# The changing composition of R & D

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**Abstract:**

There has been a trend away from basic research toward development spending at all levels within the economy. In constant dollars, basic research peaked in 1953 at 4.2% of total industrial R & D, but steadily fell to 2.8% by 1977, where it has approximately remained. Mansfield (1980) also documented this trend, and as well, he reported a mild decline in process-related R & D activities. The purpose of this paper is to investigate, in an exploratory vein, some determinants of this changing pattern of R & D spending.

**Keywords:** R and D | firm spending | management

**Article:**

## INTRODUCTION

There has been a trend away from basic research toward development spending at all levels within the economy. In constant dollars, basic research peaked in 1953 at 4.2% of total industrial R & D, but steadily fell to 2.8% by 1977, where it has approximately remained. Mansfield (1980) also documented this trend, and as well, he reported a mild decline in process-related R & D activities.[1] The purpose of this paper is to investigate, in an exploratory vein, some determinants of this changing pattern of R & D spending.

## NEW ESTIMATES ON THE COMPOSITION OF R & D SPENDING

[1] These summary statistics come from a survey of 119 large R & D firms (spending over $10 million on R & D in 1976). On average, firms spent 5.6% of their self-financed R & D on basic in 1967, but only 4.3% in 1980 (est.).

Data were collected from 146 US manufacturing firms on six categories of R & D spending between 1970 and 1981, with projected changes into 1985 and 1990.[2] As shown in Table 1, basic research spending has declined throughout the mid-1970s. However, there is some indication of a reversal in this declining trend around 1979. Similarly, the percentage of R & D going toward long-term research fell during the 1970s, but is predicted to be on the increase.

**Table 1.** Mean Percentages of Company-financed R & D in Manufacturing Industries to Basic Research, Long-term Research, Product and Process Activities: $n = 146$

| Years | Basic | Long-term | New production processes | Improvements in existing processes | New products | Improvements in existing products |
|---|---|---|---|---|---|---|
| 1970 | 2.84 | 23.10 | 15.47 | 21.44 | 25.53 | 40.76 |
| 1977 | 2.79 | 22.39 | 15.59 | 22.47 | 24.38 | 40.71 |
| 1978 | 2.78 | 22.64 | 15.11 | 22.81 | 25.81 | 39.78 |
| 1979 | 3.22 | 22.95 | 15.02 | 22.27 | 26.15 | 39.47 |
| 1980 | 3.51 | 22.26 | 14.69 | 23.46 | 28.03 | 38.66 |
| 1981 | 3.83 | 23.75 | 15.85 | 23.08 | 29.29 | 37.47 |
| 1985 (est.) | 4.72 | 24.09 | 16.14 | 22.54 | 29.31 | 36.14 |
| 1990 (est.) | 5.16 | 24.54 | 16.53 | 20.90 | 30.22 | 35.53 |

*Source:* Survey data.

Data on product/process expenditures suggest that the lion's share of R & D in manufacturing during the last decade has been directed toward improvements in existing products and processes. There does not appear to be evidence of a significant reversal in this pattern by 1990, although the mean percentages do show a slight increase away from improvements in existing processes and products toward new process and product expenditures.

## MODELING CHANGES IN THE COMPOSITION OF R & D

The economics literature is replete with studies of the determinants of *total* R & D spending. Three of these studies have extended this work by examining correlates of the *composition* of R & D. Mansfield (1981) asked to what extent increases in firm size are associated with increases in the amount spent on basic research, on R & D projects lasting five or more years, on R & D projects aimed at entirely new products and processes and on projects with less than a 50-50 estimated chance of success. Link (1982a, 1982b) examined the relationship between (1) profits, (2) diversification, (3) federally financed R & D, (4) ownership control and (5) industry concentration and both of the following categories of R & D spending: basic/applied/development and product/process.

To the author's knowledge this is the first study seeking to identify possible firm characteristics associated with changes in the composition of R & D over time. We know from the works of Caves and Porter (1977) and Porter (1976, 1979) that firms select different strategies (e.g. offensive/defensive) within an industry. Placing this body of literature parallel with the business policy literature on corporate strategy (e.g. Merrifield, 1977), the behavioral literature on the evolutionary performance of firms (e.g. Nelson and Winter, 1982) and the case studies of alternative R & D strategies (e.g. Tassey, 1983) one may conclude that an important determinant

[2] These firms accounted for 31.2% of total 1980 company-financed R & D spending within manufacturing. Approximately 83% of these firms spent more than $10 million on R & D in 1980.

of a firm's R & D activity—its size, scope and focus—is the R & D strategy adopted within the organization.

