	17.9	21.0
Rubber products	13.6	12.8	18.1	13.4
Stone, clay, and glass products	18.6	13.3	13.7	19.7
Primary metals	21.5	14.5	16.8	22.6
Fabricated metals	16.5	16.0	15.9	17.8
Machinery, except electrical	18.3	16.4	20.9	16.6
Electrical machinery	28.1	19.0	18.1	32.4
Transportation equipment	27.6	22.2	27.3	27.7
Motor vehicles	68.6	12.4	31.1	75.5
Aircraft and parts	24.3	24.3	26.0	24.1
Instruments	17.9	16.0	14.9	19.6
Other manufacturing	19.4	15.0	21.7	17.1
All manufacturing	22.5	15.6	18.4	24.4

[a]Costs are in hundreds of dollars.

Source: Department of Labor, Scientific Research and Development in American Industry (Washington: U.S. Government Printing Office, 1953), pp. 82-83.

The low-cost high-risk exploratory work which is initiated by a small company (or independent inventor) is subsequently taken over by large companies willing to undergo the less risky, but higher cost development work. For example, Willard Mueller found that of the twenty-five important new innovations introduced by DuPont from 1920 to 1950, fifteen were based upon work initially performed by small companies or independent inventors outside of DuPont.[17]

Since the ratio of supporting personnel to R&D scientists and engineers generally increases with the size of the firm, the variance in cost per research worker among different sized firms is less than the variance in cost per scientist or engineer. Table 11 gives the cost per research worker among industries and different sized companies in January 1951. When compared with Table 10, it is evident that, especially in the motor vehicle industry, the support ratio increases with firm size. It is also apparent from a comparison of Tables 10 and 11 that the use of R&D employment (research professionals plus supporting personnel) as a dependent variable gives less weight to the R&D performance of larger firms than if R&D expenditures were used. However, more weight is given to the largest firms than if only the employment of R&D scientists or engineers is used as the dependent variable. Total R&D employment is chosen as the principal dependent variable because it is more closely aligned with the firms' R&D investment expenditures. However, since there is some evidence that the employment of research professionals is

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[17]Willard F. Mueller, "The Origins of the Basic Inventions Underlying DuPont's Major Product and Process Innovations, 1920 to 1950," The Rate and Direction of Inventive Activity: Economic and Social Factors (Princeton: Princeton University Press, 1962), p. 323.

TABLE XI

AVERAGE COST PER RESEARCH WORKER, BY INDUSTRY AND SIZE OF COMPANY, 1951

(Costs are in hundreds of dollars)

	All Companies	Less than 500 employees	500 to 4,999 employees	5,000 or more employees
Food and kindred products	$8.7	$5.8	$8.7	$8.8
Textiles and apparel	8.5	7.1	11.2	7.2
Paper and allied products	7.1	5.6	6.5	8.0
Chemicals and allied products	7.9	6.9	8.2	7.9
Industrial chemicals	7.8	7.7	7.1	8.0
Drugs	9.2	6.7	9.8	9.1
Petroleum extraction and refining	8.1	7.4	6.9	8.1
Rubber products	7.2	8.7	8.4	7.1
Stone, clay, and glass products	6.6	7.7	7.1	6.5
Primary metals	10.1	9.9	5.6	11.5
Fabricated metals	7.9	7.6	7.5	8.6
Machinery, except electrical	8.0	8.3	8.8	7.4
Electrical machinery	9.4	8.4	7.6	10.0
Transportation equipment	10.0	7.8	9.5	10.0
Motor vehicles	10.9	8.0	7.5	11.2
Aircraft and parts	9.7	7.8	9.4	9.8
Instruments	7.5	7.6	6.9	7.6
Other manufacturing	8.7	8.3	9.0	8.2

Source: Department of Labor, Scientific Research and Development in American Industry (Washington: U.S. Government Printing Office, 1953), pp. 88-89.

more closely related to significant research undertakings than is total R&D employment, regression equations are also estimated with R&D employment less supporting personnel as the dependent variable.[18] These regression coefficients

[18]In a study of the drug industry, Comanor found that the number of research professionals was more closely

will be noted only if they lead to significantly different results from those obtained when using total R&D personnel.

The Independent Variables

The independent variables in the regression analysis are the firm's absolute size, its average market share, the average concentration of its markets, its diversification, the average growth in output of its markets, and the broad level of scientific and technological opportunity associated with its operations. Each of these variables is expected to have a positive influence on a firm's research intensity. With the exception of the measures of firm size and scientific and technological opportunity, these measures are derived from data gathered in the FTC Corporate Pattern Survey.

Absolute Firm Size

The hypothesis that larger firms are likely to invest in proportionately more research than somewhat smaller firms is based upon the assumption that firms are risk averters, that is, they attach a premium to the reduction

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related to the output of the research facility than was the total number of research personnel. He measured research output in terms of new products weighted by their sales during the first two calendar years following their introduction. See William S. Comanor, "Research and Technical Change in the Pharmaceutical Industry," Review of Economics and Statistics, LXVII (May, 1965), 182-90.

of uncertainty.[19] A greater number of simultaneous R&D projects enables a larger firm to balance its successes against failures and, thereby, to receive a more predictable return on its R&D investment. Therefore, even if future R&D investment returns have the same expected value among different sized firms, the variability of such returns is expected to be lower for larger firms. Since this lower variability reduces uncertainty, it can be argued that, other things equal,[20] larger firms will find risky research relatively more attractive than somewhat smaller firms.

The measure of firm size introduced in this study as an independent variable is total assets since it is the most widely used measure of conglomerate size. If the proportion of resources allocated to research by the firm increases with firm size, then the partial regression coefficient of the size variable is expected to exceed zero.

Although the choice of a measurement of absolute firm size is somewhat arbitrary, it is likely to lead to different results if the sample of firms is not homogeneous

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[19]The importance of firm size for reducing uncertainty is given extreme emphasis by J. K. Galbraith in The New Industrial State (Boston: Houghton Mifflin Co., 1967).

[20]In the multiple regression analysis to follow the market structure and technological opportunity of the firm are held constant; however, the degree of management's aversion to risks is not because it could not be adequately measured. It will be assumed, however, that interfirm differences in the degree of management's aversion to risks are random and, unless correlated with one of the independent variables, serve only to increase the unexplained variance.

with regard to factor proportions. Suppose, for example, firms are ranked according to their employment size, then labor intensive firms (those with a high labor-to-output ratio) would rank higher than if ranked by assets, or output. Similarly, capital intensive or highly integrated firms would rank higher by assets than by other measurements. In order to satisfy the condition of homogeneity with regard to factor proportions, the sample of firms are separated by dummy variables into subgroups. It is then assumed that differences in factor proportions among firms in the same subgroup are random, leading to no systematic bias in the regression coefficient for the size variable.[21] The selection of the subgroups will be discussed in a later section of this chapter.

Market Share

Schumpeter argues that a larger market share increases the willingness and ability of an industrial firm to invest venture capital in new and improved products and processes because it provides protection against the temporary disorganization of the market necessary for long-range investment, while increasing the supply of internal funds.

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[21]When total employment was used as an alternative size measure rather than total assets and dummy variables were included for each two-digit SIC industry group, the regression coefficients for the two size measures yielded substantially the same results. Hence, the assumption of intraindustry homogeneity of factor proportions appears valid.

The measure of market share for each firm introduced in the study is a weighted average of the firm's share of each of its product markets. It is computed by multiplying the firm's shipments in each of its product markets by its share of the total shipments in that market, summing over all the product markets of the firm, and dividing by the company's total shipments.[22]

Since market share is measured by the firm's sales relative to total market sales, the first procedure in determining a market share for each of the firm's markets is to define each market's boundaries. Defining a particular market is extremely difficult since it is at best an arbitrary process; however, for purposes of determining weighted averages for the firm, it was found convenient to proceed on a basis of the industry definitions of the Bureau of the Census' Standard Industrial Classification at the five-digit level of aggregation. On a basis of substitutability or "cross-elasticity of demand" the five-digit level of aggregation is probably more relevant than broader three- or even four-digit levels, although the broader categories may be more relevant from the supply

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[22]Although this procedure gives greater weight to the market shares of the firm's primary markets, that is, those markets in which it has the greatest shipments, in many instances the firm holds a larger share of markets which comprise a relatively small proportion of its total shipments. This occurs, of course, because market share also depends on the size of the market.

side.[23] There is one exception to the SIC system of defining markets which cannot be overlooked, and that is the market for beet and cane sugar. Since the two types of sugar are classified into two categories but are perfect substitutes the shipments of the two categories are combined for the purpose of determining the firm's share of the market.

