Basic Research and the Success of Federal Lab-Industry Partnerships*

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Abstract

This paper examines the role that basic research plays in the strategies pursued by industry in their interactions with federal labs. It draws on questionnaire-based data of 229federal laboratory-industry joint R&D projects with 219 companies and 27 laboratories. The study documents the relative importance of basic research in the success of the interactions by comparing the incidence of basic research on several indicators of success.' The study shows that, even though projects involving basic research tend to have higher costs, they also have a high percentage ofproduct outputs in the short term. Typical high payoff strategies for partnership were those in which the company performed several technical roles and the federal laboratory was more narrowly focused.

Introduction

It is widely believed that basic research is the component of the knowledge enterprise most distant from commercialization. Further, if the research in question were clearly linked to commercial products, it would probably not be classified as "basic" research. Therefore, when we study interactions between industry and federal laboratories, it would follow that private companies interested in making a profit would give low priority to basic research in the business strategies they pursue when interacting with labs. However, previous studies have shown that basic research figures prominently in the interactions of companies with federal labs and, therefore, the notion of commercially relevant activities by the federal labs should be broadly construed (Bozeman and Papadakis 1995).

With new market conditions and the increasing importance of innovations for business, firms have increased their search for outside sources of technical information (Rosenbloom and Spencer 1996; Roessner 1993). A strategy they often use for this purpose is to enter cooperative research and development agreements. A recent study (Miyata 1996) found that industries facing costly R&D and industries searching for basic research are more interested in cooperative R&D agreements. On the other hand, it concluded that diversification may not be a strong reason for cooperative R&D. However, companies' motivation cannot be explained simply as short term cost reductions. Another study of what industry wants from the national laboratories has shown that "companies tend to interact with federal labs for reasons that have far more to do with long-term, less tangible pay-offs than with the expectations of short-term business opportunities or technology commercialization" (Roessner 1993, p. 4 1). This is consistent with earlier results reported by Mansfield (1980) that established a direct link between firms' productivity increases and its long-term R&D expenditures.

Recently, the conditions that must obtain in order to increase the chances of reaping commercial benefits from basic research have received more attention. Most of it has been directed at understanding and managing the interface between academic institutions and industry (Lee 1996; Liyanage and Mitchell 1996; Mansfield and Lee 1996; Rosenberg and Nelson 1994). Studies of the factors that affect success of the interactions between public laboratories and industry show that the relation between firms' strategies and economic benefit are quite complex (Bozeman 1995). If increased product development and marginal economic benefits are the success criteria, then firms pursuing interaction strategies containing a larger number of technical roles are generally better off (Bozeman and Wittmer 1997). Joly and Mangematin (1996) propose a typology of public laboratories based on their scientific production, type of funding and homogeneity of research themes. They found that the patterns of interactions with industry vary depending on what type of public laboratory it is.

According to Hameri (1996), for basic research to realize its potential in commercial outcomes, the key factor in collaboration between basic research laboratories and industry is in learning by interacting: fairly long, face-to-

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face interaction allowing for the two-fold process of knowledge transfer to occur. In a related case study, Hameri and Vuola (1996) explore the commercial relevance of basic research and challenge the conventional notion of technology transfer. They suggest that basic research can serve as a catalyst or incubator for industry proposed innovations. They maintain that large-scale basic research experiments are "fertile soil to test the applicability of a new solution to a large variety of technological domains" (op. cit., p. 532).

This paper examines the role that basic research plays in the strategies pursued by industry in their interactions with federal labs. It draws on questionnaire-based data of 229 federal laboratory-industry joint R&D projects with 219 companies and 27 laboratories. The study documents the relative importance of basic research in the success of the interactions by comparing the incidence of basic research on several indicators of success.

Research Questions

We posed several questions related to the peculiarities of federal lab-industry partnerships involving basic research.

*A. How **does basic research relate to various indicators of commercial success of the partnership such as product outcomes?***

A single indicator cannot measure the commercial success of the interaction between a firm and a federal lab. Companies pursue a variety of goals in these cooperative endeavors and, for instance, may report satisfaction and even monetary gain while no new product resulted from the project. Basic research may serve some companies' purposes better than others may. Therefore, we are interested in showing what role basic research played in the success of interactions when measured according to different indicators. We also wish to find out what role it played overall in the strategies pursued by the firms.

B. How does basic research impact the costs and benefits of the partnership?

It is often believed that the costs of basic research become clear relatively early while its benefits are uncertain. However, given that previous studies (Bozeman and Papadakis 1995) already indicated a prominent role for basic research in federal lab-industry partnerships, we decided to find out what effect basic research had on the patterns of costs and benefits reported for these interactions. Is the commonly held assumption generally valid? Can one expect reports of economic benefits in the relatively short term?

