Concentration and the returns to R&D

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Abstract:

A frequently tested aspect of Schumpeter's (1950) theory of growth and development is the relationship between R&D spending and concentration. Although some researchers have found statistical support for the proposition that firms in concentrated industries do relatively more R&D (Kamien and Schwartz, 1982), most contend that the relationship is either more complex than anticipated by these tests or that there are more important correlates to consider (Nelson and Winter, 1982; Levin, forthcoming).

Keywords: R and D | concentrated industries | Schumpeterian theory

Article:[*]

I. Introduction

A frequently tested aspect of Schumpeter's (1950) theory of growth and development is the relationship between R&D spending and concentration.[1] Although some researchers have found statistical support for the proposition that firms in concentrated industries do relatively more R&D (Kamien and Schwartz, 1982), most contend that the relationship is either more complex than anticipated by these tests or that there are more important correlates to consider (Nelson and Winter, 1982; Levin, forthcoming).

Although the correlation between R&D spending and concentration is interesting in itself, other dimensions of the innovation process should be examined in order to provide a richer understanding of the influence of market structure on technological change, and hence of the original Schumpeterian model. The analysis presented in this paper is intended as a step in that direction. Specifically, the relationship between the rate of return to R&D investments — one measure of R&D efficiency — and concentration is examined empirically.

In the following section of the paper a model for estimating firms' rates of return to R&D is presented. Then, arguments are offered regarding the size of these returns across differently

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1 The studies are more correctly interpreted as tests of Villard's (1958) corollary to Schumpeter.

concentrated industries. Finally, the proposition that market structure affects the rate of return to R&D is tested empirically using firm data from the manufacturing sector.

II. The Analytical Framework

The Theoretical Model

A model commonly used in the R&D literature for estimating the rate of return to R&D spending is based on the starting assumption that the firm operates according to a three-factor Cobb-Douglas production function written in terms of output (Y), labor (L), physical capital (K), and technical capital (T):[2]

(1) $$Y = A_O e^{\lambda t} L^{\beta} K^{1-\beta} T^{\alpha}$$

where A_O is a constant, I is a disembodied rate of growth parameter, t represents time, and β and a are output elasticities. Constant returns to scale are assumed only with respect to L and K.

Differentiating equation (1) with respect to time, t, and defining productivity growth, ρ, as a Solow-type of residual leads to:

(2) $$\rho = \lambda + \phi(I_T/Y)$$

where $\phi = (\partial Y/\partial T)$is the marginal product of technical capital and where $I_T = \partial Y/\partial T$ is the net private investment of the firm into technical capital. If I_T is approximated by the firm's R&D expenditures then $\widehat{\phi}$ is interpreted from a stochastic version of equation (2) as the rate of return to R&D.[3]

The Effect of Concentration on the Rates of Return to R&D

The question raised in this paper is the degree to which the rate of return to R&D varies across differently concentrated industries. To the extent that firms in concentrated industries have larger market shares and thus enjoy the ability to appropriate the technical output from R&D, the rate of return to R&D will be higher in more concentrated industries than in lesser concentrated industries. However, since R&D encompasses myriad activities, there is no way to discern, *a priori*, the extent to which the output from R&D *per se* is appropriable.

The returns to R&D are related to the appropriability of the output from R&D which, in turn, is related to the strength of the property rights which can be obtained from the technical output. It is likely that the strength of property rights on technical output varies across types of research. One way to dichotomize R&D is into those activities undertaken by the firm that lead to process innovation and those that lead to product innovation. Product-related R&D tends to produce output which is more patentable than process-related R&D. The returns to patented output are

[2] For a critical discussion of this model see Griliches (1979). For a review of applications of this model see Bozeman and Link (1983).
[3] More accurately, if a stochastic version of equation (2) is estimated using cross-sectional firm data, then $ is an average rate of return over all firms in the sample, *ceteris paribus*.

not directly related to the size of the firm that holds the patent since the firm can assign the use of the patent to others for a fee.[4]

Process-related R&D tends to produce output which is not as easily patented, so firms must find other ways to prevent misappropriation of this type of technical output. It has been shown (Lunn, 1983) that monopoly power can be a substitute for legal property rights and hence provide some ability to prevent misappropriations of the process innovations.[5] Therefore, to the extent that concentration measures the degree of monopoly power, one should expect the output from process-related R&D to be more appropriable for firms in more concentrated industries. Hence, we posit that the returns to process-related R&D are greater in firms in more concentrated industries than in less concentrated industries. Since legal property rights are more easily Obtained for product innovations, one should not expect the returns to product-related R&D to differ by level of concentration.

The Empirical Model

The propositions stated above can be tested empirically from a stochastic version of equation (2). The effect of market concentration on the rate of return to total R&D spending can be calculated from the following regression:

$$\rho = \lambda + \phi_1(\mathrm{RD/Y}) + \phi_2(\mathrm{RD/Y})(\mathrm{CONC}) + \varepsilon \tag{3}$$

where RD = I_T represents the total R&D expenditures of a firm and CONC represents the market concentration of the industry in which the firm produces. Thus, from equation (3) the rate of return to R&D is $(\widehat{\phi}_1 + \widehat{\phi}_2\mathrm{CONC})$. Theoretically, $\widehat{\phi}_1 > 0$. If the return to R&D is greater in more concentrated industries then $\widehat{\phi}_2 > 0$.