The relevant market for each product may also be restricted by geographic location, depending on the nature of the product and the method of its distribution. Because of the availability of adequate distribution channels, most of the markets examined are considered national in scope. However, there are several exceptions. The markets for prepared animal feeds; inorganic chemicals, not elsewhere classified; fertilizers; petroleum refining; paving mixtures and blocks; hydraulic cement; gray iron foundaries; and aluminum castings are considered to be regional markets. The markets for ice cream and frozen desserts, fluid milk, and bread and related products are considered as state markets.[24]

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[23]Dr. Frank Kottke, who was responsible for the FTC Corporate Pattern Survey while a staff member of the Bureau of Economics, holds this position after years of working with the Standard Industrial Classification.

[24]These industries are among those selected by the Senate Subcommittee on Antitrust and Monopoly as being characterized by local or regional marketing. Other studies correct for geographic boundaries in these industries. See, for example, the coefficient of geographic dispersion derived by Collins and Preston in Concentration and Price-Cost Margins in Manufacturing Business (Berkeley and Los

The market shares of all but the geographic markets and the market for sugar for each firm's markets are derived by dividing the firm's value of shipments from the FTC Corporate Pattern Survey in each of its five-digit SIC product classes by the 1950 value of shipments of all firms in the same product class. For selected five-digit product classes the total shipments are taken from the Bureau of Census' Annual Survey of Manufactures: 1951. For the five-digit product classes not available from this source, total shipments for the years 1947 and 1954 are taken from the Bureau of Census' United States Census of Manufactures: 1954. To obtain an industry figure for 1950, it is assumed that changes in the value of shipments from 1947 to 1954 followed a linear trend.[25]

For the several regional and state markets, the following adjustment in industry shipments on a national basis is made to allow for geographic boundaries. From Part II of Concentration Ratios in Manufacturing Industry, 1963 a weighted average four-firm concentration ratio of the several regions of the United States is derived for each of the regional markets by multiplying the concentration

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Angeles: University of California Press, 1968); and George Stigler, Capital and Rates of Return in Manufacturing Industries (Princeton: Princeton University Press, 1963).

[25]The exact value is three-sevenths of the difference between 1954 and 1947 shipments added on to 1947 shipments. Data from the 1954 volume are gathered on a basis of the 1950 codes to account for changes in the SIC system.

ratio in each region by the value of shipments in that region, summing over all regions, and dividing by the United States total shipments. For the state markets a similar weighted average is taken except among the state concentration ratios. Since these ratios are given on a four-digit basis, the five-digit categories of the firm in these four-digit groups are summed together for purposes of determining their market share. To obtain a value of the industry shipments on a regional or state basis, the total 1950 U.S. value of shipments is divided by the ratio of the 1963 regional or 1963 state to 1963 national four-firm concentration ratios to determine a smaller industry total corrected for geographic boundaries.[26]

After the firm's share of each of its product markets, adjusted for geographic boundaries, is determined, the weighted average market share previously described is computed for each of the 181 firms in the sample.

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[26]Since the regional or state concentration ratio is invariably higher that the national concentration ratio, the ratio of regional or state to U.S. concentration ratios is greater than one. Hence, when the U.S. industry total is divided by this ratio its value is reduced.

This deflation procedure assumes that the shipments of all firms are distributed in 1950 is the same proportion as the top four firms in 1963. Although the method is not ideal, it leads to a better measure of market share and concentration for regional and state markets than if no corrections are made.

The 1963 concentration data are published in a report prepared by the Bureau of the Census for the U.S. Senate Subcommittee on Antitrust and Monopoly, 89th Cong., 2nd Sess., 1966.

Market Concentration

To measure the level of concentration in the firm's markets, a weighted average four-firm concentration ratio and a weighted average eight-firm concentration ratio are derived for each firm. While these ratios or any other single statistic do not fully describe the number and size distribution of firms in a market, they are generally acknowledged to capture the essential feature of the distribution, namely, the combined market position of the leading firms. Theoretical arguments and increasing empirical evidence indicate that high levels of market concentration increase the probability that a market behaves "oligopolistically."[27]

The procedure used to determine the measures of concentration is similar to that used to determine a weighted average market share except that the percent of shipments by the top four and top eight firms can be found directly from published data. The four-firm and eight-firm concentration ratios for each five-digit product market, except those for sugar and the several regional markets, are taken from the Report of the Senate Subcommittee on Antitrust and Monopoly, Concentration in American Industry,

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[27]See, for example, Joe S. Bain, "Relation of Profit Rate to Industry Concentration: American Manufacturing, 1936-1940," Quarterly Journal of Economics, LXV (August, 1951), 293-324; and Leonard W. Weiss, "Average Concentration Ratios and Industrial Performance," Journal of Industrial Economics, XI (July, 1963), 237-54.

1954.[28] For the sugar industry weighted averages of the four-firm and eight-firm concentration ratios for beet and cane sugar are used. For the regional markets the four-firm concentration ratio is the weighted average of the U.S. regional concentration ratios in 1963. To determine an eight-firm concentration ratio on a regional basis, it is assumed that the share held by the eight leading firms relative to the share of the top four firms on a regional basis is proportional to the share of the top eight relative to the top four on a national basis. Hence, the U.S. eight-firm concentration ratio is multiplied by the ratio of the four-firm regional to four-firm U.S. concentration ratios. The same procedure is used to determine the four-firm and eight-firm concentration ratios for the state markets except that state rather than regional weighted averages are used. To obtain a weighted average four-firm concentration ratio for each firm, the four-firm concentration ratio in each product market is multiplied by the firm's shipments in that market, summed over all product markets of the firm, and divided by the firm's total value of shipments. The same procedure is applied to the eight-firm concentration ratio for each product market to derive

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[28]U.S. Congress, Senate, Subcommittee on Antitrust and Monopoly, 85th Cong., 1st Sess., 1957. 1954 is the first year concentration ratios are available for five-digit product classes. Since concentration ratios are relatively stable over time, this is not likely to change the 1950 measurement significantly. Of course, allowance is made for changes in SIC codes between 1950 and 1954 to obtain data for the same markets.

a weighted average eight-firm concentration ratio for the firm. The procedure is repeated for both measures for all 181 firms in the sample.

Firm Diversification

There are several alternative measures of firm diversification which could be derived from unconsolidated market data.[29] The measure most relevant for producing and marketing new innovations, however, is the degree of heterogeneity of the firm's existing product markets and factors of production. If a firm operates exclusively in a narrowly defined market, it may be at a disadvantage in producing and marketing an unrelated discovery relative to a firm operating across widely heterogeneous markets.[30] As the heterogeneity of a firm's existing markets increases, then, presumably, the probability that the firm will both

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[29] See Michael Gort, Diversification and Integration in American Industry (Princeton: Princeton University Press, 1962), pp. 23-25 for measures he derived from unpublished Bureau of the Census tabulations of unconsolidated firm data.

[30] In his theoretical model of a multiproduct firm, Eli Clemens argues that with excess capacity any reasonable market accessible to the firm in which price exceeds marginal cost constitutes an invitation to entry. Firms with excess productive capacity across varied markets can generally move into new markets at a lower marginal cost than more specialized firms with more homogeneous resources. Of course, an alternative to developing new markets and processes within the firm is to acquire other firms in the area and use their facilities. See Eli Clemens, "Price Discrimination and the Multiple-Product Firm," The Review of Economic Studies, XIX (1950-51), 1-11.

recognize the commercial value and be able to market new discoveries is increased. Since the ratio of successes to failures in costly and risky R&D is higher, the expected future return on the firm's R&D investment rises. Other things equal, therefore, more widely diversified firms are expected to be more research intensive.

To develop a measure of heterogeneity of markets and factors of production for the firm, it is assumed that as shipments are grouped into more narrowly defined SIC categories, the factors of production and marketing channels of distribution become more homogeneous. Since the ratio of a firm's shipments in its primary SIC category to its total shipments yields a measure of homogeneity, the complement of this ratio provides a measure of diversification. The degree of heterogeneity of this measure depends on the definition of the primary SIC category. If the primary SIC category is defined very narrowly at the five-digit level, a firm may have a high percent of shipments outside the category and still utilize fairly homogeneous factor inputs or produce functionally related products within the same four-digit category. As the primary SIC category is defined more broadly, however, a higher percentage of shipments outside the primary industry indicates greater heterogeneity of factor inputs and product markets. In this study three alternative measures of diversification are introduced. The first measure of diversification is the percent of the firm's shipments outside its primary four-digit SIC category. The second measure is the percent of shipments outside its more broadly defined primary three-digit SIC category. The third measure is the percent of shipments outside its still broader two-digit SIC category.[31]

Growth in Market Demand

In examining the partial influence of absolute size, market power, and diversification on innovative performance, the rate of growth in market demand is held constant. Market structure is, by nature, relatively stable over time;[32] however, structural influences may be offset by disequilibrating forces such as a high rate of growth in demand.

