An economic analysis of cooperative research

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Abstract:

The U.S. government's most recent policy initiative to increase industrial research activity is the National Cooperative Research Act of 1984. Since its passage much attention has been given to this new organizational research form, but to date there has not been any systematic investigation of the participants in cooperative research. This paper is an initial attempt to fill that void. First, a classification scheme is presented to describe the research activity of firms currently engaged in cooperative endeavors, as evidenced by mandated filings reported in the *Federal Register*. Then, a model of inter-firm differences in cooperative research activity is posited and tested using survey-based data for a sample of R&D active firms in the U.S. manufacturing sector. We conclude that market power is the principal determinant of involvement in cooperative research.

Keywords: R and D | United States manufacturing | cooperative research

Article:

1. INTRODUCTION

The U.S. government has a long history of directing public policies toward R&D activity. The Department of the Navy's sponsored research programs can be traced back as far as 1789; and the Department of Agriculture's involvement in the land-grant college system dates from the mid-1800s. Since World War II, direct federal support of R&D has increased dramatically in response to growing social needs.

The economic rationale for public support of innovation, particularly industrial R&D, is based on the argument that innovation involves the process of creating information (although information of a particular type and with a particular use) and information has at least some characteristics of being a public good. The question of whether underinvestment in R&D by the private sector exists is not easily answered Even if it could be demonstrated that the level of private investment in R&D is less than the desired social level, it still remains as to the extent of federal support needed to equate the marginal social benefits derived from such investment with the marginal social costs incurred.

In addition to this theoretical argument, there is a pragmatic explanation surrounding recent public policies toward R&D. Productivity growth is one of the most important factors influencing economic well-being; but productivity growth in the U.S. private business sector began to decline in the mid-1960s, accelerating after 1973 until the late 1970s. Since R&D is an important correlate with productivity growth [1], it is no surprise that R&D has been a target variable for recent policy initiatives.

Tax incentives for R&D have long been part of the U.S. tax code [2-5]. In 1954, Section 174 of the internal revenue code codified and expanded tax laws pertaining to firms' R&D expenditures. This provision allowed businesses to deduct fully research and experimental costs in the year incurred. If the firms were to chose not to expense the costs in the year incurred, an option was available to capitalize these expenditures, other than depreciable assets such as equipment, and to amortize those expenditures over a period of not less than five years. Also, the Economic Recovery Tax Act of 1981 contained two incentives aimed at increasing corporate innovation: the Acceleratd Cost Recovery System provided special provisions for the tax depreciation of R&D equipment. The R&D tax credit allowed for a 25% credit on qualified expenses above a base period level.

Most recently, public policies in this country and elsewhere have been directed toward collaborative research efforts, research joint ventures in particular. Joint ventures are not a new organizational form, but they are becoming more prevalent [6-8]. Only once during the period from 1973 to 1980 were there more than 200 reported joint ventures. In 1982, 281 joint ventures were reported and the number increased to 348 in 1983.

In 1980, the U.S. Department of Justice, partly in response to this emerging trend, took the position that *"the closer [any] joint activity is to the basic end of the research spectrum . . . the more likely it is to be acceptable under the antitrust law"* [9]. Also, several bills concerned explicitly with R&D joint ventures were introduced in the 98th session of Congress. These led to the Joint Research and Development Act of 1984 (HR 5041)) and eventually to the passage of the National Cooperative Research Act of 1984 (PL 98-462).

The National Cooperative Research Act (hereafter referred to as the Act) has two primary objectives. First, it establishes a rule of reason for evaluating the antitrust implications of each R&D joint venture on an individual case basis:

[T]he conduct of any person in making or performing a contract to carry out a joint research and development venture shall not be deemed illegal per se; such conduct shall be judged on the basis of its reasonableness. . . .

Also, the Act limits potential liability to actual damages, rather than treble damages:

[A]ny person who is entitled to recovery on a claim under such section shall recover the actual damages sustained by such person. . . .

While the Act has been in effect for over two years, very little is known about the participants in cooperative research in general [6,7,10-12], or about the economic implications of the Act in particular [13-17]. In fact, to date no systematic empirical study of cooperative research activity at the firm level has been conducted. (The one exception relates to a study of the video display terminal industry [18].) The purpose of this paper is to attempt to fill that void.

First, a classification scheme is presented in Section II to describe the research activity of firms currently engaged in cooperative endeavors. The primary data for this descriptive analysis come from mandated filings reported in the *Federal Register.* Second, an analytical framework is developed in Section III to investigate the topic: an empirical model of participation in cooperative research is conceptualized on the basis of earlier studies of industrial R&D, then the survey-based data used to test this model are described, and finally the statistical results are presented. Concluding remarks are offered in Section IV.