The relationship between changes in a firm's R & D strategy and changes in *all* categories of the composition of a firm's R & D spending is not immediately obvious. As firms adopt a more offensive R & D strategy they may, in effect, be choosing the position of being a technological leader within their industry. One prerequisite for sustained technological leadership is a growing base of innovation-enhancing knowledge. To the extent that such knowledge must be appropriable, one investment may be basic or long-term research. If so, we would expect, *ceteris paribus,* firms whose R & D strategy is toward the offensive end of the spectrum to allocate increasing portions of their self-financed R & D toward basic or long-term research.

Another influence on the direction of a firm's R & D spending is the nature of its organizational process facilitative of innovative behavior. Internal decision-making may vary according to the structure of the R & D organization, namely the existence of a central R & D lab as opposed to only divisional labs. A role of a centralized lab is to disseminate throughout the firm specialized technical information as well as generic R & D knowledge. In one sense the central lab is the firm's gatekeeper for the output from self-financed R & D. Therefore, a firm whose R & D organizational structure is centered around a central R & D lab may have a greater opportunity for incorporating the output from basic research than a firm whose R & D activities are decentralized, *ceteris paribus.*

Not only might a firm with a central R & D lab be able to target and appropriate the output from basic research, it may have a comparative advantage in conducting basic. To the extent that there are economies of scale in basic, firms with central labs may do more basic research, and may increase their basic expenditures faster than firms with only divisional labs, *ceteris paribus.*

Accordingly, following Rosenbloom and Kantrow (1982), firms with central ('corporate') R & D labs are likely to be those whose top-level management not only understands the benefits to long-term basic research activities but also is committed to maintaining obligations directed to such ends. Thus, such firms may have an implicit commitment to increasing their percentage of R & D directed towards basic and long-term research over time, *ceteris paribus.*

Firms with central R & D labs may also have an incentive to allocate increasing amounts of their R & D to new production processes. To the extent that process innovations are generic in nature there may be an opportunity for a firm to realize multiple uses from any one process improvement. A centralized lab can act as a vehicle for disseminating knowledge about such innovations. Alternatively, divisional R & D labs might be expected to have established closer linkages with divisional marketing and manufacturing management, and thus favour product development.

Finally, the degree of diversification characterizing a firm may also be related to the changing mix of its R & D. Nelson (1959) hypothesized a positive relationship between basic research and the extent to which a firm's product line is diversified. His arguments may be extended to suggest that as firms increase their product diversity they will also allocate an increasing percentage of

their R & D toward basic, *ceteris paribus,* since they have an internal network for appropriating whatever results from the basic endeavor.

Based on these arguments, the following four regression models are considered. The variables are defined in Table 2.[3]

$$\Delta BR = \alpha_1 + \beta_1 \Delta STR + \gamma_1 CL + \eta_1 \Delta DIV + \zeta_1 PG + \varepsilon_1 \quad (1)$$
$$(+) \qquad (+) \qquad (+)$$

$$\Delta LT = \alpha_2 + \beta_2 \Delta STR + \gamma_2 CL + \eta_2 \Delta DIV + \zeta_2 PG + \varepsilon_2 \quad (2)$$
$$(+) \qquad (+)$$

$$\Delta NPROC = \alpha_3 + \beta_3 \Delta STR + \gamma_3 CL + \eta_+ \Delta DIV + \zeta_3 PG + \varepsilon_3 \quad (3)$$
$$(+)$$

$$\Delta NPROD = \alpha_4 + \beta_4 \Delta STR + \gamma_4 CL + \eta_4 \Delta DIV + \zeta_4 PG + \varepsilon_4 \quad (4)$$
$$(-)$$

The percentage change variables were calculated as the average annual change over the time period from 1970 to 1981. Each firm was asked in the survey to describe its R & D strategy in both 1970 and 1981 using a five-point Likert scale ranging from 'very defensive' ( = l) to 'very offensive' ( = 5). *ΔSTR* is measured as the numerical difference between the responses. The binary variable, *CL,* equals 1 if the firm has a central lab and *CL* equals 0 otherwise. All firms with central labs in 1981 also had them in 1970. These data were also obtained in the survey. *ΔDIV* measures the change in each firm's diversification between 1970 and 1981. This index was calculated as the difference between the number of separate four-digit SIC industries in which the firm produced in each of these two base-years.[4] Finally, *PG* is included in each equation to account for differences in the type of product produced by each firm: *PG* equals 1 for those firms in producer-goods industries, and 0 otherwise.