A study by Michael Gort found that market shares are likely to be more stable in highly concentrated markets.[33] Rapid growth, however, generates instability in several ways. First, with imperfect foresight firms adjust their

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[31] Although a firm's shipments includes vertically related markets, the effect of integration is eliminated to some degree by the exclusion of five-digit product classes contributing less than 1 percent to the firm's total shipments. By and large, such products constitute materials used in the production of other products.

[32] See Richard Caves, American Industry: Structure, Conduct, Performance (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964), pp. 31-34.

[33] Michael Gort, "Analysis of Stability and Change in Market Shares," The Journal of Political Economy, LXXI (February, 1963), 51-61.

scale of production to anticipated growth differently, leading to shifts in market shares. Second, recurrent lags in the adjustment of supply to growth in demand may result in an above normal rate of return which attracts new entry and consequent shifting in market shares. Barriers to entry limit the number of firms entering a market in response to growth in demand; however, among markets with the same entry barriers rapidly growing markets are more likely to encourage entry than less rapidly growing markets.

A firm can generally be expected to undertake new activities rather than grow within the scope of its existing product structure if the former alternative promises a higher expected return. This prospective future return on investment (whether for diversification or for homogeneous growth) depends upon, among other variables, growth in demand. Hence, while firms may possess the same degree of homogeneity among existing markets, their patterns of R&D investment may differ considerably, depending upon the relative growth in demand in their markets.[34]

A measure of growth in demand for the firm's markets is determined as follows: An index of growth for each of

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[34]Jacob Schmookler has stressed the importance of growth in demand in a number of articles. See, for example, his "Changes in Industry and in the State of Knowledge as Determinants of Industrial Innovation" in The Rate and Direction of Inventive Activity, pp. 195-232; "Economic Sources of Inventive Activity," Journal of Economic History, XXII (March, 1962), 1-2; and with Oswald Brownlee, "Determinants of Inventive Activity," American Economic Review, LII (May, 1962), 165-76.

the firm's five-digit product markets is determined by dividing the total product class shipments in the market in 1950 by the same total in 1947 and multiplying by 100. A weighted average index of growth for the firm's markets is measured by multiplying the growth index in each five-digit market by the firm's shipments in that market, summing over all of the firm's markets, and dividing by the firm's total value of shipments. The procedure is repeated for all 181 firms in the sample.

Technological Opportunity

There is considerable variation in innovative performance among the 181 firms in the sample that cannot be accounted for by any of the above variables describing the size and market structure of the individual firm. Much of this variation can be attributed to a set of influences, described by Scherer under the heading of "technological opportunity,"[35] which characterize the firm's broad field of technology. Some of these influences are undoubtedly related to industry traditions or demand conditions not reflected by market structure or growth, such as consumer tastes and preferences, durability or perishability of products, and trade credit practices. However, this set of influences, as Scherer observes, "is most likely to be associated with dynamic supply conditions dependent in turn

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[35]Scherer, American Economic Review, LV, pp. 1099-103.

upon the broad advance of scientific and technical knowledge."[36] In certain fields of technology, a vigorous scientific climate assures an almost continuous supply of technical possibilities that are much more limited in other technology fields. In the regression model presented in the following chapter, differences in technological opportunity among firms in different fields of technology will be analyzed through the use of dummy variables which assume a different value for each two-digit SIC category. Interfirm variation in technological opportunity within the same two-digit category can be viewed as a random disturbance which, unless correlated with some independent variable, imparts no bias to the regression estimates of R&D intensity, only increasing the unexplained variance.

In introducing intercept dummy variables to separate technology fields, it is necessary to take certain steps to avoid a singular matrix. More precisely, the dummy variable for food manufacturing is omitted, so that only five dummies are introduced for the six two-digit SIC categories represented.[37] Each dummy variable assumes a value of 1 for firms primarily in the same two-digit category and 0 otherwise. The regression coefficient for

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[36]Ibid., p. 1100.

[37]See Daniel B. Suits, "Use of Dummy Variables in Regression Equations," Journal of American Statistical Association, LII (1957), 548-51, for a discussion of this technique.

each dummy variable, therefore, represents a shift in the intercept between food manufacturing and the corresponding two-digit category.[38]

Summary

The basic analytical problem of this study is that of multivariate analysis, that is, reducing and interpreting the data contained in a matrix of "n" observations and "p" variates. This chapter has discussed the nature and character of both dimensions of this matrix.

The observations comprise a sample from a universe of the 1,000 largest manufacturing firms in 1950. As a representative of all manufacturing firms the sample has certain biases: (1) it includes only publicly-owned corporations reported in Moody's Industrials; (2) it has no representatives from certain important industries in the manufacturing sector; (3) it includes only firms among the 1,000 largest in 1950; and (4) it includes only those firms reporting R&D employment in Industrial Research Laboratories of the United States (1950). The sample is representative, however, of large manufacturing firms engaged primarily in company-financed R&D in organized research laboratories. It provides, therefore, an adequate

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[38]J. Johnston in Econometric Methods (New York: McGraw-Hill, 1960), p. 222 also discusses this technique and interprets the regression coefficients obtained for intercept dummy variables.

sample for testing the assertions of those favoring an industrial environment of only a few large conglomerate firms as optimal for research.

The variables in the model are as follows: (1) firm innovative performance measured by its employment in R&D laboratories per 1,000 total employees in 1950; (2) absolute firm size measured by total assets in 1950; (3) market share measured by a weighted average of the firm's share in each of its five-digit product classes in 1950; (4) market concentration measured by a weighted average four-firm concentration ratio and a weighted average eight-firm concentration ratio of the firm's five-digit product classes; (5) three alternative diversification measures--the percent of shipments outside the firm's primary four-digit, primary three-digit, and primary two-digit SIC categories in 1950; (6) market growth in demand measured by a weighted average growth in shipments index from 1947 to 1950 for the product classes of the firm; and (7) dummy variables to represent the influence of variates which are expected to influence the research effort of firms differently across broad (two-digit SIC) industry groups but which are relatively homogeneous among firms primarily in the same industry group.

On the basis of various considerations such as the understanding and interpretation of results, the availability of appropriate probability tests and inferential procedures, and the economical use of degrees of freedom, correlation and regression techniques are chosen for the multivariate analysis of this study. Regression equations and the interpretation of their parameter estimates are presented in the following chapter.

CHAPTER IV

FIRM SIZE, MARKET STRUCTURE AND RESEARCH: THE EVIDENCE FROM UNCONSOLIDATED FIRM DATA

Industry structure may be expected to influence the innovative performance of the nation's industrial sector if differences in research intensity among firms performing organized R&D can be explained by differences in their industrial environments. More specifically, the results of a least squares multivariate, cross-section analysis of the sample of 181 large R&D-performing firms provide empirical evidence of the separate influences of firm size, market share, concentration, diversification, and market growth on technical research, while holding the level of scientific and technological opportunity constant.

In this chapter correlation techniques are used when it is desirable to determine preliminary interrelationships and associations among different variables. Major emphasis, however, is placed on regression techniques, which not only allow a relaxation of the assumption of multivariate normality, but are particularly useful in explaining the relationships among the variables when the direction of causation is assumed. In this study the direction of causation is hypothesized to be from the independent variables measuring a firm's size and market structure to the dependent variable measuring its research effort. The hypothesized relations are tested on a basis of the parameter estimates of appropriate regression equations.

The Regression Model

The following additive regression model is used to explain differences in research intensity among firms by differences in their industrial structures:

$$R_i/N_i = b_o+b_1\log A_i+b_2M_i+b_3C_i+b_4D_i+b_5G_i+\sum_j b_jd_{ij} + u_i$$

where R_i is the number of persons employed by the ith firm in its R&D laboratory or laboratories in 1950; N_i is total employment in thousands for the ith firm in 1950; $\log A_i$ is the logarithm of total assets in millions of dollars for the ith firm in 1950; M_i is the average market share of the ith firm in 1950 expressed as a percentage; C_i is the average (weighted by 1950 shipments) 1954 four-firm concentration ratio or 1954 eight-firm concentration ratio for the ith firm's markets in 1950; D_i is the percent of the firm's 1950 shipments outside of its primary four-digit SIC category, outside of its primary three-digit SIC category, or outside its primary two-digit SIC category; G_i is an average growth index for the ith firm's markets between the years 1947 and 1950; d_{ij} are dummy variables with a value of 1 if the ith firm is in the jth two-digit

SIC category and 0 otherwise; and u_i is the error term, assumed random with zero expected value and constant variance.[1]

The Question of Collinearity: Absolute Size Versus Diversification and Structural Market Power

In arguing that extremely large firms are necessary to offset the costs and risks of research and development, it is frequently assumed that large firms are invariably large in relation to their markets and are typically characterized by more diversified resources. While this assertion is probably valid in contrasting large firms with small firms, the correlation between absolute firm size and market share, market concentration, or diversification is not expected to be as high among only large firms. If, indeed, firm size is highly correlated with the other

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[1]Empirical studies which have formulated a relation between firm size and innovative performance have found the error terms of untransformed linear regressions of the absolute size variable to be heteroscedastic and the observations of extremely large firms to dominate the regression estimates. The expression of the dependent variable as a ratio to measure research intensity has the effect, however, of correcting for heteroscedasticity. The absolute size variable is expressed as a logarithm to reduce the effect of extreme values when estimating the influence of firm size on research intensity. See John R. Meyer and Edwin Kuh, The Investment Decision (Cambridge: Harvard University Press, 1957), pp. 265-66.