C. ***How does basic research** relate to the other **technical activities performed during** the interactions?*

The interactions involved several technical activities in many combinations. A previous study (Bozeman and Wittmer 1997) had shown that there was no particular combination of technical roles which was clearly related to success in commercialization or economic benefits. However, we are interested in asking in what combination of technical activities does basic research appear when either economic benefits or losses are reported. Does it make a difference whether basic research is performed or not? Is there any pattern in which basic research must appear when reports of either gains or losses are given?

Methods and Indicators

Methodology

The study is based on data from questionnaires sent to industrial organizations that have interacted with federal laboratories during the period of five years between 1989-1994. The data include 229 federal laboratory-industry interactions or projects (Bozeman, Papadakis, and Coker 1995). The projects are from 27 federal government laboratories, including most of the leaders in federal laboratory-industry commercial activity. The interactions between private companies and federal laboratories considered in the study included collaborative R&D, formal CRADAs, personnel exchange, resource sharing and use of specialized equipment, licensing of technology, and technical assistance. Individual projects may include more than one type of interaction.

The project, not the laboratory, was the unit of analysis, However, the choice of laboratories was not random. It was known from previous studies (U.S. GAO 1989; Bozeman 1994) that most federal laboratories do not have significant interactions with business organizations. Only those commercially-active federal laboratories meeting any of a variety of commercialization criteria were included (Bozeman, Papadakis, and Coker 1995). Among the labs included in the study are all the DOE multi-program labs, and more than one lab from the Department of Defense, NASA, and NIST. The effective sampling population was 544 industry-federal laboratory projects. A total of 229 usable surveys were returned, yielding an effective response rate of 42.2 percent.

Type of Technical Activity and indicators of Success

The data on the types of technical activity performed in the project were obtained from the questionnaire. The respondent was asked to indicate whether the company or the federal laboratory performed basic research, precommercial applied research, applied research, development, or testing as a part of the interaction. There is always some question, of course, as to the stability of meaning abut such concepts as basic research. However, there is some strong evidence that industrial respondents to questionnaires have relatively stable and valid concepts of

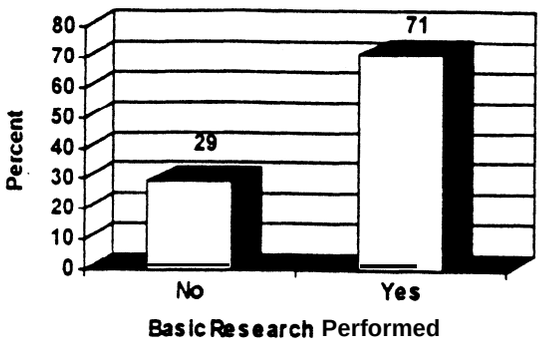

Figure 1. Percent of cases involving basic research

basic research (Link 1996).

The indicators of success are based on the industry respondents' reports of outcomes of the project and their assessment of the costs and benefits of working with the federal laboratories. The results of the project included: (1) whether a product had been developed and marketed; (2) whether an existing product had been improved; (3) whether product development activity was currently underway. The assessment of benefits and costs included: (1) measures of monetary value of the interactions and the technical outputs used by companies; (2) companies' estimate of the economic benefits and costs of projects; (3) jobs created at the companies as a result of the projects; (4) perceptual measures of satisfaction with the project experience. The analysis of net benefit of the interaction is based on the direct subtraction of costs from benefits reported by the respondents.

Resource limitations did not permit on-site verification of respondents' reports. All data are from the questionnaire responses provided. The inability to verify such factors as new product development or reported benefits is, of course, a limitation of the study.

Findings

Frequency of Basic Research Activities

Basic research was a very prominent activity in the industry-federal lab interactions surveyed. As can be seen from Figure 1, one or both partners in 71 percent of the cases performed basic research. Another indication of the prominence of activities toward the basic research end of the spectrum of type of R&D activity results from comparing their frequency relative to other activities. Figure 2 shows that the federal laboratories performed basic research 58 percent of the time and that the companies did 39 percent. From Figure 3 we can see that the companies collaborated in performing basic research as frequently as the labs performed it on their own (27 percent).

Basic Research and Product Output

We probably would not expect basic research to be closely linked to commercial product outputs in the short time span of a single industry-federal lab interaction. However, the results show that basic research was performed in a relatively high number of projects that had some sort of product outcome. For example, Table 1 shows that in almost 40 percent of cases in which only the company performed basic research, a marketed product resulted from the interaction. When considering the total of federal lab-industry interactions, both basic research was performed and a marketed product resulted from the project in only 16.4 percent of cases (Figure 4). However, the results are quite impressive for products under development as a result of the partnership when either the federal lab alone or both performed basic research during the project. Almost half of those cases yielded a product under development (46.7 percent and 48.3 percent respectively, Table 1).

