Firm size, university based research, and the returns to R&D

By: Albert N. Link and John Rees

Link, Albert N., and John Rees. "Firm Size, University-Based Research, and the Returns to R&D," *Small Business Economics*, April 1990, 2: 25-31. https://doi.org/10.1007/BF00389891

Abstract:

This paper compares university-based research relationships between small and large firms as an explanation for the difference in innovative activity across firm sizes. We test the hypothesis that there are diseconomies of scale in producing innovations in large firms due to the inherent bureaucratization process which inhibits both innovative activity as well as the speed with which new inventions move through the corporate system towards the market. By utilizing university-based research relationships, small firms are able to avoid bureaucratic inefficiencies.

Keywords: firm size | R and D | university-based research

Article:

I. Introduction

Over the past decade scholars have studied the role of small-sized firms in the innovation process. A number of important conclusions have come forth as a result of these inquiries.[1] First, small firms are more innovative (in terms of the number of product innovations) relative to their size than large firms. Second, product innovations coming from small firms appear to be more significant than those coming from large firms. Surprisingly, no studies to date have sought to explain, or even speculate, why small firms have this innovation-related advantage.[2]

This paper compares university-based research relationships between small and large firms in an effort to identify one factor that might explain this noted difference in innovativeness. Our hypothesis is that innovation-based diseconomies of scale exist in large firms owning to the fact that bureaucratization in the innovation decision making process inhibits not only inventiveness but also slows the pace at which new inventions move through the corporate system toward market. Small firms who utilize university-based research relationships and are as a result more efficient in their internal R&D, partially avoid such problems.

---

[1] Much of this research is summarized in U.S. Small Business Administration (1986) and in Link and Bozeman (1987).

[2] Relatedly, Acs and Audretsch (1987a, 1987b, 1988) show that the market environment most conducive for innovation is similar for both large and small firms. Also, they show that industry structure influences large firms' ability to innovate relative to small firms' ability to innovate, other things remaining equal.

This paper is outlined as follows. In Section II, the data that form the basis for our empirical investigations are described. In Section III, we provide an overview of firms' involvement in university-based research relationships. The empirical analysis in Section IV demonstrates that small firms are able to leverage their internal R&D activity through their research relationships with universities to a greater extent than large firms and, thus, enjoy a higher return on their research investments.

II. Description of the data

A. The sample of firms

In 1986/87 we assembled a data set related to firms' involvement with university-based research programs. Based on preliminary interviews with directors from both university and state research centers, several broad industry groups were identified to be the major 'users' of such external research relationships. These industry groups included computing equipment, machine tools, and aircraft and components. From these broad industry groups, a population of 1046 firms was identified from the 1986 DUNS file of the Dun and Bradstreet Corporation. After an initial mail survey to vice presidents of production/engineering, and follow-up telephone resurveys, complete information (defined below) was obtained on 209 firms.[3]

When surveyed, these firms were asked to classify themselves into one industry category based on their primary line of business. From their classification, these firms could be placed into five major SIC industry groups within the U.S. manufacturing sector: metalworking machinery (SIC 354), office and computing machinery (SIC 357), electronic components and accessories (SIC 367), aircraft and parts (SIC 372), and engineering and scientific instruments (SIC 381). The distribution of firms across these five industry groups is shown in Table I. Table II presents the distribution of these sample firms by size category. Along with the number of firms in each size category, the average number of employees per firms is also reported in that table.

Table I. Distribution of sample firms by industry

Industry	No. Firms
SIC 354	15
SIC 357	69
SIC 367	82
SIC 372	19
SIC 381	24
	209

[3] Whenever possible reported survey information (e.g., sales data) was verified against published data (e.g., Form 10-K data) to insure response reliability. When explainable differences occurred (e.g., a survey respondent reporting sales in $ millions rather than S thousands) the primary data were corrected.