For a discussion of the merits of this model versus a multiplicative model, see F. M. Scherer, "Market Structure and the Employment of Scientists and Engineers," American Economic Review, LVII (June, 1967), 525-26.

independent variables in the model depicting market share, market concentration, or diversification, then doubt is cast on the ability to separate the influences of each of these market structural variables from that of absolute size per se.

Table 12 presents the simple correlation coefficients between firm size and measures of market share, concentration, and diversification. Firm size is measured by both

TABLE XII

SIMPLE LINEAR CORRELATION COEFFICIENTS BETWEEN FIRM SIZE AND MARKET SHARE, CONCENTRATION, OR DIVERSIFICATION

	Market share	Concentration[a]	Diversification[b]
Assets	0.358	0.113	-0.073
Log assets[c]	0.386	0.144	-0.080

[a]Equal to the weighted average four-firm concentration ratio for the firm's market.

[b]Equal to the percent of shipments outside the firm's primary three-digit SIC category.

[c]The log variable is less dominated by extreme values and better satisfies the assumption of normality than does the untransformed variable.

total assets and the logarithm of total assets, a measure which better satisfies the assumption of normality since it is less dominated by extreme values. The measure of concentration chosen is the average four-firm concentration ratio. The percent of shipments outside the firm's primary three-digit SIC category is used to depict diversification.

While the correlation coefficients between the measures of firm size and market share are statistically significant at the .01 level, their relationship is not so strong that the separate influences of each of the two variables on the innovative performance of the firms sampled cannot be estimated.

Positive correlation does not, of course, mean causality. Nevertheless, it can generally be interpreted that an increase in firm size results in an increase in discretionary market power, that is, size in relation to the market. For the 181 large firms in the sample only 13 percent of the variation in average market share can be explained by the variation in absolute firm size measured by total assets. Hence, it appears that, while not mutually exclusive, the traditional distinction between absolute size and size in relation to the market is relevant.[2]

The correlation coefficients in Table 12 also indicate that the distinction between "bigness" and "fewness" is valid among the largest firms. The tendency for larger firms to operate in more concentrated markets increases only modestly among the 181 large firms in the sample. Furthermore, while it is generally true that the number of product markets of a firm increases with its size (a linear correlation between total assets and the number of product

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[2]Other variables affecting a firm's market share are, of course, the number of its markets and the total size of each of its markets.

markets contributing more than 1 percent to the firm's total shipments was found to be .35), the percentage of nonprimary shipments among the firms sampled is independent of size.[3]

The Empirical Results

Table 13 summarizes the results of several multiple regression equations based upon the additive ratio model relating several structural variables to the research intensity of individual firms. In each of the equations the dependent variable is the number employed by the company in its R&D laboratories per 1,000 total company employees. In equations A through C the same independent variables are introduced with the exception of the measure of firm diversification, which is measured by the percent of the firm's shipments outside its primary four-digit SIC category in equation A, outside its primary three-digit category in equation B, and outside its primary two-digit category in equation C. Equation D introduces the eight-firm concentration ratio rather than the four-firm concentration ratio in equation B. Equation E introduces the square of the four-firm concentration ratio as a new variable along with the other variables in equation B. Also

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[3]This result is in agreement with that found by Michael Gort for the percent of nonprimary employment by 741 large firms in 1954 in Diversification and Integration in American Industry (Princeton: Princeton University Press, 1962), pp. 65-74.

TABLE

REGRESSION COEFFICIENTS AND STANDARD ERRORS FOR ADDITIVE
181 LARGE RESEARCH-PERFORMING FIRMS BY SELECTED

Equation	Intercept (food)	Log A	Market share	Concentration ratios 4-firm	8-firm	4-firm squared	Percent of outside 4-digit	3-digit
A	3.663	1.191	-0.038	-0.010			0.087	
		(3.393)	(0.207)	(0.141)			(0.078)	
B	5.071	1.839	-0.057	-0.020				0.095
		(3.424)	(0.209)	(0.139)				(0.087)
C	8.785	1.020	0.004	-0.048				
		(3.444)	(0.212)	(0.142)				
D	7.696	1.754	-0.036		-0.062			0.092
		(3.405)	(0.200)		(0.136)			(0.088)
E	-7.539	1.513	-0.057	0.416		-0.004		0.080
		(3.455)	(0.209)	(0.623)		(0.005)		(0.091)
F	17.403	-0.134	-0.219	-0.351			*0.190	
		(3.726)	(0.228	(0.166)			(0.093)	
G	21.399	0.333	-0.206	-0.270				*0.243
		(3.729)	(0.226)	(0.163)				(0.103)
H	27.112	-0.836	-0.153	-0.321				
		(3.781)	(0.230)	(0.166)				
I	22.901	1.235	-0.305		-0.185			*0.252
		(3.715)	(0.213)		(0.167)			(0.103)
J	-10.081	-0.791	-0.193	0.817		-0.009		0.196
		(3.806)	(0.226)	(0.798)		(0.006)		(0.108)

* Significant at the .05 level

The standard errors are in parentheses below their corresponding

XIII

MODEL EXPLAINING DIFFERENCES IN RESEARCH INTENSITY AMONG
VARIABLES CHARACTERIZING THEIR INDUSTRIAL ENVIRONMENTS

shipments primary 2-digit	Market growth	Dummy variables for same technology in					$\bar{R}^2$
		Chemi-cals	Petro-leum	Stone, clay, glass	Primary metals	Motor vehicles	
	0.018 (0.066)	*38.499 (4.652)	*16.428 (5.734)	0.085 (5.666)	-5.192 (5 569)	1.297 (6.970)	.4420
	0.016 (0.066)	*37.587 (4.912)	*14.165 (5.817)	-0.895 (5.732)	-6.376 (5.932)	-0.276 (7.101)	.4418
-0.062 (0.110)	0.013 (0.067)	*40.266 (4.704)	*16.232 (5.827)	0.461 (5.730)	-2.915 (5.640)	2.469 (7.350)	.4285
	0.019 (0.065)	*37.718 (4.911)	*14.730 (5.946)	-0.890 (5.714)	-6.128 (5.956)	0.240 (6.948)	.4424
	0.028 (0.069)	*37.287 (4.937)	*13.707 (5.860)	-0.666 (5.750)	-6.749 (5.960)	0.072 (7.130)	.4402
	0.113 (0.075)						.0404
	0.088 (0.076)						.0480
0.007 (0.137)	0.119 (0.077)						.0174
	0.056 (0.072)						.0396
	0.120 (0.079)						.0585

regression coefficients.

included in each of these five equations are the index of market growth for the firm and intercept dummy variables for each two-digit SIC category with the exception of food products which assumes the value of the intercept in order to avoid a singular matrix. Equations F-J are identical with equations A-E, respectively, except that the dummy variables are omitted.

The Influence of Firm Size

Although the structural advantages of size for research are often cited in association with the other variables in the model depicting market share, diversification, and oligopoly, increased firm size may have a favorable effect on a firm's research effort net of these other influences. Larger firms with larger total R&D programs can be expected to balance successes against failures and, therefore, receive a more predictable return on their investment. If firms are risk averters, that is, they place a premium on the reduction of uncertainty, then investment in risky research may be relatively more attractive to larger firms. Furthermore, larger firms may be better able to absorb market introduction costs, such as promotion and distribution expenses, necessary to exploit commercially their innovations.

To test the hypothesis that firm size has a favorable influence on research intensity, net of its relation with the other structural variables, the logarithm of total assets is introduced as an independent variable in the additive multiple regression model.[4] If the proportion of resources allocated toward R&D increases with the size of the firm, the partial regression coefficient for the size variable is expected to be significantly positive. Among the equations summarized in Table 13, the regression coefficients for the absolute size variable are not statistically significant. Hence, it can be concluded that, other things equal, firm size per se has no influence on the proportion of resources which research-performing firms allocate to R&D.[5]

The Influence of Market Power

The Schumpeterian hypothesis asserts that monopoly power has a favorable influence on the innovative effort of a firm by providing protection against the temporary disorganization of the market necessary for long-range investment, while increasing the supply of internal funds.

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[4] The logarithm of assets is used rather than the absolute value because the distribution is less skewed. This technique is also used by Edwin Mansfield in "Firm Size, Market Structure, and Innovation," Journal of Political Economy, LXXI (December, 1963), 556-76.