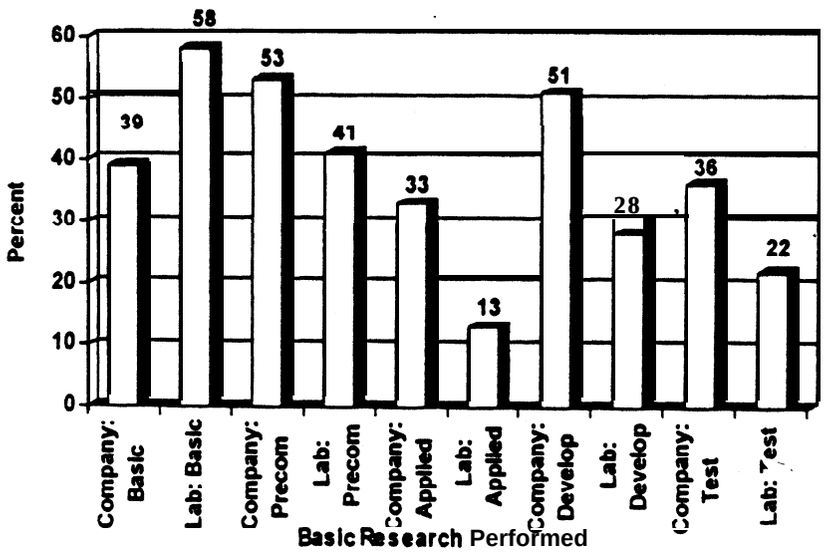

Figure 2. Percent of R&D activity by type and performer

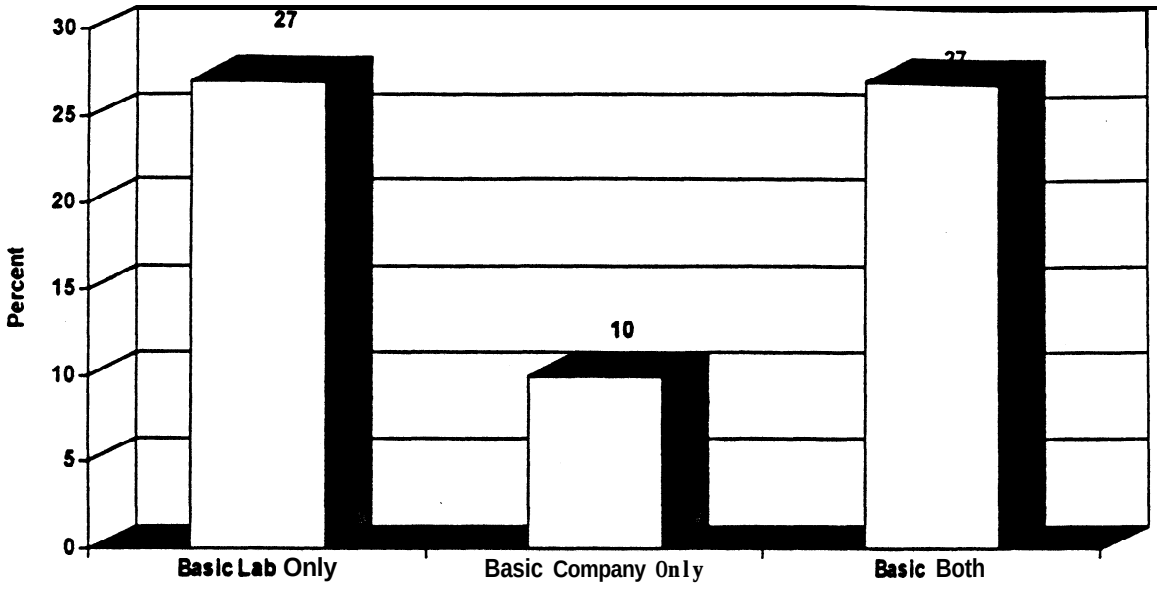

Figure 3. Percent performing basic research

Figure 5 shows that, as one would expect, the performance of basic research does not make marketing or improvement of a product more likely. However, the percentage of cases in which a product was marketed is almost the same with or without basic research and a slightly higher proportion of cases in which a product was improved resulted from interactions without basic research (32 percent vs. 22 percent). So contrary to expectation, basic research didn't make product output much less likely either. Furthermore, the number of projects that led to a product under development is significantly higher when basic research was performed (43 percent vs. 27 percent).

*Were **previous experiences** important for basic research leading to a marketed product?*

Previous experience with the lab slightly increases the chance that the project will result in a marketed product. A comparison of means indicates that projects in which basic research was performed and a marketed product resulted were somewhat less likely to result from interactions with companies that had no previous experience with the lab (p=.024). However, the same is true in general for projects leading to marketed products, whether basic research was performed or not (p=.012). However, the cases in which company personnel were former lab contractors had a higher chance of being involved in projects where basic research was not performed and no marketed product resulted (p=.000). So generally speaking, previous experience does enhance the chances of product output for projects in which basic research was performed but in almost the same way as it enhances the chances for all projects.

Does it matter who initiates the interaction?