Table II. Distribution of sample firms by size category

No. Employees	No. Firms	Avg. No. Employees
< 100	40	31
100 to 249	83	118
250 to 499	19	328
500 to 999	17	653
1000 to 9999	22	2,930
> 10,000	28	76,556

B. Innovation-related characteristics of the firms in the sample

Although there are many ways to characterize the innovativeness of a firm, one dimension relates to self-financed R&D activity. The sample firms were classified as R&D-active or not based on two separate criteria: R&D expenditures and R&D personnel. *A priori,* there was no reason to believe that these two indices would be perfectly correlated For example, a firm that relies heavily on contracted research may not have an R&D budget proportional to its R&D staff. Likewise, especially in smaller firms, the R&D budget may be so insignificant both in absolute and relative terms that the category 'R&D personnel' is not meaningful. Or, the accounting system may not be refined sufficiently to separate R&D expenditures from other investments even when personnel are classified as related to R&D. Nevertheless, 93 percent of the firms in this sample expended funds on R&D in 1986 and 88 percent of all firms had at least one individual classified under the heading of R&D personnel. Table III shows the percentage of sample firms involved in R&D using each criterion. With the exception of firms with more than 10,000 employees, there is a marked similarity between the percentage of firms with an R&D budget and those with classified R&D personnel. In this largest category, 93 percent of the firms reported an R&D budget but only 68 percent reported having R&D personnel. Perhaps, and the data do not permit an investigation of this point, these largest firms rely most heavily on contracted research which is paid internally and conducted externally. For the entire sample of firms, the correlation coefficient between total R&D expenditures and total R&D personnel is 0.65 (significant at the 0.01 level or better).

Table III. Percentage of sample firms involved in R&D by size category

No. Employees	$ Percentage	Emp. Percentage
< 100	88%	83%
100 to 249	93	90
250 to 499	95	95
500 to 999	100	100
1000 to 9999	100	95
> 10,000	93	68

Table IV presents the percentage of sales devoted to R&D activity by size category for all firms in the sample. It appears that small firms devote a greater percentage of their sales to R&D than do large firms. While the percentage differences do not seem to be significant between the middle size categories, they are distinct between the categories of firms with less than 100 employees and with more than 10,000 employees. For all firms in the sample, the average percent of sales allocated toward R&D is 10.6 percent.

Table IV. Percentage of sales devoted to R&D by size category

No. Employees	Percentage
< 100	13.3%
100 to 249	10.4
250 to 499	12.2
500 to 999	12.3
1000 to 9999	10.5
> 10,000	5.0

A similar pattern across size categories for all firms in the sample is shown in Table V. There, the percentage of total personnel involved in R&D decreases from 16.1 percent for firms with fewer than 100 employees to 7.9 percent for firms with more than 10,000 employees. The variation between the middle categories is again not striking.

Table V. Percentage of total personnel involved in R&D by size category

No. Employees	Percentage
< 100	16.1%
100 to 249	12.1
250 to 499	15.1
500 to 999	11.4
1000 to 9999	11.9
> 10,000	7.9

III. Overview of firms' university-based research relationships

Sixty-nine percent of the sample firms were involved with at least one university-based research program in 1986. As shown in Table VI, the degree of university involvement appears to increase with firm size. Whereas just over 50 percent of the smallest firms (less than 250 employees) were active in at least one research relationship with a university in 1986, about 90 percent of the firms with more than 1,000 employees were so involved.

Table VI. Involvement with university-based research programs by size category

No. Employees	% Firms
< 100	59%
100 to 249	51
250 to 499	74
500 to 999	94
1000 to 9999	86
> 10,000	100

Information on three specific categories of involvement with a university-based research program was collected: faculty used as technical consultants (Consultants), contracted research projects (Contracts), and graduate students used as research assistants (Research Assts.). If a sample firm participated in at least one of these dimensions, then it was classified in Table VI as involved in a university-based research program. The percentage of firms active in each of these three types of activities is shown in Table VII by size category. In general, firms in the larger size categories make greater use of university faculty as technical consultants; however, in all

three cases the percentage of firms with more than 10,000 employees who are involved in any dimension is greater than for any of the other size categories.