[5] When only professional research personnel per 1,000 company employees is introduced as an alternative dependent variable in each of the equations in Table 13, the regression coefficients of the logarithm of assets are found to be negative but not statistically significant. The reduced importance of firm size is explained by the fact that the ratio of supporting personnel to research professionals increases, on the average, with firm size. See supra, pp. 46-50.

To test this hypothesis the partial influence of a firm's market share on its research intensity is estimated in each of the equations in Table 13. In each case firm market share is found to be an insignificant factor in explaining differences in research intensity among the firms sampled. Furthermore, in all but one of the equations market share is found to be negatively related to research intensity. From these results, therefore, there is no evidence that the Schumpeterian hypothesis holds among the large firms in the sample.

A neo-Schumpeterian hypothesis of perhaps more interest to antitrust policy is that, given the firms' own market shares, those operating in more highly concentrated, oligopolistic markets are expected to display a special affinity toward technological innovation.[6] As the market share of the dominant few firms increases and pricing interdependence becomes fully recognized, so the argument goes, firms are compelled to grapple for their market position through more complex innovative and other nonprice competitive strategies.[7] If this hypothesis holds, the average concentration of the firm's markets is

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[6]A firm's market share and the share held by the top several firms are not independent since a firm may at times also be a dominant producer. The simple correlation coefficients between market share and four-firm or eight-firm concentration ratios are .40 and .33, respectively.

[7]Henry H. Villard, "Competition, Oligopoly, and Research," Journal of Political Economy, LXVI (December, 1958), 483-97.

expected to have a significant positive influence on research intensity. In equations A through E, however, the average four-firm market concentration ratio for the firm's markets is found to have no significant influence on its research intensity.

In the additive model a linear relationship is assumed between research intensity and market concentration. However, it is possible that a nonlinear relationship exists between the two variables. In particular, it has been hypothesized that moderate levels of concentration beyond some threshold level may be preferable over completely atomistic markets as an incentive for firms to innovate, but after concentration exceeds some optimum level the group discipline present when pricing interdependence becomes recognized may be extended into other areas of firm behavior, including technological innovation.[8]

To test this hypothesis equation E introduces the square of the concentration ratio as an additional variable in equation B. If the relationship is curvilinear of the form described above, then the net regression curve relating concentration to research intensity would be a parabola which is concave to the concentration axis. A comparison of the estimated net relationship between market concentration and research intensity reveals a better fit when

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[8]See Scherer, American Economic Review, LVII, pp. 524-31.

a nonlinear relationship is hypothesized, although the total unexplained variance is not significantly changed when the concentration ratio squared, C_i^2, is added to the regression equation. Nevertheless, the partial regression coefficient for C_i^2 is negative, indicating a curve which, if anything, is concave to the concentration axis.[9]

Since this hypothesis is important for determining a possible optimal level of industrial concentration for research and development, it deserves additional attention. Figure 1 describes the net regression curves (the influence of the other variables held constant at their means) relating concentration to research intensity. The equations represented in their linear and nonlinear forms are, respectively,

$$R/N = 23.63 - 0.0204\ C$$

and $$R/N = 11.73 + 0.4163\ C - 0.0037\ C^2$$

The nonlinear equation reaches a maximum at a concentration level of 56 percent. Although this finding may not be significant in itself, it gains added significance in that it closely agrees with the results of Scherer, who estimates an optimal concentration for research of from 50 to 55 percent using cross industry data. Hence, while the

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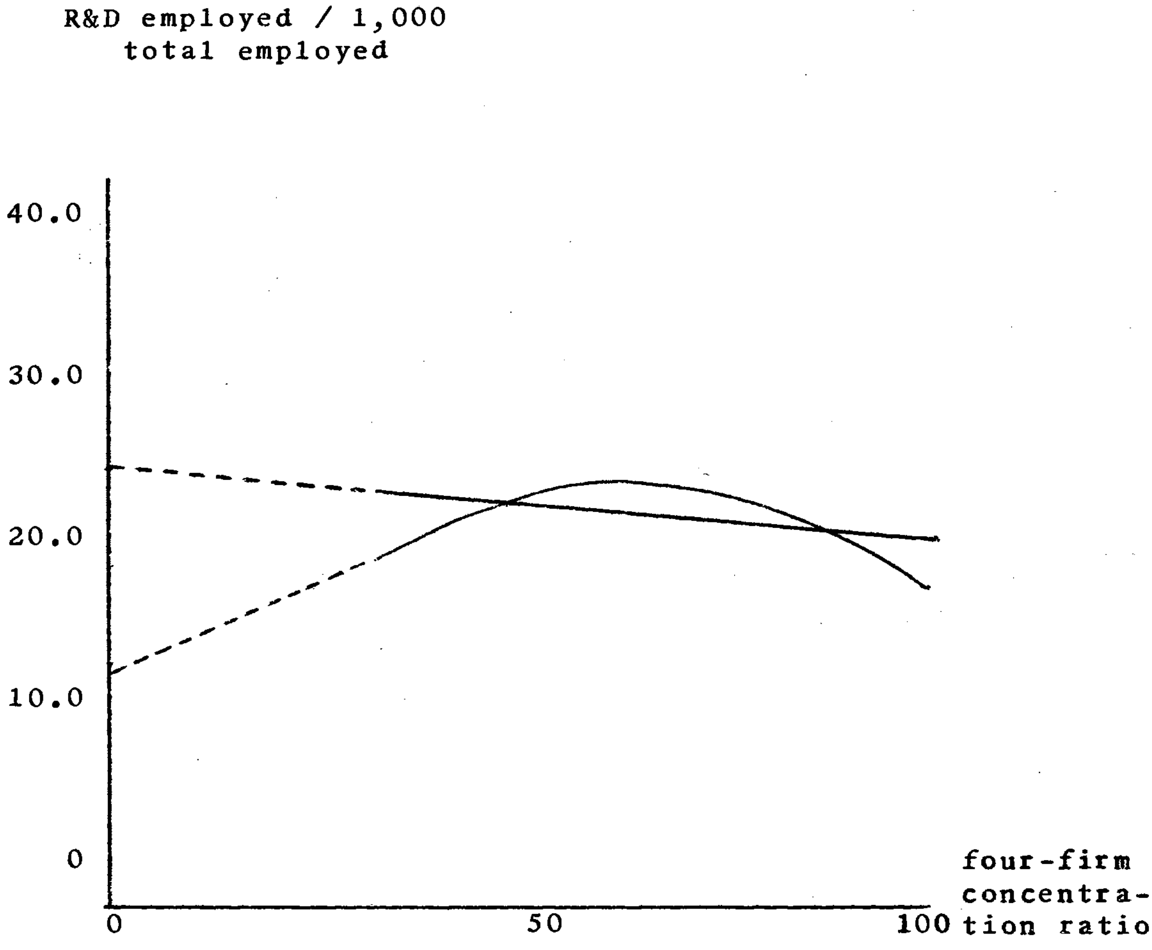
[9]Although the regression coefficients for C_i and C_i^2 are not significant according to conventional t ratio standards, their standard errors are expanded due to the high correlation between the two variables (r = .98). Hence, the standard error for C_i increases from 0.139 to 0.623 when C_i^2 is added to regression equation.

results must be taken as tentative, a "suggested" optimal four-firm concentration ratio for research may occur between 50 and 60 percent.[10]

Figure 1.--Linear and nonlinear net regression curves relating concentration and research intensity[a]



[a]The frequency distribution of observed values for concentration begins at a value of 29 percent. Hence, there is no method to determine the shape of the regression curve below this level.

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[10]Although the estimated maximum is slightly higher than Scherer's, it is based upon a weighted average of more narrowly defined markets. Since Scherer defines industries on a, more or less, three-digit SIC level, his concentration ratios are generally below those used in this study. Scherer, American Economic Review, LVII, 524-31.

When the dummy variables are omitted in equation F through J, the regression coefficients take on the same signs as in equations A through E, respectively; however, the regression coefficients for the four-firm concentration ratio in equations F-H and the regression coefficient for the four-firm concentration ratio squared in equation J are significant at the 10 percent level in a one-tailed test. Further analysis reveals that the dummy variables and four-firm concentration ratio compete for explanatory power because they are negatively correlated. Table 14 presents the average research intensity and average market concentration for firms primarily in the same two-digit industry group. It is evident that the more research intensive chemical firms operate in markets which are slightly less concentrated, on the average, than the full sample mean. Firms in the less research intensive motor vehicle industry, on the other hand, operate in markets which are, on the average, more concentrated than the full sample mean.[11]

In the additive model it is assumed that differences in the slope parameters relating market concentration to

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[11]Although the negative relation between average research intensity and average concentration among firms across two-digit SIC categories contrasts with the findings of Scherer, the conflict can be explained by the fact that Scherer's cross-industry sample includes nearly all of manufacturing and, hence, his group average is lower than among the industry categories selected in this study. Ibid., p. 529.