II. A CLASSIFICATION OF COOPERATIVE RESEARCH ACTIVITY

The Act requires that any party to a cooperative R&D venture must file a description of the activity with the U.S. Attorney General and the Federal Trade Commission. This notification is then published in the *Federal Register.* The *Federal Register* filings were analyzed as a first step toward understanding the nature of the firms that are involved in cooperative research and the focus of their activity.

By December 1, 1986,52 filings had been reported in the *Federal Register.* Based on these published summaries, seven categories of cooperative research activity were developed [19]. These categories are listed in Table 1 along with the number of filings associated with each category. 'One-half of the 52 filings are related to industry associations established to fund or conduct research (e.g. the Semiconductor Research Corporation), or to research ventures geared toward one particular project (e.g. Intel Corp. and Xicor Corp. are engaged in cooperative activities in the joint development of EEPROM devices for manufacture).

Table 1. Classification of cooperative research activity based on *Federal Register* filings

Categories	Number of filings	Mean number of participants per filing	Percentage of participants who are R&D active
No. 1: Industry associations	15	17.7	46.2%
No. 2: Project specific research ventures	11	3.3	41.7%
No. 3: Research corporations with own facilities	8	10.9	69.0%
No. 4: Trade associations/research affiliates	7	24.0	23.2%
No. 5: Research conducted for environmental/regulatory concerns	5	9.0	13.3%
No. 6: University-based research centers	3	5.7	70.6%
No. 7: Independent research institutes	3	10.3	45.2%
	52		

While most filings come under one of these two categories, the greatest number of participants per cooperative research venture is associated with category No. 4 – Trade Associations/Research Affiliates (e.g. Portland Cement Association). Based on those seven filings, the mean number of participants per filing is 24. The least number of participants per filing is associated with Project Specific Research Ventures in category No. 2.

Most of the participants who are engaged in the cooperative research activity which underlies the data summarized in Table 1 are R&D-active firms. The percentages of the participants in the reported cooperative venture that are active in R&D are in the third column (a firm is defined as R&D active if it is listed in *Business Week's* 1986 "R&D Scoreboard"). Of the seven categories listed, those associated with University-Based Research Centers (category No. 6) (e.g. the West Virginia University/Industry Cooperative Research Center which was established to conduct research, stimulate innovation, and develop the field of fluidization and fluid particle science) and with Research Corporations With Own Facilities (category No. 3) (e.g. Microelectronic and Computer Technology Corporation) are dominated by firms who have active R&D programs. This may suggest that cooperation of the type in these two categories is a complement to internal R&D. After carefully examining the nature of the cooperative research, the only objective conclusion is that most filings are related to projects in electronics, semiconductors, and information processing. Based on *Federal Register* data, it does not appear that any generalization can be made about the character of firms who engage in cooperative research. Thus, to investigate further this issue an empirical model is posited and survey data gathered to test it.

III. THE ANALYTICAL FRAMEWORK

A. The Empirical Model

An empirical model is posited in order to investigate the determinants of inter-firm differences in cooperative research activity. Two factors are emphasized in this analysis: profitability and market power.

Cooperative research, like any form of research, involves risk and uncertainty, and as such it requires substantial and often prolonged financial support. External funding is difficult enough to obtain by firms engaged in the more traditional R&D endeavors, and may be virtually non-existent for those proposing cooperative activities. Thus, internal sources of financing must be available for nearly any research form of this type.

It has been argued that the R&D-to-profits relationship is stronger in some types of firms than in others [20]. Theoretical analyses conclude that marginal firms, those engaged in "risky" R&D ventures, face an active self-financing constraint and thus current profits are a necessary condition for R&D spending. Established firms doing "routine" product development will not be as constrained by cash availability and will not require high current cash flows to finance their research programs. Related empirical research supports this generalization [21, 22]. Given this, and the fact that cooperative research is likely to be oriented toward the basic or generic end of the R&D spectrum [13], it follows that firm profitability should be a prerequisite for firms to be active in that form of research.

However, a countervailing theoretical argument exists [23]. Firms with low or declining profits may feel pressure to innovate in order to remain competitive [24]. If so, increased R&D is a reasonable method for pursuing such a strategy. Because of waning profitability, cooperative research may be the preferred organizational arrangement for such undertakings owing to the ability of the participants to share costs. So then, firm profitability and involvement in cooperative research should be inversely related to each other. Thus, the theoretical literature is conflicting, although the empirical literature suggests a positive relationship between profitability and participation in cooperative research.