Similarly, by dichotomizing RKD expenditures into process-related, PROCRD, and product-related, PRODRD, investments we obtain:

$$\rho = \lambda + \phi_3(\mathrm{PROCRD/Y}) + \phi_4(\mathrm{PROCRD/Y})(\mathrm{CONC}) + \phi_5(\mathrm{PRODRD/Y}) + \phi_6(\mathrm{PRODRD/Y})(\mathrm{CONC}) + \varepsilon \tag{4}$$

The return to process R&D is $(\widehat{\phi_3} + \widehat{\phi_4}\mathrm{CONC})$ and the return to product R&D is$(\widehat{\phi_5} + \widehat{\phi_6}\mathrm{CONC})$. Again $\widehat{\phi_3} > 0$ and $\widehat{\phi_5} > 0$, so an empirical test of the proposition that the return to process R&D is greater in concentrated industries rests with $\widehat{\phi_4} > 0$.

III. The Empirical Analysis

The Data Set

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[4] See McGee (1966) for a discussion of patent exploitation.

[5] It has been shown (Bozeman and Link, 1983; Scherer, 1983) that firms in more concentrated industries have a greater incentive to invest in process relative to product R&D, *ceteris paribus*. Relatedly, Ravenscraft and Scherer (1982) report that the process R&D to profitability relationship is stronger than that for product R&D. These empirical tests are based on the theoretical work of Scherer (1967) and Kamlen and Schwartz (1976).

Equations (3) and (4) were estimated using Compustat data from a sample of 223 U.S. manufacturing firms. Output was measured as net sales defined as gross sales and other operating revenue less discounts, returns, and allowances deflated by the Bureau of Labor Statistics' industry specific producer price index. Labor was represented by the total number of employees as reported to its stockholders. Physical capital was approximated by the value of gross plant representing tangible fixed property such as land, buildings and equipment, deflated by the Bureau of Economic Analysis' implicit price index for non-residential gross private investments. The average share of labor in total sales, b, over the period was estimated as the total labor expenditures of the firm in 1977 per unit of 1977eales. For those firms not reporting labor-related expenditures to Compustat, labor's share was computed using the product of the average 1977 annual wage in each firm's industry as reported by the Bureau of the Census and the total number of 1977 employees in the firm. The average share of capital is (l–b) .

Total factor productivity between 1975 and 1979 was measured in a two-stage process. First, a residually measured index, $g_t = (\ln Y_t - b\ln L_t - (1-b)\ln K_t)$ was calculated for each firms t = 1975-79, using these data. Then, following Mansfield (1980) and others, ρ was measured as the slope coefficient from a regression of g on trend for each firm.

Data on each firm's total 1977 R&D expenditures, RD, also came from Compustat. The percentages used to dichotomize total R&D into process- and product-related investments were obtained by survey (Link, 1980; Bozeman and Link, 1983). The original sample of 275 major R&D manufacturing firms was surveyed to obtain information on the composition of their R&D. Specifically each firm was asked to report the percentage of their self-financed R&D expenditures in 1976-77 that resulted in new or improved products or new or improved production processes. The sum of these two percentages equals 1.0. These percentages were then imputed to R&D data to calculate PROCRD and PRODRD. A complete data set was obtained for 223 of these firms.[6]

Concentration data are represented by the published four-firm concentration ratio, CONC, corresponding to the four-digit industry in which each firm in the industry produces. No adjustments were made for diversified firms. Each firm in the sample was assigned to a given four-digit industry on the basis of its primary line of business. These measures came from the 1972 *Census of Manufactures*.

The Regression Results

The least-squares results from equation (3) are reported in column (1) of Table 1. The estimated rate of return to all manufacturing firms (as represented by this sample) is 5.3 percent.[7] The estimated coefficient on the R&D term is positive and significant at the .05 level. The estimated coefficient on the interaction term is also positive, implying that the return to R&D is greater in more concentrated industries; however, the coefficient on the interaction term is not significant at a conventional level.

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[6] This subsample of 223 firms accounted for 58.6 percent of total 1976 net sales in manufacturing and 63.5 percent of total manufacturing R&D. A complete description of the sample and the sampling methodology is in Link (1980), or is available upon request from this author.

[7] The rate of return is (.033 + .00049 CONC). CONC at its mean of 41 yields a return of .053, or 5.3 percent.