TABLE XIV

AVERAGE RESEARCH INTENSITY AND AVERAGE MARKET CONCENTRATION OF FIRMS BY TWO-DIGIT SIC INDUSTRY GROUP AND TOTAL SAMPLE

Industry	Number of firms	Average research intensity	Average firm concentration ratio
Foods	42	9.39	53.62
Chemicals	49	49.42	51.59
Petroleum	27	26.32	49.19
Stone, clay, glass	19	9.61	57.37
Primary metals	24	6.33	55.21
Motor vehicles	20	11.12	74.05
Total sample	181	22.54	55.27

research intensity are constant among different industry groups. There is reason to expect, however, that the importance of concentration for research varies according to the type of research performed. In particular, Comanor's findings suggest that there may be an interaction between concentration and product differentiation in their influence on research spending. More specifically, concentration may be positively related to research in industries which produce relatively homogeneous material inputs but unrelated to research in industries which are characterized by a high degree of product differentiation.[12]

[12]William Comanor, "Market Structure, Product Differentiation, and Industrial Research," The Quarterly Journal of Economics, LXXXI, No. 4 (November, 1967), 639-57.

To examine the possibility that the importance of concentration for research depends upon the degree of product differentiation, the total sample is stratified into three subsamples according to the degree of product differentiation expected for the firm's products. In each subsample intercept dummy variables are used, when necessary, to separate two-digit SIC industry groups, but each subsample is allowed to take its own best-fitting slope coefficients. The first subsample consists of firms primarily in foods and motor vehicles and equipment, two industries which deal primarily with consumer goods which are generally more differentiable than producer goods.[13] The second subsample consists of firms primarily in chemicals. The degree of product differentiation among chemical firms is heterogeneous, varying from cosmetics and drugs which are highly differentiable to industrial chemicals which are not. Finally, firms primarily in petroleum; stone, clay, and glass; and primary metals are combined into a third subsample. Product differentiation

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[13]Although Comanor includes consumer nondurables with material inputs and consumer durables with investment goods for the purpose of obtaining two groups which are characterized by different degrees of product differentiation, his choice is somewhat arbitrary and is based upon Bain's mentioning of only three nondurables consumer goods industries in which product differentiation is slight. Ibid., p. 648.

in these material input industries is expected to be slight or negligible.[14]

When multiple regression equations are estimated for each subsample of the same form as equations A through E in Table 13, the partial regression coefficients for the four-firm concentration ratio and, alternatively, the eight-firm concentration ratio are not satistically significant. Similarly, when a quadratic relationship is hypothesized neither the four-firm concentration ratio nor the four-firm concentration ratio squared are found to be significant in any of the three subsamples.[15] Hence, it may be concluded on a basis of these results, that market concentration is unimportant for research, regardless of the degree of product differentiation in the industry.

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[14]For a discussion of the importance of product differentiation among industries see Joe S. Bain, Industrial Organization (New York: Wiley, 1959), pp. 218-35.

[15]The net regression curves relating concentration to research intensity, analogous to equations B and E in Table 13, for the subsample of firms in the material input industries, the group for which Comanor found concentration to be significant, are as follows:

$$R/N = 15.47 - \underset{(0.197)}{0.0108}\, C \text{ and}$$

$$R/N = -3.16 + \underset{(0.932)}{0.6703}\, C - \underset{(0.008)}{0.0059}\, C^2$$

The nonlinear function reaches a maximum research intensity when the four-firm concentration ratio is 57.

The Influence of Diversification

Richard Nelson has developed the hypothesis that industrial diversification should stimulate innovation.[16] Research, particularly basic research, Nelson noted, is likely to lead to unpredictable discoveries in a variety of fields. A widely diversified firm is in a better position than a more specialized firm to recognize and to exploit the commercial possibilities of such discoveries. Other things equal, therefore, diversified firms are expected to engage in proportionally more research because a given R&D outlay has a higher probability of success.

To test this hypothesis three multiple regression equations are estimated with all independent variables the same except the measure of diversification. For equation A diversification is measured by the percent of the firm's shipments outside its primary four-digit SIC category. In equation B diversification is measured by the percent of shipments outside the firm's more broadly defined primary three-digit SIC category. Finally, in equation C diversification is measured by the percent of the firm's shipments outside its still broader primary two-digit SIC category. Since each successive measure represents the percent of the firm's shipments in less homogeneous markets, they measure

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[16] Richard R. Nelson, "The Simple Economics of Basic Research," Journal of Political Economy, LXVII (June, 1959), 297-306.

different degrees of heterogeneity for the firm. More precisely, the third measure depicts a greater degree of heterogeneity than the second which, in turn, depicts greater heterogeneity than the first.

The partial regression coefficients in equations A through C are not statistically significant; however, the three-digit diversification measure in equation B is greater than the four-digit measure in equation A. As heterogeneity increases beyond the two-digit level, however, the regression coefficient not only declines but becomes negative. A comparison of the regression coefficients in equations A through C with those in equations F through H, respectively, reveals that when the dummy variables are omitted, the regression coefficients for the three diversification measures increase, and they follow the same pattern relative to each other in each set of equations. This pattern occurs because, as shown in Table 15, the dummy variables representing two-digit SIC industry groups are positively correlated with each measure of diversification. The research intensive chemical firms are, on the average, more diversified than the full sample mean. In contrast, the less research intensive food companies tend to be less diversified, on the average, than the full sample mean. It should be noted, however, that the primary metals firms are, on the average, the least research intensive but are more diversified, on the average, than the full sample mean.

TABLE XV

AVERAGE RESEARCH INTENSITY AND AVERAGE DIVERSIFICATION, BY INDUSTRY GROUPS AND TOTAL SAMPLE

Industry	Number of firms	Average research intensity	Average percent of firm's shipment outside primary 4-digits	3-digits	2-digits
Food	42	9.39	29.91	10.69	3.25
Chemical	49	49.42	40.78	30.17	12.27
Petroleum	27	26.32	19.28	19.28	9.37
Stone, clay, glass	19	9.61	28.12	21.85	11.11
Primary metals	24	6.33	44.09	35.10	13.92
Motor vehicles	20	11.12	19.85	19.31	14.63
Total sample	181	22.54	31.85	22.60	10.10

It can be concluded from these results that diversified firms are likely to invest in a higher proportion of research, but the advantages of diversification for research occur among technically related product markets within the same two-digit SIC industry group. There is no indication that increased "conglomerateness" per se increases a firm's emphasis on research.[17]

[17]When only professional research personnel per 1,000 total employees is introduced as the dependent variable in equations A through J, the regression coefficients exhibit the same general pattern; however, the regression coefficients are more significant. Hence, the regression coefficient for the second diversification measure in equation B is significant at the 10 percent level in a one-tailed test and the t ratios for the other diversification variables are correspondingly higher. If the number of professionals is more closely aligned to risky research

The Influence of Market Growth

Rapidly growing markets are likely to be characterized by changing technologies which offer strong inducements to entry in the form of gains to innovating firms. Since a period of time will normally elapse between the adjustment of supply to rapidly growing demand, the profit rate of firms in rapidly growing markets are expected to be higher than for the economy as a whole. Rapidly growing markets also afford a new firm greater opportunity of achieving a significant scale of output while diminishing the necessity of encroaching on the markets of established firms.

Not only are effective barriers to entry lessened in rapidly growing markets, but the behavior of established firms in such markets is likely to differ in response to other market structural influences. In particular, the interdependence among firms in highly concentrated markets is expected to diminish in growing markets because the "size of the pie" is increasing. Firms may have a greater incentive to act competitively if they can expect to increase their sales without provoking response from their rivals.[18] It follows, therefore, that in examining

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than the total number of R&D employees, this result suggests that diversification may be more important for research than for development expenditures.

[18]See Richard Caves, American Industry: Structure, Conduct, and Performance (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964), pp. 29-30.

market structural influences market growth should be held constant.

The inclusion of the market growth variable also provides information on the relation between market growth and a firm's research intensity. Although the regression coefficients in Table 13 for the market growth variable are not significant, further analysis reveals that the market growth variable also competes for explanatory power with the dummy variable because they are positively correlated. When the dummy variables are omitted from the regression equations A-E in Table 13, the regression coefficients for market growth increase. Although markets in more research intensive industries generally grow more rapidly, the causal direction between market growth and research intensity is not firmly established. While rapidly growing markets may encourage more R&D, investments in new and improved products and processes generally lead to more rapid increases in market sales.

Scientific and Technological Opportunity

The dummy variables to depict technological opportunity and other variables, such as factor proportions, are found to be significant in the chemical and petroleum industries but not in the other industry groups sampled. Hence, the expected values of research intensity, net of the influence of the independent variables measuring size and market structure, for firms in the chemical and petroleum industries are significantly greater than for firms in the other industry groups sampled.