One of the most frequently investigated topics in industrial organization is the relationship between market power and innovative activity. Specifically, is it the possession of, or rather the quest for, market power that stimulates innovation? The so-called Schumpeterian position is that market dominance is an important determinant. Since cooperative research has a greater degree of "publicness" than internal R&D, by design, firms who have the ability to internalize the benefits from shared knowledge are, following Schumpeter, more likely to invest in it. Relatedly, firms in concentrated industries make more widespread use of best available technology [25]. Participation in cooperative research is one means of obtaining related technological information, so it follows that cooperation is an organizational arrangement that should be favored by firms in concentrated industries. However, others have demonstrated that the relationship between innovation (R&D investments) and monopoly power cannot be unambiguously predicted from theory [26, 27]. The empirical research is also mixed [17, 28-31]. Thus, the relationship between involvement in cooperative research and the profitablity and market power of the participants is an empirical issue.

B. The Data Set

The data used to examine this issue were gathered by survey. A random sample of 436 firms, stratified by manufacturing industry, was selected from the "R&D Scoreboard" in *Business Week* to receive a mail survey on cooperative research activity. Cooperative research was defined to be any formal or informal relationship among firms for the purpose of conducting research. This definition includes consortia arrangements, but not university-based research relationships. As such, this definition is broader than equity-based research joint ventures.

After the initial mailing in 1985, and a follow-up mailing in early 1986, data were collected from 92 firms regarding their involvement in cooperative research. The sample of 92 firms represents a 21% rate of response.

Many of the firms who did not participate in the surveys may not have done so because they were not active in cooperative research, and thus the focus of the study was not relevant to their behavior. Of the 92 participating firms, 62 reported that they were involved to some degree in cooperation.

The possibility of response bias was investigated by estimating the probability of survey participation as a function of firm size (n = 436). The dependent variable in this analysis equaled "1" if the surveyed firm returned a completed questionnaire, and "0" if it did not. Firm size was measured as 1984 (SALES) in billions of dollars. The estimated probit equation, with asymptotic *t*-statistics in parentheses, is:

$$F^{-1}(P_i) = \begin{array}{l} -1.23 + 0.032\,SALES \\ (-20.42)(3.54) \end{array} \quad (1)$$

where, $P_i = F(\alpha + \beta X_i) = F(z_i)$, F is the cumulative probability function, and X equals SALES. Based on the positive sign and level of significance of the estimated coefficient on SALES, it appears that this sample of 92 participating firms is not random from the *Business Week* population of R&D active firms within manufacturing, but rather it is biased toward the larger firms within that sector. A similar result was obtained when an R&D expenditures (RD) variable, measured in billions of dollars, was used in place of SALES:

$$F^{-1}(P_i) = \begin{array}{l} -1.21 + 0.84\, RD. \\ (-20.36)(2.79) \end{array} \quad (2)$$

Selected descriptive statistics for this sample are reported in Table 2. Also, the distribution of these 92 firms across two-digit industries is shown in Table 3. A relatively wide range of firm sizes is accounted for in this sample, reflecting primarily the cross-industry distribution of participants. As a whole, the firms in this sample accounted for 25.1% of all company-financed R&D in manufacturing in 1984.

Table 2. Descriptive statistics for the sample of firms (*n* = 92)

Variables	Mean*	Standard deviation
Sales	$4560.7	$13086.1
R&D expenditures	$114.8	$384.5

*In $millions.

Table 3. Distribution of sample firms by two-digit SIC industry

SIC code	Industry	*n*
20	Food and kindred products	6
21	Tobacco products	0
22	Textile mill products	1
23	Apparel and other textile products	0
24	Lumber and wood products	0
25	Furniture and fixtures	0
26	Paper and allied products	4
27	Printing and publishing	1
28	Chemicals and allied products	15
29	Petroleum and coal products	7
30	Rubber and miscellaneous plastic products	1
31	Leather and leather products	1
32	Stone, clay and glass products	3
33	Primary metal industries	3
34	Fabricated metal products	4
35	Machinery, except electrical	14
36	Electric and electronic equipment	16
37	Transportation equipment	8
38	Instruments and related products	6
39	Miscellaneous manufacturing	2
	Total	92

Participation in cooperative research was measured as the percentage. Of company-financed R&D allocated in 1984 to cooperative research (CRPCT). Profitability (PROFIT) was measured as the ratio of 1984 profits to firm sales, as reported by *Business Week.* As an alternative, profitability was measured as the return on equity. The empirical results presented below are virtually unchanged when this latter measure is used.

