On the classification of industrial R & D

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Abstract:

There is a long history of debate about the appropriateness of the National Science Foundation's classification of industrial R&D into the categories of basic research, applied research, and development. This paper presents empirical evidence that this classification accurately describes the scope of R&D that is self-financed and conducted in most industrial firms. However, larger firms are more likely to disagree about the appropriateness of the classification, and the disagreement relates in large part to the narrowness of the definition of development.

Keywords: R and D | industrial research | National Science Foundation classification

Article:[1]

1. Introduction

Although industrial research and development (R&D) expenditure data have been collected for the National Science Foundation (NSF) by character of work for nearly 40 years, the fundamental question regarding the appropriateness of the basic research, applied research, development classification has yet to be resolved.

The first definition of basic research was developed by Dearborn et al. (1953) based on industry interviews. Their definition, used in the NSF 1953-54 survey, was (NSF, 1956):

Basic or fundamental research - projects which are not identified with specific product or process applications, but rather have the primary objective of adding to the overall scientific knowledge of the firm.

However, concern was expressed by the NSF about the appropriateness of the reporting definition for basic research.[2] Thus, in the NSF 1955-56 survey, the term *fundamental* was deleted, and the definition used in that survey, and basically since, was (NSF, 1959):

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[2] See NSF (1956).

Basic research - research projects which represent original investigation for the advancement of scientific knowledge and which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company.

Since this definitional change, several studies have systematically examined the relevance of the category of basic research.[3] Industry input into the formulation of alternative categories has also been solicited by the NSF, but no consensus has been reached.

Surprisingly, a number of policy initiatives have emerged under the explicit assumption that basic research, for example, is a well-defined and measurable element of a firm's R & D activities. The US Department of Justice's (1980) antitrust guidelines, which formed the foundation for the National Cooperative Research Act of 1984, referred explicitly to basic research activities as part of its justification for encouraging collaborative ventures.[4] In addition, a basic research credit was included as part of the Tax Reform Act of 1986 to encourage industrial support of university-based and non-profit-based basic research and experimentation. Still, the question remains as to how best to define and gather data to determine the extent to which research activities can be directed toward national priorities.[5]

The purpose of this paper is to present empirical evidence regarding the accuracy with which the NSF's basic/applied/development categories describe the scope of R & D undertaken by industry.

2. The data set and empirical analysis

As a result of extensive interviews with an advisory group of 15 R&D directors/managers assembled for this study from the chemicals industry (Standard Industrial Classification (SIC) 28), the machinery industry (SIC 35), and the electric and electronic equipment industry (SIC 36), a survey instrument was designed to assess the NSF's classification categories. These three industries were selected because they are among the more R&D-intensive and basic research-active industries in the manufacturing sector. However, any generalization of the findings presented below to other manufacturing industries, or to the non-manufacturing sector, should be done cautiously.

The Bureau of the Census surveys annually the largest R&D performing firms. Because the definitions of basic research, applied research, and development examined herein are those that are used by the NSF, there was no reason to believe that larger firms would have any difficulty

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[3] See Nason et al. (1978). See also Applied Management Sciences (1989) and Bureau of the Census (1993) for discussions about future data concerns and needs. Collins (1990) recently reviewed the completeness of NSF R&D statistics disaggregated by character of work.

[4] Also important was the relatively high measured rate of return to basic research reported by Mansfield (1980) and Link (1981). See also Griliches (1986) for similar empirical findings.

[5] Gibbons and Panetta (1993, p. 4) stated in a recent White House Memorandum on principles of the fiscal year (FY) 1995 R&D budget that "R&D data is [sic) collected in the categories of basic, applied, development, and facilities ... [These categories) provide little information about the relevance of these investments to society ... And [these categories] are not particularly helpful in policy and budget decision making." In fact, they (1994, p. 1) will be considering for FY 1996 an alternative "reporting structure ... [that) will be much more extensive than the three R&D reporting categories now collected (basic research, applied research, and development)."

understanding the survey instrument or completing it in a manner consistent with its intent. There could be a problem with the response consistency of smaller, less R&D-intense firms if time series dollar estimates were being collected because these firms are not asked to complete Census' RD-1 Survey each year. However, care was taken in the selection of the advisory groups to include industry representatives from firms that are not surveyed annually.