Table VII. Involvement with university-based research programs by type of activity and by size category

No. Employees	Consultants	Contracts	Research Assts.
< 100	41%	15%	47%
100 to 249	44	22	38
250 to 499	67	44	72
500 to 999	76	29	59
1000 to 9999	77	54	64
> 10,000	96	96	82

The existing literature on industry-university research relationships suggests that these types of relationships are fostered by firms for two major reasons: it is a mechanism to reduce research costs and a method to identify potential productive employees. To investigate this issue further, each firm was asked to indicate which of the following were incentives (expected results from the relationship) to their participating in a university-based research relationship: 'problem solving in production processes' (Pbl. Sol.), 'product development' (Prd. Dev.), 'use of university computing facilities' (Compt.), 'use of other university facilities' (Facil.), and 'gaining access to students as future employees' (Emplmt.). The percentage of firms noting each of these as incentives is shown in Table VIII by size category.

Table VIII. Incentives to engage in university research relationships by size category

No. Employees	Pbl. Sol.	Prd. Dev.	Compt.	Facil.	Emplmt.	Tax
< 100	3%	61%	5%	23%	55%	24%
100 to 249	19	69	18	19	65	16
250 to 499	57	71	29	57	79	40
500 to 999	37	63	6	19	69	29
1000 to 9999	42	47	5	16	84	11
> 10,000	63	77	13	62	93	54

With the exception of firms in the smallest two size categories, fewer than 100 employees and 100 to 249 employees, the potential for solving production process problems appears to be an important reason for firms to forge research relationships with universities. The importance of this potential as an incentive for such collaboration does not vary much by size category beyond firms with 250 or more employees. Over 60 percent of the firms in the sample view product development as an important incentive for engaging in a research relationship with a university. The use of university relationships as a vehicle to gain access to computing facilities appears to be primarily a small-firm (more than 500 employees) phenomenon. It may be the case that large firms have the in-house computer capabilities to conduct the requisite research operations. Access to other university facilities as an incentive for engaging in a university-based research relationship is important to some firms, but it does not seem to be systematically related to the size of these firms. In accordance with anecdotal information, gaining access to students as future employees is a significant incentive for firms of all sizes to pursue university-based research relationships.

The last column in Table VIII reports firms' responses to a question regarding the importance of 'federal tax incentives as a motivation for engaging in collaborative research' with a university. While responses vary over size categories, only in the largest size category, firms with more than 10,000 employees, did more than 50 percent of the firms respond affirmatively.

Three response categories were used to determine firms' overall success with their university research relationships. The lion's share of the firms were satisfied with their collaborative research experience, as reported in Table IX.[4]

Table IX. Firm's overall success in university research relationships by size category

No. Employees	"Very Satisfied"	"Somewhat Satisfied"	"Not Satisfied"
< 100	29%	64%	7%
100 to 249	38	62	0
250 to 499	71	29	0
500 to 999	44	56	0
1000 to 9999	46	54	0
> 10,000	25	75	0

This overview of the primary data suggests several preliminary patterns of firm behavior. One, firms in all size categories were engaged in university research relationships to use, in general, faculty as technical consultants; and firms in the larger size categories do this to a greater degree than firms in the smaller size categories (Table VII). This collaboration tends to be oriented primarily toward product development and secondarily toward problem solving in areas related to production (Table VIII). Two, in addition to research expertise, firms in all size categories viewed access to students as future employees as a significant incentive for engaging in a university-based research relationship (Table VIII).

IV. The empirical analysis

This section presents the results of two empirical investigations into aspects of firms' participation in university-based research activity. In Part A, the trend noted in Table VI that firms in the larger size categories were more active in university-based research relationships than firms in the smaller size categories is investigated statistically. The specific question considered is: Is the probability of involvement with a university-based research program related to firm size? In Part B, the impact of external research relationships on the rate of return to firms' internal R&D is examined. Does the rate of return to R&D vary by firm size? Does the rate of return to R&D vary according to research participation with a university?

A. The propensity to engage in external research relationships

An inspection of the descriptive information in Table VI suggests that the propensity to engage in a university-based research relationships is related to firm size. The percentage of firms active with a university-based research program increases with category size.