**Table 2.** Regression Variables in Eqns (1)-(4)

| | |
|---|---|
| *ΔBR* | = change in the percentage of company-financed R & D allocated to basic research |
| *ΔLT* | = change in the percentage of company-financed R & D allocated to long-term research |
| *ΔNPROC* | = change in the percentage of company-financed R & D allocated to new production processes |
| *NPROD* | = change in the percentage of company-financed R & D allocated to new products |
| *ΔSTR* | = change in R & D strategy |
| *CL* | = (0, 1) binary variable indicating the existence of a centralized R & D lab |
| *ΔDIV* | = change in product-diversification |
| *PG* | = (0, 1) binary variable indicating producer-goods industries |

[3] The dependent variables in Eqns (3) and (4) relate to *new product* and *new process* spending. The conceptual arguments offered in support of these models relate more toward these two categories than to the categories for *improvement in existing products or processes.* Nevertheless, similar regressions were estimated for these latter two categories of spending. All estimated regression coefficients were statistically insignificant. These latter results are not reported here in Table 3, but are available upon request from the author.

[4] See Link (1982b) for a more detailed discussion.

The direction of influence of the independent variables as predicted from the conceptual arguments are shown in parentheses below the relevant parameters.[5]

The Empirical Results

The least-squares results from Eqns (1)-(4) are reported in Table 3. The results support partially the propositions hypothesized above. Firms whose R & D strategy has become more offensive have, during the 1970s, also been allocating a greater percentage of their R & D toward both basic and long-term research projects. The estimated coefficient on *ΔSTR* is positive and significant in the first two models. These firms do not appear to have significantly altered their new process/new product mix in response to this change in strategy.

**Table 3.** Estimated Regression Results from Eqns (1)–(4): $n = 146$ ($t$-statistics in parentheses)

| **Independent variables** | ***ΔBR*** | ***ΔLT*** | ***ΔNPROC*** | ***ΔNPROD*** |
|---|---|---|---|---|
| *ΔSTR* | 0.024 | 0.174 | 0.241 | –0.065 |
| | (2.27)[b] | (3.71)[a] | (1.53) | (–0.94) |
| *CL* | 0.229 | 0.145 | 0.670 | –0.950 |
| | (3.11)[a] | (2.04)[b] | (2.75)[a] | (–1.94) |
| *ΔDIV* | 0.016 | 0.009 | –0.008 | 0.012 |
| | (1.91) | (1.31) | (–0.18) | (0.71) |
| *PG* | 0.223 | 0.362 | 0.199 | –0.322 |
| | (1.15) | (1.65) | (2.08)[b] | (–2.31)[b] |
| Constant | –0.323 | –0.353 | –0.578 | 1.163 |
| | (–1.15) | (–0.43) | (–0.89) | (1.25) |
| $R^2$ | 0.483 | 0.471 | 0.408 | 0.361 |

[a] Significant at the 0.01 level.
[b] Significant at the 0.05 level.

Firms with central R & D labs have also been increasing the portion of their R & D allocated to basic and long-term research. The estimated coefficients on *CL* in Eqns (1) and (2) are positive and significant. As well, firms with a centralized R & D lab have been increasing their R & D allocations toward new process innovations at the expense of new product-innovations. Changes in diversification are not a significant correlate with any of the categories of R & D spending. Although the estimated coefficient on *ΔDJV* is positive in the *ΔBR* equation (as hypothesized), it is significant only at the 0.10 level.

Finally, there are industry differences in changes in the composition of R & D. Firms in producer goods industries (*PG* = 1) have, on average, been increasing their new process-related R & D while firms in consumer-goods industries have been increasing their new product-related R & D.[6]

[5] Descriptive statistics for all variables are available upon request from the author.
[6] In subsequent regressions the sample of 146 was dichotomized into those firms in producer-goods industries and those in consumer-goods industries in order to investigate the possibility that the influence of the strategy and organizational laboratory structure variables may be industry-specific. Each of the above models was re-estimated separately for each subgroup of firms. The only apparent industry differences in the relationships reported in Table 3 are with the impact of *ΔSTR* on both *ΔNPROC* and *ΔNPROD.* In consumer-goods industries firms whose R & D strategy has become more offensive during the 1970s have significantly increased their R & D investments in new-

## IMPLICATIONS AND CONCLUSIONS

These findings, although preliminary, are interesting in that a new class of so-called determinants has been identified. They are especially important in the context of R & D management. The paradigm hypothesized in this paper suggests that managers should be aware of the R & D spending consequences of structural decisions made within the firm. This may be obvious with regard to the linkage between changes in overall R & D strategy and the R & D spending responses. However, managers perhaps need to pay greater attention to innovative-related information flows characteristic of their R & D laboratory structure, or even of the hierarchical structure within each lab.

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product innovations. Firms in producer-goods industries have, in turn, not competed in terms of new products, but rather have competed in terms of basic and long-term research.

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