Difference of means tests also show that projects involving basic research were more likely to lead to a marketed product if the interaction was initiated either by top managers of the lab or the company (p=.024). However, this is not different from the case where the same relation exists between who initiated the interaction and marketed products, whether basic research was performed or not (p=.00 1 and p=.004 respectively). The finding about the involvement of top managers is consistent with more general findings in the policy implementation literature (e.g., for an overview see Bozeman and Straussman 1990) that top managers' involvement accelerates change and increases the likelihood of implementation. Top managers control resources and require less time for approval. Top managers face fewer veto points in making organizational decisions.

Table 1. **Product outcomes and basic research activities**

Strategy		% Product Marketed	% Product Developed	% Product Improved
		22.7% n=207	38.7% n=212	25.0% n=212
Basic-Company	n=23	39.10%	26.10%	26.10%
Basic-Federal Lab	n=57	29.80%	46.70%	20.00%
Basic-Both	n=60	11.70%	48.30%	23.30%

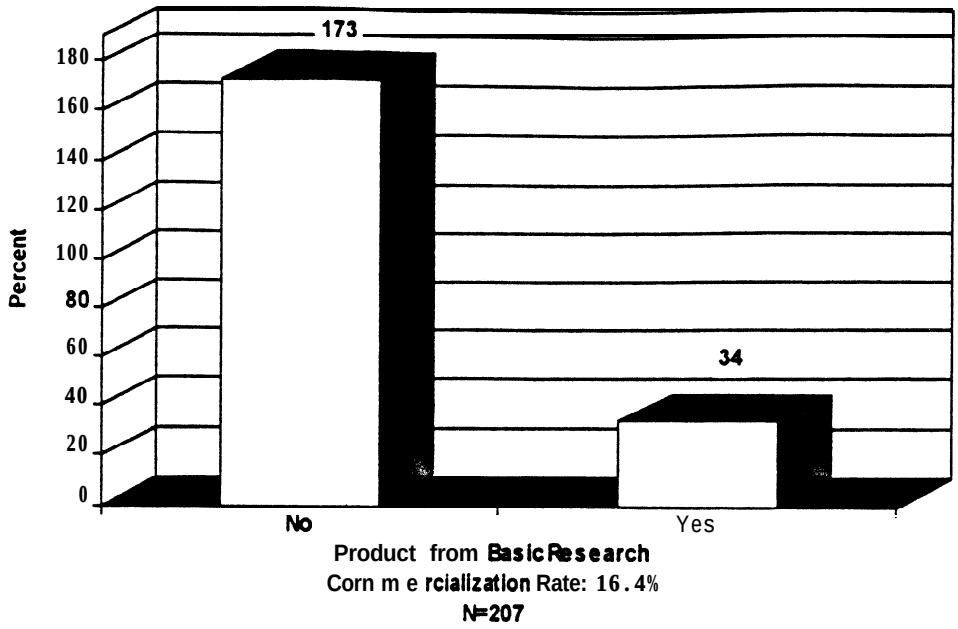

Figure 4. Did basic research yield a product?

Influence of company size: The average size of companies that conducted projects in partnership with the federal laboratories in which basic research was performed and resulted in a marketed product was significantly smaller than the rest almost by a factor of 3 (p=.008). The relation is similar in general, independently of whether basic research was performed, except that in this case the difference is greater and these companies are smaller by a factor of 5 (p=.001). Approximately the same relation between size and marketed product output exists when the number of R&D employees is considered, both in general (p=. 11) and when there is no basic research performed (p=.03 1).

A set of case studies of technology development from federal laboratory partnerships (Bozeman and Roessner 1995) provided evidence of the reasons why company size seems linked to technology marketing and the use of federal laboratory basic research. Often, small companies have limited capacity for in-house basic research and tend to rely on federal laboratories to either provide entirely or supplement company research. In such instances the basic research is not simply one part of the company's basic research portfolio, but rather a major component and, often, a major factor in the company's line of business. It is understandable in such cases that the basic research would be more central and that it would more likely be used directly in product development.

