The simple economics of basic scientific research: A test of Nelson's diversification hypothesis

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Abstract:

Although risk is associated with all forms of research and development (R&D) activity, uncertainty is an inherent characteristic of basic research-defined as original investigation for the advancement of scientific knowledge that does not have a specific commercial objective [7]. Thus, it is not surprising that the outcome and direction of basic research is often unpredictable. More than two decades ago Richard Nelson [8] hypothesized that because of this uncertainty product diversification will be a prerequisite for basic research: simply, "firms that have their fingers in many pies" (p. 302) are better able to profit from whatever inventions or discoveries may result. Previous empirical studies have estimated the effect of product diversification on a firm's total R&D intensity [1], [3], [5], [9], but Nelson's hypothesis about basic research has never been tested explicitly. In this note we present evidence supportive of the Nelson argument as well as offer some initial insight into the nature of R&D activity at a disaggregate level.

Keywords: R and D | Richard Nelson | basic scientific research | diversification

Article:*

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I. THE EMPIRICAL ANALYSIS

Empirical investigations into the effect of diversification on R&D activity have generally been formulated in terms of a regression model relating the firm's R&D-intensity to an index of its product diversification, holding constant other firm and industry specific variables that are believed to affect R&D. Such models cannot be viewed as adequate for testing Nelson's proposition since basic research represents only a small fraction of total R&D and that fraction varies across firms both inter- and intra-industry [6]. The following regression model focuses specifically on inter-firm differences in basic research expenditures:

$$(1) \qquad BR/SIZE = \alpha_0 + \alpha_1 DIV + \alpha_2(1/SIZE) + \alpha_3(PROF/SIZE) + \alpha_4 CONC + \alpha_5 HIGH + \alpha_6 LOW + \alpha_7 COMPLEX + \varepsilon$$

The data employed come from a sample of 250 manufacturing firms for 1977. The dependent variable, BR/SIZE, represents basic research intensity. Data on basic research expenditures for each firm were obtained by survey.[2] Firm size, SIZE, is measured as net sales (gross sales and other operating revenue less discounts, returns, and allowances) as reported by *Compustat*.

DIV represents an index of the extent of each firm's product diversification. This index is formulated to reflect the number of markets served by each firm: it is simply the number of 4-

[1] There is a pragmatic explanation for the paucity of research into R&D activity at a disaggregate level. No data on R&D expenditures by character of use are published beyond the 2-digit or 3-digit levels: these data are reported annually by the National Science Foundation [7].

[2] These data were obtained by survey. Each industrial firm listed in the 1977 Fortune 1000 was surveyed to obtain the percentage breakdown of its R&D expenditures into basic research versus applied research and development. Each firm was provided National Service Foundation definitions and an explanation of these terms. A total of 359 firms responded to the survey request; however only 250 firms returned a completed questionnaire. The other 109 firms responded that the requested information was confidential or that company policy prohibited participation in surveys. For the manufacturing sector as a whole, the coverage ratio of this sample in terms of net sales is 52.2 per cent; in terms of R&D expenditures, 46.9 per cent. A more complete description of the distribution of survey responses by 2-digit industries is available from the authors by request.

The primary problem anticipated with this survey relates to the appropriateness of the category labeled basic research. Since the early 1950s, the National Science Foundation has used this category in an attempt to compare R&D expenditures in all sectors of the economy using a common definition. Nason, Steger, and Manners [6] have considered the appropriateness of using the label "basic research" for survey activity and concluded that it does have validity. Although most firms categorize R&D differently, they are familiar enough with external reporting that the term is meaningful and useful.

digit industries in which the firm operates as reported by Standard & Poor's in the *1977 Register of Corporations*.[3]

Relative firm profit, PROF/SIZE, is explicitly held constant. The rationale for this variable can be traced to Schumpeter [11]. Innovation involves risk and uncertainty. Consequently, substantial and often prolonged financial support is necessary to sustain the activities. Although many researchers have relied on this argument for predicting a positive relationship between R&D and profitability, it is equally valid for predicting a positive relationship between basic research and profitability. Although all categories of R&D involve risk, the outcome of basic research is inherently more uncertain. Thus, firms with available sources of internal financing may invest more intensely in basic research, *ceteris paribus*. PROF is measured as the firm's after-tax, after- divided profits plus depreciation and depletion, lagged one year, as published by *Compustat* [2], [3].

CONC represents an index of industry concentration corresponding to the 4-digit industry in which Standard and Poor's classifies each firm. Again, the theoretical justification for market structure affecting basic research intensity (in particular, R&D intensity in general) is attributed to Schumpeter [11] who suggested that market power (or the promise of market power) is a necessary condition to insure that firms internalize the benefits of their innovative investments. The 4-digit concentration ratios used here come from the *1972 Census of Manufactures*.