[4] There is not sufficient variation between the three response categories to conduct a more detailed investigation of interfirm differences in success with university-based research.

To test formally for the influence of size on the propensity to engage in an external research relationship, a probit model was estimated. The independent variables in this model were firm size (SIZE) measured in terms of firm sales ($millions), industry concentration (CR),[5] and a binary variable equalling 1 if the firm was involved in basic research and 0 if it was not (BASRES).

The probit results, with asymptotic t-statistics in parentheses, are:

$$\begin{array}{cccccc} F^{-1}(P) = & 0.114 + & 0.016\,\text{SIZE} - & 0.004\,\text{CR} + & 0.19\,\text{BASRES} \\ & (0.31) & (2.94) & (-0.44) & (0.63) \end{array}$$

$$-2 \times \text{log of the likelihood function} = 185.92$$

where $P = F(\alpha + \beta_0 \text{SIZE} + \beta_1 \text{CR} + \beta_2 \text{BASRES}) = F(z)$ for F being the cumulative probability function. These regression results complement the pattern of activity shown in Table VI. The probability of participating in a university-based research program does increase with firm size.[6] The estimated coefficient on SIZE is significant at the 0.01 level or better. Industry concentration and involvement in a basic research program have no explanatory power in this specification.

B. Firm size, university-based research relationships, and the returns to R&D

A framework frequently used by researchers in economics for estimating the returns to R&D reduces to the following regression model:[7]

$$\text{TFPG} = \alpha + \beta(\text{RD}/Q) + \varepsilon$$

where TFPG represents total factor productivity growth, (RD/Q) is the ratio of R&D spending to firm sales, and β is the estimated rate of return to R&D which could be interpreted as an index of R&D efficiency.

To estimate this model, data were needed for the calculation of total factor productivity over a defined period. Sufficient data for these calculations were not available for all firms in the sample. TFPG over the period 1982 to 1987 could be calculated for only 158 R&D-active firms of the 209 firms in the sample. The 51 firms deleted from the analysis were mostly small firms

[5] $0 < \text{CR} < 100$. These data came from Weiss and Pascoe (1986).

[6] A non-linear size variable was included in separate regressions, but the associated coefficient was not significant. As well, two other independent variables were considered. An index of foreign competition was included in a separate regression. This variable, based on data from the International Trade Commission and the Bureau of Industrial Economics, was constructed as the ratio of industry (four-digit) imports divided by the value of industry shipments plus imports less exports (Link and Bauer, 1989). It exhibited no statistical influence on the estimated probability. And, a vector of three-digit SIC industry dummies was included in the various versions of the model. As a group, these dummies were not significantly different from zero and thus were deleted. Similar results were obtained when SIZE was measured in terms of employees.

[7] This model is fully explained in Griliches (1979). See Link (1987) for a review of the empirical literature. Using cross-sectional firm data from the U.S. manufacturing sector, the estimated rate of return to internal R&D is in the neighborhood of 20 percent.

with fewer than 100 employees. Overall, the rate of return to the 158 firms in this subsample was 26.1 percent. This result is reported in Table X.

Table X. Estimated rates of return to R&D expenditures

Category	Estimated Rate of Return
Subsample of 158 firms	26.1%
Large firms	26.0%
Small firms	26.1%
Firms involved in university research	34.5%
Firms not involved in university research	13.2%
Large firms	
Involved in university research	29.7%
Not involved in university research	14.1%
Small firms	
Involved in university research	44.0%
Not involved in university research	13.9%

Several versions of the basic model were estimated. First, to test for differences between the rate of return to R&D in large versus small firms, a second regressor was included in the above equation. Its equalled a binary variable interacted with the (RD/Q) term where the binary variable was given the value 1 for firms with less than 500 employees and 0 otherwise. The estimated least-squares coefficient on this term was not statistically different from zero, implying that there was no statistical difference between the returns in the two size groups.[8] This result is also reported in Table X.