Summary

The multivariate cross-section analysis presented in this chapter provides a basis for testing several hypotheses relating a firm's size and market structure to its innovative performance. More precisely, the net influences of a firm's size, market share, the level of concentration of its markets, and the diversification of its resources on the number employed in its R&D laboratories per 1,000 total employees are estimated, holding the influence of its average growth in market demand and technological opportunity constant.

Firm size per se is found to have no significant positive influence on the proportion of resources allocated to research among the major industries sampled. This result is not surprising since it generally agrees with that of other researchers who have estimated the influence of firm size on research intensity among large research-performing firms. Of more interest than the effect of size is the possible influence of several market structural variables on a firm's research intensity, holding firm size constant.

The first hypothesis concerning the influence of market structure is that of Schumpeter, who argues that a firm's monopoly power increases its incentive and ability to invest venture capital in new innovations. If the hypothesis is true, then the research intensity of the firm is expected to increase with its average market share. Among the 181 industrial firms sampled, however, market share is found to have no significant influence on R&D employment per 1,000 total employees.

A neo-Schumpeterian hypothesis relates the innovative performance of the firm to the concentration of its markets. The avoidance of price competition in highly concentrated, oligopolistic markets, so the argument goes, creates a competitive drive to seek new and improved products. If this hypothesis is true, then the research intensity of the firms sampled is expected to increase with the average concentration of their markets. The net influence of concentration on research intensity in both a linear and nonlinear model is found to be statistically insignificant according to conventional standards; however, there is modest support for the hypothesis that moderate levels of concentration may be more conducive to research than either very low or very high levels of concentration.

A third hypothesis assigns a potentially important role to diversification as a stimulus to innovation. As a risk averter, a conglomerate firm will presumably engage more readily in uncertain research since it can expect to make commercial use of a higher proportion of unexpected discoveries. The estimated influences on research intensity of three alternative measures of firm diversification which depict progressively greater heterogeneity suggest, however, that the advantages of diversification for research generally occur within technically related markets.

Of the remaining variables included in the multiple regression analysis, the dummy variables separating the firms into two-digit SIC industry groups according to their primary markets are found to be significant for the chemical and petroleum firms. Although the interfirm variance in average market growth is not important in explaining variation in firm innovative performance within two-digit industries, it is found to be an additional variable which, like diversification, is positively associated with the level of scientific and technological opportunity in the firm's major industry group.

CHAPTER V

SUMMARY AND CONCLUSIONS

The essential thrust of this study has been to clarify the role of the industrial firm, typically operating in a number of product markets, on the technical progress of the nation's industrial system. Because of the availability of unconsolidated market data for a number of research-performing corporations it has been possible to estimate the separate influences of market structural variables, often assumed to be highly correlated with firm size, on a firm's innovative performance.

Of particular importance for antitrust policy is the assertion, popularized most recently by Galbraith,[1] that traditional antitrust policy concerned with promoting competition through the diffusion of market power is obsolete when dealing with the large technically oriented firms. According to this view the costs and risks of modern technology dictate enormous industrial complexes and high levels of market concentration in order to guarantee the resources and planning necessary for technological innovation.

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[1]John Kenneth Galbraith, The New Industrial State (Boston: Houghton Mifflin Co., 1967).

While the results of empirical studies relating absolute firm size to innovative performance are fairly consistent, the empirical findings of studies relating market concentration to innovative performance have been mixed. The inconsistency in the latter findings can undoubtedly be traced to the shortcomings of market data for multimarket firms reporting consolidated financial statements. Hence, measures of absolute firm size are readily available, but in determining the influence of the distribution of firm sizes within an industry on the industry's level and intensity of technological innovation, researchers have been forced to rely on aggregates of consolidated firm data classified by the primary activity of the reporting company.[2] If the industries examined are defined too narrowly, then much of the R&D activities of multiindustry firms may be directed toward products outside the industry. If broad industry categories are examined, then most of the aggregated firm's product sales fall within one category but in varying proportions among the submarkets within the categories.

In the present study the problem of secondary markets of the firm is solved by treating each firm as a separate observation. Not only are budget decisions regarding investment in research expected to be made at the firm

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[2]Data on innovative performance classified on an establishment basis are not available.

level, but each multiple product firm faces a, more or less, unique set of market environmental conditions, depending on the nature and extent of its conglomeration. Utilizing unpublished data gathered by the Federal Trade Commission on the separate markets of individual firms, it has been possible to quantify a number of the structural influences by assuming that the impact of each of a firm's markets on its research performance depends on the relative importance of each market for the firm's total operation. Hence, importance is attached not only to a firm's primary market but to its nonprimary markets as well. The multiple regression equations estimated from unconsolidated firm data provide more meaningful estimates of the influence of market structure on the innovative performance of large firms than were heretofore available from the analysis of published data on industry aggregates.

Turning first to the relation between absolute firm size and technological innovation, empirical evidence reveals that, while firm size may be a major determinant of whether or not firms perform organized research, an increase in firm size per se does not lead to a more than proportional increase in innovative effort among the research-performing firms examined in this study. Among firms engaged primarily in company-financed R&D, therefore, increased firm size cannot be expected to lead to more research. It appears, therefore, that the technological necessities of large size are applicable, at most, to only a limited number of complicated large scale techniques generally supported by government funds. To argue that only large mature corporations are capable of significant innovative activity in today's industrial system is to overlook the sources of many of the significant technical advances of this century.[3]

Even if the largest firms possess certain unique technological potentialities relative to smaller firms, there is no guarantee that such firms will undertake the desired research effort. The costs and risks of innovative activity are largely determined by the magnitude of the advance sought. Larger firms with conservative managements may avoid major advances and center their attention on minor product improvements necessary to maintain a technical parity with other firms in their markets unless they are forced to innovate under the pressure of effective competitive market forces.

There is considerable disagreement, however, on what constitutes a "competitive" market environment for industrial firms. Advocates of the view that both "bigness" and "fewness" are desirable conditions for research, contend that although highly concentrated markets may lead firms to shrink from price competition, nonprice competition,

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[3]See, for example, John Jewkes, David Sawers, and Richard Stillerman, The Sources of Invention (New York: St. Martin's Press, 1958) for evidence of the origin of many significant inventions during the 1900-1950 period.

including technical rivalry, will flourish. Hence, the competitive vigor of an industry is supposedly enhanced by high levels of market concentration if competitive behavior is judged in terms of both price and nonprice rivalry.

Opponents of this view contend that while completely atomistic markets may not be conducive to privately-sponsored research, an increase in market concentration beyond moderately low levels not only fails to encourage innovative effort, but the implicit collusive price behavior among firms in highly concentrated markets may be extended to other forms of competitive behavior as well, notably rivalry in research. Firms in highly concentrated markets may avoid major technical advances in favor of the "quiet life," while characteristically high barriers to entry remove the stimulus to innovation in the form of new entrants capitalizing on a new idea. Hence, an effective competitive environment is not composed of only a few large firms but consists of a diffusion of economic market power among medium- and small-sized firms in addition to large firms.

The empirical results of this study lend modest support to the latter hypothesis that a nonlinear relation exists between a firm's research effort and the concentration of its markets. Hence, neither very low nor extremely high levels of market concentration are conducive to research. Although tentative, the results suggest that a possible optimal level of market concentration may occur when the largest four firms in a market possess between 50 and 60 percent of its sales. It should be mentioned, however, that in increasing the amount of nonprice competition in an industry there may be a decline in price competition.

Related to and accompanying the emphasis upon industrial research and development among modern industrial corporations has been a movement toward greater diversification. Although expenditures on research and development provide a basis for diversification through internal growth, the history of most large firms reveals that they have achieved their diversified market structures largely through acquisitions. This latter alternative not only avoids early competitive struggles in a new market but may provide the firm with a patent base or experienced research personnel it can use for further product development. Although but one of many possible reasons for diversification through merger, the acquiring of an established firm can remove a substantial portion of the initial costs and risks of entering new product markets.[4] Having established a broad product base and a variety of productive resources, the conglomerate firm may be able to make profitable use

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[4]For a more comprehensive argument relating R&D to mergers see Murry N. Friedman, "The Research and Development Factor in Mergers and Acquisitions," in Study No. 16 of the U.S. Senate, Subcommittee on Patents, Trademarks, and Copyrights, 85th Cong. 2nd sess., 1958, pp. 1-35.

of a higher percentage of its research projects. Other things equal, therefore, the more heterogeneous the firm's existing product markets the higher the proportion of resources the firm is expected to allocate to research.

The validity of the above hypothesis is partly supported by the empirical results of this study. Hence, more diversified firms tend to be more research intensive. However, the advantages of diversification for research are probably greatest within technically related areas. This conclusion is borne out by the fact that firms do not have to have widely heterogeneous markets or be extremely large to receive the advantages of diversification for research.