Two dimensions of the firm's technological environment are also held constant in equation (1).[4] The first dimension is the richness of opportunity for new product breakthroughs; the second is the degree of product complexity. Wilson [13] and others argue that the greater the opportunity for new product breakthroughs, the greater the incentive for the firm to engage in R&D activity, *ceteris paribus*, especially product-oriented R&D. Similarly, more complex configuration options of the firm's final products are expected to increase the potential profitability from R&D, *ceteris paribus*.

The impact of these variables on basic research is an empirical question. Following Wilson, high opportunity industries, HIGH, are basic chemicals, plastics, synthetics; pharmaceuticals; computers; electric equipment and components; aircraft and missiles; scientific instruments; optical and photographic equipment; and medical instruments and supplies. Low opportunity industries, LOW, include primary food, textile, wood, paper, stone, clay, glass, and the metal industries. All other manufacturing industries are medium opportunity. Firms were classified into these categories by dummy variables. Again following Wilson, product complexity, COMPLEX,

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[3] No attempt was made to weight this index by the percentage of the firm's sales in each industry. Since the output of basic research is (by definition) unknown *a priori*, the incentive to undertake it is provided by the potential to use whatever results. Since firms can expand their market shares through successful research, it is the number of markets serviced by each firm that is important. Grabowski [3] and McEachern and Romeo [5] measured DIV as the number of 5-digit SIC product lines in which a firm produced. Those data were last published in Fortune's *1966 Plant and Product Directory*. The range for DIV is 1.0 to 39.0, with a mean of 7.72 and a standard deviation of 6.66.

[4] It is assumed that the firm's environment can be depicted accurately by the 4-digit industry in which it is classified [13].

was measured for each durable goods industries as the percentage of output sold to the consumer, investment, and government sectors: nondurable goods industries were given a value of 0.[5]

Approximately 21 per cent of the 250 firms in the sample conducted zero basic research. Ordinary least squares analysis is therefore inappropriate since the regressand is bounded and observations are clustered at that bound. Equation (1) was estimated using tobit analysis [12]. The tobit coefficients are reported in Table I. Because of the difficulty in interpreting the non-linear tobit coefficients, elasticities (evaluated at the mean) are also reported.

Table I. Estimated Tobit Results (t-statistics in parentheses)

Variables	Coefficients	Elasticities
Intercept	–1.63	
	(–4.93)	
DIV	.896	1.03
	(2.29)	
1/SIZE	–76.67	–.243
	(–1.69)	
PROF/SIZE	11.26	.639
	(3.32)	
CONC	.141	.848
	(.311)	
HIGH	.513	.206
	(2.15)	
LOW	.278	.984
	(1.08)	
COMPLEX	.313	.091
	(.802)	

Likelihood ratio test: $\chi^2 = 123.4$

The estimated coefficient on DIV is positive and-statistically significant at the .05 level. We view this finding as empirical support for Nelson's diversification hypothesis. Also, as predicted, profitability positively influences basic research intensity. The estimated coefficient on CONC is not statistically different from zero. The only environmental variable to significantly affect basic research intensity is HIGH.[6]

II. CONCLUSION

These empirical findings are subject to two qualifications. One, the statistical model was formulated on the assumption that basic research decisions are influenced by the extent of the firm's product diversification. Diversification may well be the consequence of past basic

[5] The durable goods industries are defined as the 3-digit industries in SICs 24, 25 and 32 to 39. COMPLEX represents the share of final output from each of these 3-digit industries as calculated from the 1972 U.S. Input-Output tables. The value of COMPLEX is the same for each firm in a given 3-digit durable industry. There were 172 firms in the survey sample in 28 different 3-digit durable industries [13].

[6] It is interesting to note that when equation (1) was estimated using total R&D expenditures and applied research plus development expenditures (obtained from the survey) per unit of net sales as the dependent variable, the estimated (using ordinary least squares) coefficient on DIV was positive but not statistically different from zero. The estimated coefficients on the variables PROF/SIZE, HIGH, LOW, and COMPLEX were statistically significant at the .05 level or better.

endeavors. Two, as Nelson, noted, inter-firm differences in the proportion of R&D allocated to basic research may also reflect the risk-avoidance nature of the firm's management. This firm characteristic was not included in our analysis. Nevertheless, this study is a first empirical, to our knowledge, attempt to investigate Nelson's hypothesis directly by analyzing R&D expenditures at a disaggregate level.

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