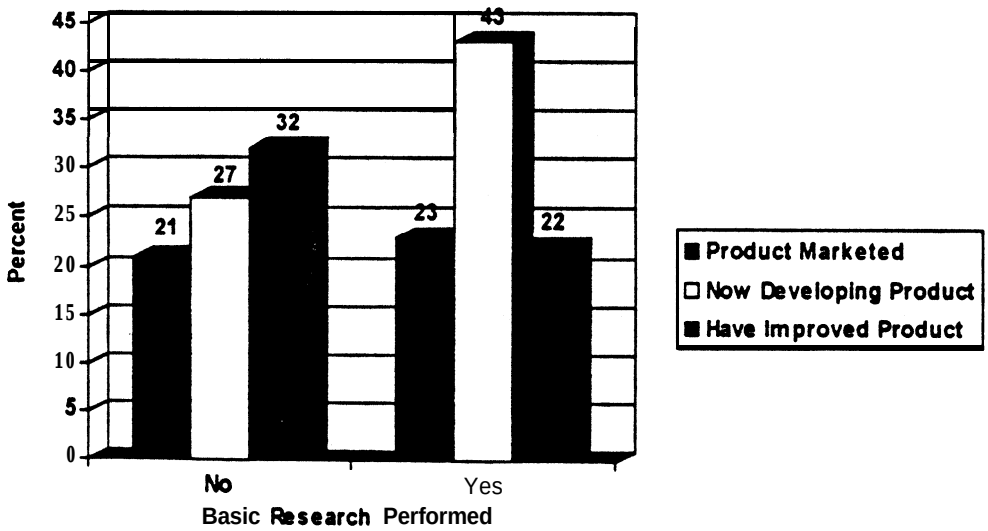

Figure 5. Product output by basic research

Did the type of project make a difference?

The only significant relation was established between projects involving CRADAs and marketed outputs. However, the relation was negative. There was a greater chance that CRADAs did not lead to marketed products, both in the general case (p=.000) and in the special case in which basic research was not involved (p=.008). Quite possibly, the finding about CRADAs is an artifact. During the late 1980s and early 1990s there was a concerted effort, especially in the Department of Energy (the largest percentage of the projects examined come from DOE laboratories), to increase the number of CRADAs. Thus, the percentage of CRADA projects is much higher for the more recent projects, the ones which have had the least time to gestate.

Personnel Hired from Basic Research Partnerships

A previous analysis of this data had already established that "the vast majority of federal laboratory-industry interactions do not result in any job creation or loss for the companies directly involved" (Bozeman, Papadakis, and Coker 1995, p. 44). Analysis of the interactions from the vantage point of the particular role of basic research does not alter the validity of that general conclusion. However, as we can see in Table 2, the cases in which the company performed basic research, and the lab did not, have a higher than average rate of hiring personnel than the rest. The percentage of companies performing basic research alone that did hire personnel as a result of the interaction amounted to 26.1 percent which almost doubles the overall average of companies hiring.

Companies' Satisfaction with Partnership

The industry respondents indicated in a high percentage that they were satisfied with the experience of cooperation with the lab. Indeed, 89 percent agree or strongly agree that they are satisfied with the interaction. This strong indication of satisfaction is also present in cases where basic research was performed. Actually, the percentage of cases that agree or strongly agree that the interaction was a good investment of company resources is higher when basic research was performed than the general case (92.9 percent vs. 89 percent).

Table 2. Company hiring and basic research

Hiring	% Companies Hired	% No Hire
n=209	13.90%	86.10%
Basic Company	26.10%	73.90%
No Basic Company	12.40%	87.60%
Basic Both	11.70%	88.30%
No Basic Both	14.80%	85.20%

Table 3 and Figure 6 show the percentages for each satisfaction category according to who performed basic research. In each case the value is the percentage of cases for each basic research performer reporting each degree of satisfaction. For example, of all the cases in which basic research was performed, by either partner or both, .7 percent strongly disagree, 6.3 percent disagree, 47.2 percent agree, and 45.8 percent strongly agree that working with the federal laboratory was good use of company resources. Actually, of those cases reporting dissatisfaction most did not involve the performance of basic research.

Costs and Benefits

The presence or absence of basic research does have an impact on the patterns of costs and benefits for the companies interacting with the laboratories. Figure 7 shows median benefits and costs with and without basic research. The median benefit value does not change significantly but the costs are typically much higher when basic research is performed. However, some interesting patterns emerge when the median benefits and costs are calculated for particular product outcomes. For cases leading to an improved product, the medians are in a very similar relation as the general case: benefits are almost the same with or without basic research and costs increase significantly in the former case (Fig. 8). In the case of a product under development, costs increase and benefits diminish, but the median benefit with basic research is still higher than the median cost (Fig. 9). And in the cases with a marketed product, both benefits and costs increase and typical benefits exceed costs by a 2 to 1 margin (Fig. 10).

A comparison of means analysis confirms these observations. The average benefit/cost ratio when the interaction included basic research, and led to a marketed product, is smaller than the rest of all other interactions by a 3 to 2 factor (p=.015) but is still greater than 1. In general, the average ratio for all interactions leading to a marketed product is larger than it is for those that did not by a factor of 8 to 3 (p=.062).

These observations confirm the notion that basic research is an expensive endeavor, costs are inevitable higher. However, the fact that in typical cases benefits are still larger than costs seems to indicate that even in the fairly short term, basic research is not as high risk as one may suppose.

Basic Research in the Overall Strategy for Lab-Industry Partnerships

Previous analysis (Bozeman and Wittmer 1997) has shown that the number of technical roles played by the company is an important predictor of net benefit obtained by the company in the interaction. The more technical roles performed by the company the higher the marginal benefit. The same study indicates that there seems to be no magic combination of particular activities constituting a clear cut

Table 3. Company satisfaction and basic research activity

Company Satisfaction	Strongly Disagree	Disagree	Agree	Strongly Agree
Basic (n=201)	0.70%	6.30%	47.20%	45.80%
Basic Lab (n=205)	--	6.80%	54.20%	39.00%
Basic Company (n=205)	--	9.50%	42.90%	47.60%
Basic Both (n=205)	1.70%	5.00%	41.70%	51.70%

winning strategy.