Examined herein are the 1993 responses from 101 R&D directors/managers from these three industries to the question: "In your opinion, do the categories of basic research, applied research, and development accurately describe the scope of R & D that is financed by your company?" (YES = 1; NO = 0).[6]

Sixty firms were surveyed by mail and telephone in each industry. The group of 15 directors/managers with whom the instrument was developed and pre-tested was not included in the sample population of 180. The 101 respondents represent an overall response rate of 56%.[7] Forty-two responded from SIC 28, 23 from SIC 35, and 36 from SIC 36.[8] Of the 101 participating directors/managers, 93 reported that their company completed the RD-1 Survey on a regular basis.

Eighty-nine of the 101 R & D directors/managers responded affirmatively to the focal survey question. This agreement rate could be interpreted as an overwhelming vote of confidence on the part of industry regarding the appropriateness of the NSF classification. However, as shown below, this agreement is not uniform across all sized firms.

Because the dependent variable of interest in this study is dichotomous, equalling "1" for those respondents answering the survey question YES, and "0" for those answering NO, inter-respondent differences could not be examined statistically using the more traditional ordinary least-squares (OLS) regression model. The following probit model was alternatively estimated:

$$E(P_i) = F(\alpha + \beta_1 SIZE_i + \beta_2 BASIC_i) \qquad (1)$$

where F is the cumulative normal probability function. P_i is coded as a "1" for those respondents answering the survey question as YES, and "0" for those answering NO; *SIZE* represents firm size, measured as 1992 sales ($billions) as reported by Compustat; and *BASIC* represents the percentage of each firm's R&D allocated to basic research as reported on the survey.

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[6] See Link (1994) for greater detail about the evolution of this key question.

[7] The sample population was selected from Compustat. A disproportionate number of more highly R&D-intensive firms was selected owing to the fact that such firms are more likely to undertake basic research (Link, 1987).

[8] Non-response bias was statistically considered in two ways (Link, 1994). First, there was no statistical difference between the average level of sales, R&D, or employment between the final sample of 101 respondents and the sample of 79 non-respondents, in total or by industry. Of the 101 respondents, 62 promptly returned completed surveys by mail; the other 39 (as well as the 79 that never responded) were contacted by telephone and encouraged to participate in the study. There was no statistical difference between the agreement percentage in the sample of 62 initial participants and the sample of 39 follow-on participants. This is interpreted as some evidence that the concept validity of the basic/applied/development categories is not different between the 101 respondents and the 79 non-respondents.

The probit model can be compared to an OLS regression model in the following way. Consider the unobservable continuous index P_i^* which measures the degree to which respondents agree that the NSF categories of basic research, applied research, and development accurately describe the scope of R&D that is financed in their company. Then, the appropriate OLS regression model to examine inter-respondent differences would be:

$$P_i^* = \alpha + \beta_1 SIZE_i + \beta_2 BASIC_i + \epsilon_i \tag{2}$$

where ϵ is the classical OLS regression error term. In terms of the probit model in Eq. (1), $P_i = 1$ if $P_i^* > 0$ and $P_i = 0$ if $P_i^* \leq 0$.

There are a priori reasons to suggest that the sign of the estimated coefficient on *SIZE* could be either negative or positive. On the one hand, larger firms may be less inclined to agree on the appropriateness of any single R & D classification because they are more diversified both by category of research effort and by line of business to which R & D is directed. On the other hand, larger firms have participated more frequently in the annual Census-administered RD-1 Survey, and thus are relatively more accustomed to the NSF reporting definitions.

Based on the historical concerns associated with the reporting definition of basic research, it is expected that the sign of the estimated coefficient on BASIC would be negative.

The estimated probit results from Eq. (1) are reported in the first column of Table 1. While the vast majority of firms in the sample reported that the NSF classification appropriately describes the scope of their R&D, disagreements were prevalent in larger firms. Evaluated at the mean, the partial effect of a $1 billion increase in sales is to reduce the probability of agreement by 1.49 percentage points.[9] The estimated coefficient on the percent basic variable is positive, contrary to expectation, but not significant at a conventional level. Nevertheless, disagreements regarding the accuracy of the NSF categories may be associated with either the inability of firms to distinguish between applied research and development, or to the appropriateness of the reporting definition of development.[10] In fact, qualitative information collected during this study suggests that both of these explanations are valid. The more general case is that the more development undertaken in a firm the more likely it is to view engineering activities and related customer services as important aspects of development; such activities are excluded from the NSF definition.[11] The estimated results in Column (2) are similar when the *BASIC* variable is deleted.