Market power was quantified in two ways: by a weighted industry concentration ratio (WCR) and by a weighted market share variable (WMS) for each firm. As part of the survey, each firm was asked to allocate its 1934 sales across its lines of business. For each firm, each line of business was assigned a four-digit SIC industry concentration ratio. Four-digit categories outside of the manufacturing sector were ignored. Concentration data correspond to 1982 [32]. The results presented below are invariant to the use of adjusted 1977 industry concentration ratios [33]. Each concentration ratio was weighted by the relevant percentage of the firm's total sales in order to construct the firm-specific variable, WCR. In a similar fashion, each firm's share of total industry sales was calculated, by line of business, and then weighted by the relevant percentage of total sales. Industry sales for 1984 used in these calculations were estimated by taking 1982 sales by four-digit industry [32] and inflating them by a producer price index [34]. The empirical results reported below are unaffected by the use of this price index compared to the Consumer Price Index.

Descriptive statistics on these variables are in Table 4 for the entire sample of 92 firms, for the subsample of 62 firms who are involved in cooperative research, and for the subsample of 30 firms who are not involved in cooperation.

Table 4. Descriptive statistics on the primary data

Variables	***n* = 92**	***n* = 62**	***n* = 30**
CRPCT:			
mean	0.049	0.073	0.00
standard deviation	0.063	0.065	NA
PROFIT:			
mean	0.026	0.019	0.040
standard deviation	0.039	0.029	0.051
WCR:			
mean	0.434	0.434	0.433
standard deviation	0.179	0.186	0.167
WMS:			
mean	0.038	0.046	0.020
standard deviation	0.085	0.099	0.034

C. The Statistical Results

The empirical model analyzed has the general form:

$$\text{CRPCT} = f(\text{PROFIT}, \text{WCR}, \text{WMS}). \tag{3}$$

As defined in the previous section and in Table 4, the dependent variable is truncated at zero. Thirty of the 92 firm-specific observations equal zero: 62 of the observations have positive values within the unit interval. Tobit analysis is the appropriate statistical technique for analyzing a vector of positive observations that are truncated at one end.

In order to examine inter-firm differences in CRPCT, two questions must be considered: To what extent do changes in the independent variables influence a firm's decision to undertake cooperative research (that is, to go from CRPCT = 0 to CRPCT > 0) ? and, To what extent do changes in the independent variables influence the extent of cooperative research (that is, variations in CRPCT given CRPCT > 0) ? Tobit analysis is, intuitively, a combination of probit analysis (which is concerned with the dichotomous choice of cooperating or not) and regression analysis (which is concerned with variations in cooperation once the choice to cooperate is made).

The Tobit model is:

$$y_i = \begin{cases} y_i^* \text{ for } y_i^* > 0 \\ 0 \text{ for } y_i^* \leq 0 \end{cases} \tag{4}$$

where y_i refers to the dependent variable CRPCT, $y_i^* = X_i\beta + \varepsilon_i$, $E(\varepsilon_i) = 0$, $\text{Var}(\varepsilon_i) = \sigma^2$, and where X_i is the vector containing independent variables PROFIT, WCR, WMS, and a constant. The estimated Tobit coefficients from eqn. (4), β, along with ordinary least squares (OLS) coefficients for comparison, are reported in Table 5.

Table 5. Tobit and OLS regression estimates based on eqn. (4) (ratio of $\hat{\beta}/s_\beta$ in parenthesis: n=92)

Independent variables	**Tobit**	**OLS**
PROFIT	–0.207	–0.017
	(–0.88)	(–0.11)
WCR	0.128	0.126
	(2.74)*	(3.96)*
WMS	0.199	0.178
	(2.02)**	(2.39)**
Intercept	–0.256	–0.012
	(–1.12)	(–0.71)
Standard error	0.075	0.056
R^2	—	0.229
F-ratio	—	8.71*
χ^2_3	16.285*	—

*significant at 0.01 level.
**significant at 0.05 level.

Profitability does not appear to be an important determinant of firms' participation in cooperative research. While the estimated Tobit coefficient on PROFIT is negative, it is not significantly different from zero. The market power variables are statistically important. Firms in more highly concentrated industries, and those with larger market shares, are more active in cooperative research, as measured here. The Tobit coefficient on both of these variables is positive and significant at the .01 and .05 levels, respectively. This quantitative finding is not at odds with the interpretation of Schumpeter discussed above.