Further elaboration of these results shows that, even though there is no particular combination of roles that constitutes a winning strategy, there is a contrast between the eight strategies earning $1,000,000 or more in the partnership and the fifteen that lost $500,000 or more. The eight "winners" are displayed in Table 4 not in order of earnings but according to the performance of basic research: first by neither partner, second by the company, third by both and finally by the laboratory alone. What can be observed here, besides the number of technical roles played by the company, is that the lab, generally, either performs basic research and nothing else (with two single role exceptions in cases 8 and 1) or it performs a few roles on the other segment of the spectrum, from precommercial applied R&D to testing but not basic research.

Contrasting the observation of Table 4 with the "loser' cases in Table 5, the distinction becomes stronger. Except for cases 5 and 6, the rest are either joint basic research projects with no other components or both lab and company share several technical roles. The combinations of roles played by the company do not complement those played by the lab. This indicates that one important consideration in designing a strategy for high payoff partnerships with the federal labs is that the company must be in command of most of the technical phases of product development while the lab is more narrowly focused to make a specific contribution to the project. More often than not, it will be performing basic research.

Conclusions

Industrial contributions to basic research deserve particular scrutiny during times of declining R&D investment. Generally, industry is not a primary provider of basic research. During the past decade, only about 10 to12 percent ofindustrial R&D performers expended any amount on basic research (Bozeman and Crow 1988; Bozeman and Crow forthcoming). Thus, the basic research profile of industry-federal laboratory partnerships is of particular significance because 71 percent of those partnerships performed basic research potentially useful for the company. In 39 percent of those projects, the company itself was active in the performance of basic research. One conclusion., then, about industry-federal laboratory partnerships is that they are more likely than most industrial R&D projects to involve basic research. But does the basic research contribute to more than cooperative good will?

Tracing the impacts of basic research is notoriously difficult. The impacts of basic research are not easily appropriated by individual companies, given the externalities involved, and the time streams through which impacts occur vary considerably across projects and companies (Sherwin and Isenson 1967; IIT 1968; Batelle 1973;