In summary, the results of this study suggest that the size of a firm and the structure of its markets have an influence on the proportion of its resources allocated toward research. However, the influence of these structural variables are of too small a magnitude to suggest that public policy deliberately alter the industrial structure to meet certain prescribed conditions. Most significant in these findings in the fact that upper limits exist on the favorable influence of each of the structural variables. Hence, firm size is important for undertaking research, but while its importance varies among the firm's primary operations, there is no evidence that firms need to be extremely large to achieve the advantages of scale. Although increases in concentration beyond extremely low levels may stimulate research, this does not imply that industries should be allowed to reach extremely high levels of concentration. Indeed, if market concentration becomes too high it is possible that technological innovation may decline. Finally, while diversification may be important in opening up new investment opportunities for research, there is little apparent advantage for research in operating across heterogeneous markets which are technically unrelated.

Although these findings suggest that antitrust policy directed toward restricting high levels of market and aggregate concentration of economic power is not in conflict with the goal of promoting technological progress, there is a need for additional research on the relation between a firm's size and market structure and its emphasis on technical research and development based upon more recent data. It is also apparent that with the increased diversification of large industrial firms the usefulness of this research will depend, to a large extent, on its ability to analyze every market of the multiple-product firm. A contribution of this study has been to suggest one possible method for using unconsolidated sales data for conglomerate firms, should such data be made available for public use in the future. Furthermore, the findings of this study, based upon 1950 data, take on added significance when compared to the results of other studies based upon more recent industry or consolidated firm data. Hence, while further research concerning the relation between industry structure and technological performance is desired, the findings of this study, like those of most other studies, give no indication that the objective of technological progress requires a major recasting of antitrust policy.

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APPENDIX A

List of companies in sample, by major industry group

Food Products, except Beverages

Swift & Company

Armour & Company

National Dairy Products Corporation

The Borden Company

General Foods Corporation

National Biscuit Company

Wilson & Company Inc.

Corn Products Refining Company

American Sugar Refining Company

H. J. Heinz Company

General Mills, Inc.

California Packing Corporation

Standard Brands, Inc.

Cudahy Packing Company

Quaker Oats Company

Carnation Company

International Milling Company

William Wrigley, Jr. Company

Ralston Purina Company

Hershey Chocolate Corporation

Food Products, except Beverages (cont'd)

Great Western Sugar Company

Pillsbury Mills, Inc.

Stokely-Van Camp, Inc.

Pet Milk Company

John Morrel & Company, Inc.

Best Foods, Inc.

Beech-Nut Packing Company

Kellogg Company

Beatrice Foods Company

National Sugar Refining Company

United Biscuit Company of America

Rath Packing Company

Allied Mills, Inc.

Clinton Foods, Inc.

Purity Bakeries Corporation

Golden State Company, Ltd.

Oscar Mayer & Company

Ward Baking Company

Kingan & Company, Inc.

Gerber Products Company

Godchaux Sugars, Inc.

Penick & Ford, Ltd., Inc.

Chemicals and Allied Products

E. I. du Pont de Nemours & Company

Union Carbide & Carbon Corporation

Chemicals and Allied Products (cont'd)

Dow Chemical Company

Monsanto Chemical Company

General Aniline & Film Corporation

Diamond Alkali Company

Mathieson Chemical Corporation

Rohm & Hass Company

Commercial Solvents Corporation

Pennsylvania Salt Manufacturing Company

Heyden Chemical Corporation

American Potash & Chemical Corporation

Hooker Electrochemical Company

Victor Chemical Works

Harshow Chemical Company

Durez Plastics and Chemical, Inc.

American Cyanamid Company

Sterling Drug, Inc.

Rexall Drug, Inc.

American Home Products Corporation

Parke, Davis & Company

Abbott Laboratories

E. R. Squibb & Sons

Merck & Company, Inc.

Charles Pfizer & Company & Inc.

Sharp & Dohme, Inc.

Vick Chemical Company

Mead Johnson & Company

Chemicals and Allied Products (cont'd)

Smith Kline & French Laboratories

The Lambert Company

Colgate-Palmolive-Peet Company

Sherwin-Williams Company

Air Reduction Company, Inc.

Archer-Daniels-Midland Company

Glidden Company

International Minerals & Chemicals Corporation

Columbia Carbon Company

Virginia-Carolina Chemical Corporation

Eagle-Picher Company

Interchemical Corporation

American Agricultural Chemical Company

Davison Chemical Corporation

Devoe & Raynolds Company, Inc.

American-Marietta Company

Sun Chemical Company

International Salt Company

Cook Paint & Varnish Company

Imperial Paper & Color Corporation

Nopco Chemical Company

Petroleum and Related Products

Standard Oil Company (New Jersey)

Standard Oil Company (Indiana)

Socony-Vacuum Oil Company, Inc.

Petroleum and Related Products (cont'd)

The Texas Company

Gulf Oil Corporation

Standard Oil of California

Cities Service Company

Sinclair Oil Corporation

Shell Oil Corporation

Phillips Petroleum Company

Atlantic Refining Company

Union Oil Company of California

Tide Water Associated Oil Company

Sun Oil Company

Pure Oil Company

Continental Oil Company

Standard Oil Company (Ohio)

Skelly Oil Company

Mid-Continent Petroleum Corporation

Lion Oil Company

The Flintkote Company

Deep Rock Oil Corporation

Certain-teed Products Corporation

Anderson-Prichard Oil Corporation

Quaker State Oil Refining Corporation

Bird & Son, Inc.

Kendall Refining Company

Stone, Clay, and Glass Products

Pittsburgh Plate Glass

Owens-Illinois Glass Co.

United States Gypsum Co.

Johns-Manville Corp.

Libbey-Owens-Ford Glass Co.

National Gypsum Co.

Lone Star Cement Corp.

Corning Glass Works

Harbison-Walker Refrac. Co.

Lehigh Portland Cement Co.

Carborundum Co.

Ideal Cement Co.

Hazel-Atlas Glass Co.

Raybestos-Manhattan, Inc.

General Refractories Co.

Marquette Cement Mfg. Co.

Gladding McBean & Co.

Medusa Portland Cement Co.

American Window Glass Co.

Primary Metal Products

United States Steel Corporation

Bethlehem Steel Corporation

Aluminum Company of America

Republic Steel Corporation

Jones & Laughlin Steel Corporation

Primary Metal Products (cont'd)

National Steel Corporation

Inland Steel Company

Wheeling Steel Corporation

Reynold Metals Company

Scovill Manufacturing Company

Allegheny Ludlum Steel Corporation

American Steel Foundaries

Revere Copper & Brass, Inc.

United States Pipe and Foundry Company

Acme Steel Company

Lukens Steel Company

National Malleable & Steel Castings Company

Granite City Steel Company

Copperweld Steel Company

Carpenter Steel Company

Vanadium Corporation of America

Laclede Steel Company

Superior Steel Corporation

Crucible Steel Co. of America

Motor Vehicles and Equipment

General Motors Corporation

Ford Motor Company

Chrysler Corporation

Borg-Warner Corporation

General American Transport Corporation

Motor Vehicles and Equipment (cont'd)

The Studebaker Corporation

Kaiser-Frazer Corporation

Hudson Motor Car Company

Packard Motor Car Company

Briggs Mfg. Co.

Eaton Mfg. Co.

White Motor Co.

Thompson Products, Inc.

Timken-Detroit Axle Co.

Houdaille-Hershey Corp.

Auto Car Co.

The Weatherhead Company

Cummins Engine Co., Inc.

Pacific Car and Foundry Co.

King-Seeley Corp.

APPENDIX B

Form Approved
Budget Bureau No. 56-4903

UNITED STATES OF AMERICA
FEDERAL TRADE COMMISSION
Washington 25, D. C.

Return one copy of this report to:

Bureau of Industrial Economics, Federal Trade Commission, Washington 25, D. C. before January 1, 1952

FTC Form M1
Page __ of __pages

SPECIAL REPORT
STUDY OF CORPORATE INDUSTRY PATTERNS
Value of Shipments from Manufacturing Establishments in 1950

Name of Reporting Corporation ______________________

Name of Operating Corporation
(where different from above) ______________________

Name of Establishment ______________________

Address of Establishment ______________________
(State) (County) (City) (Number) (Street)

Certification

This report has been prepared by me or under my personal supervision from records of the above-named corporation and is correct to be best of my knowledge and belief, and covers the operations of this corporation from ____________ to ____________

____
(Title) (Date) (Signature)

Product	Product Class Code Number	Value of Total Shipments and Interplant Transfers (Omit Cents)
Col. A	Col. B	Col. C
TOTAL -- ALL PRODUCTS		

VITA

Thomas Monroe Kelly

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE INFLUENCES OF SIZE AND MARKET STRUCTURE ON THE RESEARCH EFFORTS OF LARGE MULTIPLE-PRODUCT FIRMS

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