Twelve two-digit industry dummies were included in other versions of eqn. (4), but as a group these variables were not significant and thus deleted. Referring to the distribution of sample firms in Table 3, firms in industries SIC 22, 27, 30 and 31 were included in the intercept term. The null hypothesis that the coefficients on 12 industries dummies equaled zero could not be rejected: $x_{12}^2 = 10.95$. As well, the possibility of non-linear relationships between WCR and WMS with CRPCT was tested, but the non-linear terms were not significant. This finding is in contrast with the inverted-U relationship between concentration and R&D found by others [26-28].

In an OLS regression, the change in $E(y)$ with respect to X_j is $\partial E(y)/\partial X_j = \beta_j$, the relevant regression coefficient. However, in a Tobit model, the change in $E(y)$ resulting from a change in X_j has two distinct parts: (1) the change in the values of y above the limit, $\partial E(y^*)/\partial X_j$, and (2) the change in the probability of being above the limit, $\partial F(z)/\partial X_j$, where $F(z)$ is the cumulative normal density function. The two parts can be combined to yield $\partial E(y)/\partial X_j$ as:

$$\partial Ey/\partial X_j = \left[F(z)\left(\partial Ey^*/\partial X_j\right)\right] + \left[\partial Ey^*\left(\partial F(z)/\partial X_j\right)\right] \quad (5)$$

The term in the first bracketed expression is the change in the expected value of y (Ey^*) by firms above the limit ($y^* > 0$) weighted by the probability of being above the limit ($F(z)$), and the term in the second bracketed expression is the change in the probability of being above the limit weighted by the expected value of y above the limit. This decomposition interpretation draws directly from [35, 36]. The values of the terms in eqn. (5), based on the analysis underlying the results in Table 5, are reported in Table 6.

Table 6. Calculated values of the components of the determinants of cooperative research

X_j	$\partial Ey/\partial X_j$	$\partial Ey^*/\partial X_j$	$\partial F(z)/\partial X_j$
PROFIT	–0.13795	–0.09676	–1.00736
WCR	0.08533	0.05985	0.62312
WMS	0.13321	0.09344	0.97274

Z =0.42955 evaluated at the mean of all X_js
$F(z)$ =0.66624
Ey =0.04860
Ey^* =0.07295

Since y is the percentage of firm R&D allocated to research joint ventures, and thus $0 \leq y \leq 1$, and since $0 \leq F(z) \leq 1$, then for each X_j, $[\partial Ey^*/\partial X_j]$ may be compared numerically to $[\partial Ey^*/\partial X_j]$ in order to determine the relative impact of a change in X_j on the expected value of y by firms above the limit versus the probability of being above the limit. Such a comparison for changes in the market power variables, WCR and WMS, is revealing, as seen from the calculations in Table 6. Increases in market power have a much greater impact on whether a firm decides to engage in a cooperative research than on whether a participating firm will allocate a marginal dollar to such activity. That is, $\partial F(z)/\partial \text{WCR} > \partial Ey^*/\partial \text{WCR}$, and $\partial F(z)/\partial \text{WMS} > \partial Ey^*/\partial \text{WMS}$. Alternatively stated, to the extent that market power affords firms the ability to appropriate technical knowledge, that ability is critical for their decision to engage in cooperation. Once that decision is made, additional market power has little effect on the allocation of marginal R&D dollars to that activity.

IV. CONCLUSION

The principal conclusion from the survey-based portion of this study is that there are systematic differences in the extent of cooperative research across firms in the U.S. manufacturing sector, and these differences reflect firms' abilities to appropriate, through their market position, the knowledge gained in that form of research. It is also important that firm differences in cooperation are not an industry-specific phenomenon.

Any implications drawn from this conclusion must be interpreted cautiously for several reasons. First, since this is the initial empirical investigation of this topic, there are no other findings to which these results can be compared. Public information in the *Federal Register* appears to be of limited use for determining general characteristics of firms engaged in cooperative research. Second, while the sample of 92 firms analyzed herein accounts for a sizeable portion of total R&D in manufacturing, it is not necessarily representative of all innovative firms in that sector. R&D is only one source of innovation-enhancing technical knowledge [3]. Finally, the empirical model is simplistic in its formulation, not accounting for endogenous factors.

Still, the results of the survey-based analysis are interesting. The finding that market power primarily influences the dichotomous decision to engage in cooperation is important. If cooperative research begets additional market power, then that power will have only a limited influence on the extent of industry participation in cooperative ventures. It will not, by itself, provide a strong incentive for new firms to engage that organization form, or for existing participants to allocate additional resources to that activity. In other words, there may now already exist a stable group of firm participants in cooperative research ventures. Since it appears from anecdotal evidence that this cooperation existed prior to the passage of the National Cooperative Research Act of 1984, it may be that the importance of the Act is simply to mandate reporting rather than influence the amount of activity undertaken.

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