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[9] Probit coefficients, like those presented in Table 1, are not partial derivatives as are OLS regression coefficients. However, partial effects can be calculated from probit coefficients. The calculated partial effect of a $1 billion increase in sales leading to a 1.49 percentage point reduction in the probability of agreement is comparable to an OLS regression estimate of β_1 in Eq. (2).

[10] The current definitions are essentially the same as they were for the 1955-56 NSF survey (NSF, 1959):
Applied Research – Research projects which represent investigation directly to the discovery of new scientific knowledge and which have specific commercial objectives with respect to either product or process.
and,
Development – Technical activity concerned with nonroutine problems which are encountered in translating research findings or other general scientific knowledge into products or processes.

[11] Quantitative information was not collected. However, Link (1994) reports paraphrased responses from the survey to support this generalization.

Table 1. Estimated probit models (asymptotic *t*-ratios in parentheses)

	(1)	(2)	(3)	(4)
Constant	1.27 (6.25)	1.41 (7.38)	1.05 (2.86)	1.25 (3.60)
SIZE	–0.107 (–2.57)	–0.094 (–2.31)	–0.128 (–2.80)	–0.123 (–2.64)
BASIC	0.102 (1.23)	—	0.135 (1.35)	—
Industry dummies	no	no	yes	yes
k	2	1	6	5
log(L)	–30.15	–31.79	–24.12	–26.25
$\chi^2_{(k)}$	13.33	10.07	25.41	21.14
n	101	101	101	101

Mean value of *SIZE* = \$1.81 billion.
Mean value of *BASIC* = 3.66%.

The results in Columns (3) and (4) are similar to those in Columns (1) and (2) except that industry specific intercept terms are included. The three two-digit SIC industry groups were separated to include pharmaceuticals (SIC 283) and computer and office equipment (SIC 357). Regarding the specification reported in Column (4), for example, no single industry intercept coefficient was significant, although as a group they were jointly significant – $\chi^2_{(4)} = 11.07$ (*P*-value = 0.026). The calculated partial derivative on *SIZE* for the specification in Column (4) is -0.013, virtually identical to the partial for the specification in Column (1).[12]

All of the probit models were tested for heteroskedacticity by allowing the error term to vary according to $\sigma_i = \sigma \exp(\gamma\ SIZE_i)$ where y is the coefficient on *SIZE* in the model for heteroskedacticity.[13] No test indicated that heteroskedacticity was present. For the specification in Column (4), for example, the log likelihood was -25.97 and a likelihood ratio test of γ = 0 gave $\chi^2_{(1)} = 0.55$ (P-value = 0.46). Similar results were also observed when using $\sigma_i = \exp(\gamma_{\text{i}}\ SIZE + \gamma_2\ SIZE^2)$.

3. Concluding observations

Although the survey results summarized herein suggest that the vast majority of the industrial firms studied find that the NSF classification appropriately describes the scope of their R & D activities, the disagreements that exist are among the larger firms in the sample. And, this disagreement is not related specifically to the reporting definition of basic research. Rather, based on qualitative information collected through the survey interviews, the disagreements relate in large part to the narrowness of the definition of development. This later finding suggests that the NSF's reported level of industrial expenditures on R&D may in fact understate the relevant portion of investments (from the perspective of firms) allocated to the research and development aspect of the innovation process in the three industries studied herein.

Efforts are now under way to quantify a broader range of investments in the innovation process through the NSF's Manufacturers Innovation Survey. Although quantification of investment

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[12] Firm size was alternatively measured as total R&D expenditures and total employment. The estimated results are similar to those reported in Table 1. See Link (1994).
[13] See Greene (1993).

activity throughout the innovation process is long overdue, it is premature to evaluate the success of, or implications from, this still-in-process undertaking.[14]

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[14] See Organization for Economic Co-Operation and Development (OECD) (1992) for the genesis of this endeavor.

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