Table 1. Least-Squares Regression Results from Equations (3) and (4) (t-statistics in parentheses)

Independent Variables	**(1)**	**(2)**
RD/Y	.033	
	(2.03)**	
(RD/Y) (CONC)	.00049	
	(1.51)	
PROCRD/Y		.183
		(2.61)*
(PROCRD/Y) (CONC)		.0019
		(1.97)**
PRODRD/Y		.009
		(0.83)
(PRODRD/Y) (CONC)		–.00029
		(–1.31)
R^2	.21	.36

The results from equation (4), reported in column (2), are more revealing. The estimated rate of return to process-related R&D is 26.1 percent compared to a 2.1 percent return to product-related R&D.[8] The estimated coefficient on the (PROCRD/Y) (CONC) term is positive and significant at the .05 level. This finding supports our proposition that the returns to process-related R&D are indeed greater in more concentrated industries. There is no statistical evidence that the return to product-related R&D varies across firms in differently concentrated industries. The estimated coefficient on the (PRODRD/Y) (CONC) term is not significant at a conventional level. The positive effect of concentration on the returns to process-related R&D and the lack of any effect for concentration on the returns to product-related R&D support the proposition that market power enables firms to appropriate innovative output when property rights are relatively weak (that is, market power is a substitute for property rights with respect to innovative output).

IV. Concluding Remarks

The findings presented here complement those of other researchers who have concluded that the market structure of an industry impacts on the direction and rate of innovation of its firms. The dimension of innovation examined is the rate of return to R&D, in total and by type. Our findings do suggest that the returns to R&D, more specifically to process-related R&D, are greater in more concentrated industries. To the extent that higher returns to R&D proxy more successful innovative activity, then (following Scherer (1967), Demsetz (1969), Kamien and Schwartz (1976), and others) we may conclude that not only is the incentive to innovate (cost reducing process-related innovations) greater in less competitive environments but also the returns on those investments are on average higher.

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[8] Similar differences in the size of the rates of return to R&D by character of use are reported in Mansfield (1980), Terleckyj (1982), and in Bozeman and Link (1983). The model used (specifically the dependent variable) to estimate the rate of return to P&D is not specified well enough to fully capture the product quality aspects of product-related R&D. Thus, the numerical size of the (PRODRD/Y) coefficient is probably biased downward. Changes in total factor productivity reflect primarily process-related innovations.

REFERENCES

Bozeman, B. and A. N. Link. INVESTMENTS IN TECHNOLOGY: CORPORATE STRATEGIES AND PUBLIC POLICY ALTERNATIVES. New York: Praeger, 1983.

Demsetz, H. "Information and Efficiency: Another Viewpoint." JOURNAL OF LAW AND ECONOMICS 12 (April 1969): 1-22.

Griliches, Z. "Issues in Assessing the Contribution of Research and Development to Productivity Growth." BELL JOURNAL OF ECONOMICS 10 (Spring 1979): 92-116.

Kamien, M. I. and N. L. Schwartz. "On the Degree of Rivalry for Maximum Innovative Activity., QUARTERLY JOURNAL OF ECONOMICS 90 (May 1976): 245-260.

Kamien, M. I. and N. L. Schwartz. MARKET STRUCTURE AND INNOVATION. Cambridge: Cambridge University Press, 1982.

Levin, R. C. "Toward an Empirical Model of Schumpeterian Competition." BELL JOURNAL OF ECONOMICS, forthcoming.

Link, A. N. "Allocating R&D Resources: A Study of the Determinants of R&D by Character of Use." Final report submitted to the National Science Foundation, 1980.

Lunn, J. "The Roles of Property Rights and Market Power in Appropriating Innovative Output." JOURNAL OF LEGAL STUDIES, forthcoming.

Mansfield, E. "Basic Research and Productivity Increase in Manufacturing." AMERICAN ECONOMIC REVIEW 70 (December 1980): 863-873.

McGee, J. S. "Patent Exploitation: Some Economic and Legal Problems." JOURNAL OF LAW AND ECONOMICS 9 (October 1966): 135-162.

Nelson, R. R. and S. G. Winter. "The Schumpeterian Tradeoff Revisited." AMERICAN ECONOMIC REVIEW 72 (March 1982): 114-132.

Ravenscraft, D. and F. M. Scherer. "The Lag Structure of Returns to Research and Development." APPLIED ECONOMICS 14 (December 1982): 603-620

Scherer, F. M. "Research and Development Resource Allocation under Rivalry." QUARTERLY JOURNAL OF ECONOMICS 81 (August 1967): 354-394.

Scherer, F. M. "Concentration, R~/) and Productivity Change." SOUTHERN ECONOMIC JOURNAL 50 (July 1983): 221-225.

Schumpeter, J. A. CAPITALISM, SOCIALISM AND DEMOCRACY, 3rd edition. New York: Harper and Row, 1950.

Terleckyj, N. E. "R&D and U. S. Industrial Productivity in the 1970's," in D. Sahal THE TRANSFER AND UTILIZATION OF TECHNICAL KNOWLEDGE, pp. 63-100, Lexington, MA: D. C. Heath, 1982.

Villard, H. H. "Competition, Oligopoly, and Research." JOURNAL OF POLITICAL ECONOMY 66 (December 1958): 483-497.