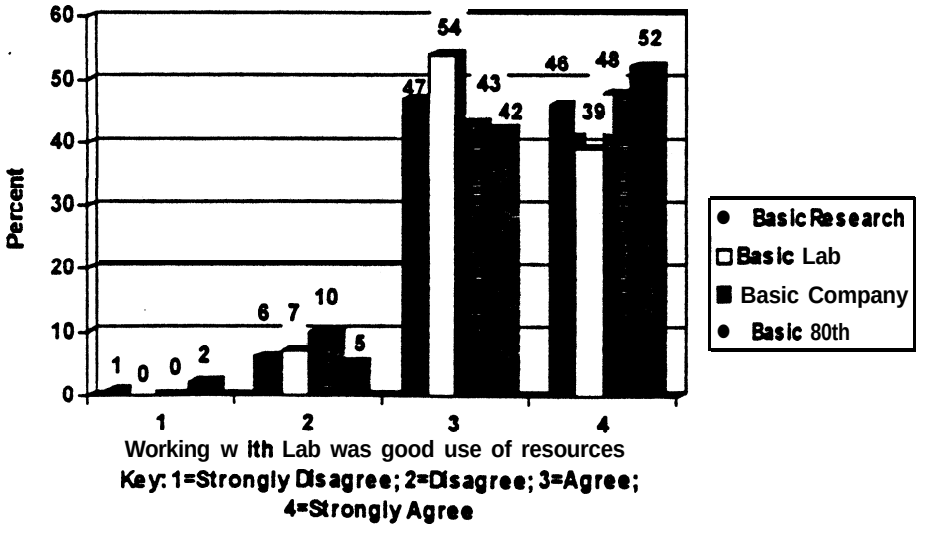

Figure 6. Companies' satisfaction by basic research performer

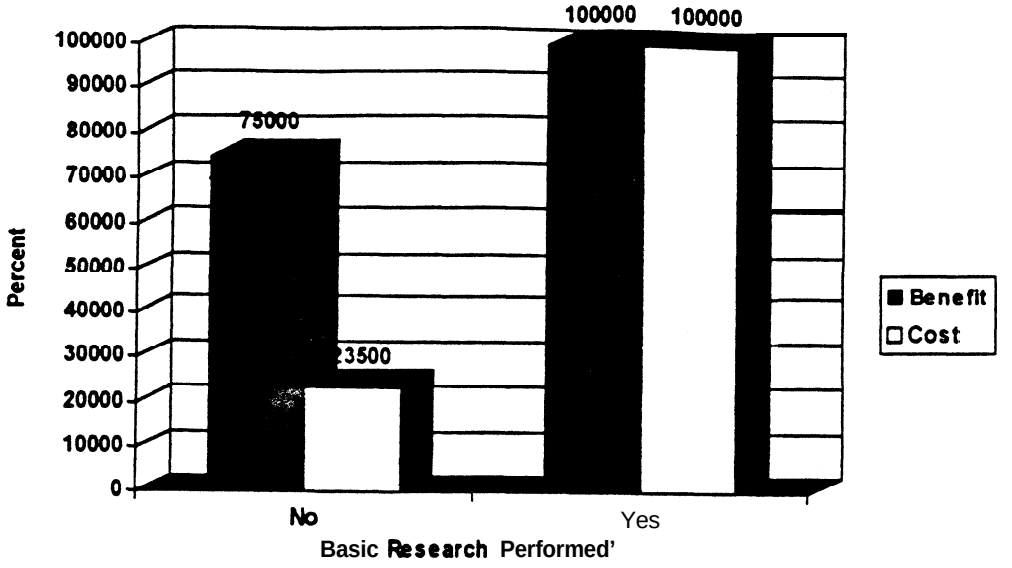

Figure 7. Median benefits and costs of interaction

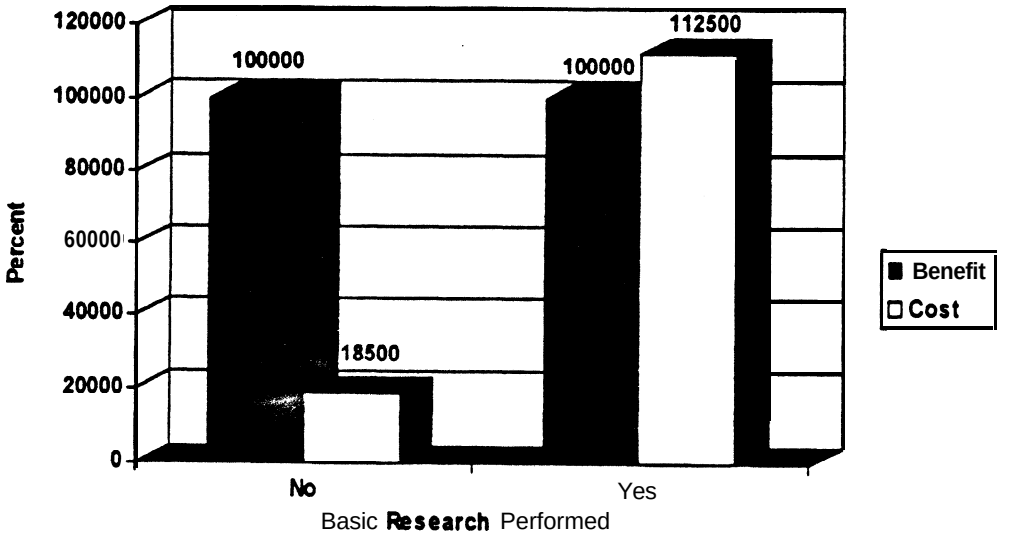

Figure 8. Median benefits and costs with an improved product

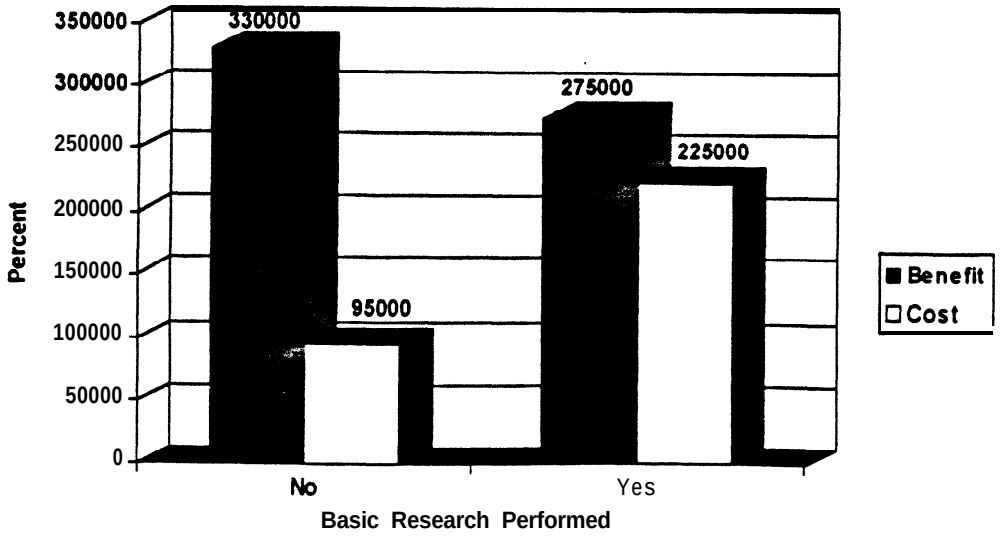

Figure 9. Median benefits and costs with a product under development

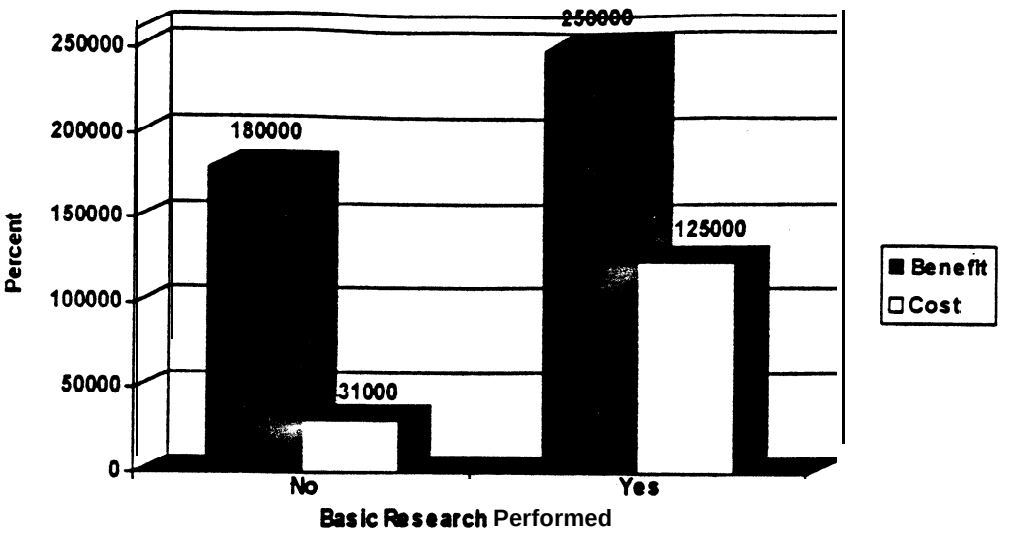

Figure 10. Median benefits and costs with a marketed product

Roessner et al. 1996). But if assessing the full range of benefits of basic research is a challenge well beyond our research, a partial, near-term assessment seems, from the evidence, quite manageable. The evidence is mixed. As most industry-federal laboratory partnerships, those involving basic research produce few job creation miracles. But the product development implications of basic research-related projects are well worth considering. The fact that 16.4 percent of the basic research projects led, in a brief time span, to marketed products seems to us a reasonable return, one that compares favorably to other industrial R&D product development rates (Mansfield 1980). Perhaps more important, however, is the fact that nearly 19 percent of the projects had products under development. When one takes into account the percentage of projects already yielding products and those in which product development is well underway, it somewhat dispels the notion that basic research is an overhead investment with no real prospect of short-term return.