Second, a similar specification was estimated to account for possible differences in the rate of return to firms engaged in and not engaged in a university-based research relationships. For this, the binary variable equalled 1 if the firm was so engaged and 0 otherwise. As reported in Table X, the estimated returns to R&D in firms involved in university-based research relationships are more than twice those of firms that are not – 34.5 percent versus 13.2 percent.[9]

Finally, segmenting both by size and by university involvment by including two regressors in the original specification (one with a size dummy and the other with an university-based research dummy), the returns to R&D in small, university-based research-active firms was found to be quite large. As reported in Table X, the estimated rate of return to R&D in this group of firms was 44.0 percent compared to (1) 29.7 percent in large university-based research-active firms, (2) 14.1 percent in large non-university-based research-active firms, (3) 13.9 percent in small non-university-based research-active firms. Small firms appear to be able to transfer knowledge

[8] Link's (1980) analysis of the rate of return to R&D among firms in the chemicals industry found that the return increased with firm size to a modest threshold level, and then remained constant.

[9] This finding may not be inconsistent with the findings of others that the returns to basic research are greater than for other categories of R&D spending. Generally, research conducted at universities is toward the basic end of the R&D spectrum; however, the underlying data (see Tables VII and VIII) do not allow us to separate clearly this form of research relationship. This finding also corresponds favorably with that of Link and Bauer (1989). They report, based on a sample of 92 manufacturing firms, the rate of return to R&D in firms involved in cooperative research programs with other firms is nearly three time that of firms not so involved – 37 .7 percent versus 12.9 percent.

gained from their unviersity research association most effectively, compared to large firms, to increase the returns to their internal R&D activities.

V. Conclusions

While the results presented in this paper by no means explain fully why small firms have an innovation-related advantage over large firms, they do point out one interesting difference between an aspect of large and small firm research behavior. Although large firms are more active in university-based research *per se,* small firms appear to be able to utilize their university-based associations to leverage their internal R&D to a greater degree than large firms.

The analysis presented here did not take into account many of the other important factors associated with R&D efficiency, and so the results presented in Table X should be interpreted with caution. Still, the findings are noteworthy enough to encourage other investigators to investigate in more detail the ways in which firms internalize external technical information.

Acknowledgement

This paper was prepared for the Conference on Innovation and Technological Change: An International Comparison, organized by the Wissenschaftszentrum Berlin für Sozialforschung, Berlin, August 10-11, 1989. Funding for this research came from the U.S. Small Business Administration under contract SBA-89-989.

References

Acs, Z. J. and D. B. Audretsch, 1987a. 'Innovation in Large and Small Firms', *Economics Letters*, **23** (1), 109–112.

Acs, Z. J. and D. B., 1987b, 'Innovation, Market Structure, and Firm Size', *Review of Economics and Statistics* **69** (4), 567–574.

Acs, Z. J. and D. B. Audretsch, 1988. 'Innovation in Large and Small Firms: An Empirical Analysis', *American Economic Review* **78** (4), 678–690.

Griliches, Z., 1979, 'Issues in Assessing the Contribution of Research and Development to Productivity Growth', *Bell Journal of Economics* **10**, 92–116.

Link, A. N., 1980, 'Firm Size and Efficient Entrepreneurial Activity: A Reformulation of the Schumpeter Hypothesis', *Journal of Political Economy* **88**, 771–782.

Link, A. N., 1987, '*Technological Change and Productivity Growth*, London: Harwood Academic Publishers.

Link, A. N. and L. L. Bauer, 1989, *Cooperative Research in U.S. Manufacturing*, Lexington, Mass: Lexington Books.

Link, A. N. and B. Bozeman, 1987, 'Firm Size and Innovative Activity: A Further Examination', final report to the Office of Advocacy, U.S. Small Business Administration.

U.S. Small Business Administration, Office of Advocacy, 1986, *Innovation in Small Firms*, Washington, D.C.

Weiss, L. W. and C. A. Pascoe, 1986, *Adjusted Concentration Ratios in Manufacturing, 1972 and 1977*, Washington, D.C.