The chief strategic issue arising from this study pertains to the appropriate technical roles for the respective partners in industry-federal laboratory basic research projects. Our results indicate that role specialization helps. Interestingly, those projects in which both the federal laboratory and the company provide basic research are less beneficial in terms of product development and marginal benefit. One cannot directly infer from the data just why this is the case. But several possible explanations seem plausible and worthy of further exploration. In the first place, joint basic research typically requires a higher level of cooperation and joint programming, resulting in increased coordination costs. Second, a lack of role segmentation seems to require a greater melding of organizational work habits and cultures. Since the companies and federal laboratories are likely to have quite different work cultures, with different incentives and rewards, closer cooperation on basic research may accentuate differences. Our findings suggest that while it isbeneficial for companies to contrib-

Table 4. Patterns of R&D for $1,000,000+ net benefit projects

Rank Net Benefit	Basic Fedlab	Precom Fedlab	Appl Fedlab	Dev Fedlab	Test Fedlab	Basic Comp	Precom Comp	Appl Comp	Dev Comp	Test Comp
2				X	X				X	X
6							X		X	
3		X	X	X		X	X	X	X	X
4			X	X		X	X	X	X	X
7	X					X	X	X		
8	X				X	X	X	X	X	
1	X			X			X		X	X
5	X						X	X	X	

Table 5. Patterns of R&D for **$500,000+** net loss projects

Rank Net Loss	Basic Fedlab	Precom Fedlab	Appl Fedlab	Dev Fedlab	Test Fedla b	Basic Comp	Precom Comp	Appl Comp	Dev Comp	Test Comp
1		X					X			
2		X	X		X		X	X	X	X
3	X					X				
4	X	X	X	X	X	X	X	X	X	X
5		X					X			
6					X		X		X	
7	X					X				
8	X	X				X	X			
9		X	X			X	X		X	
10						X				
11	X	X				X	X	X		
12	X	X	X			X	X	X	X	X
13	X	X	X			X	X	X	X	X
14	X	X		X	X	X			X	X
15	X					X				

ute several technical roles to collaborative projects, more successful projects entail a smaller, more focused set of technical roles for federal laboratories. This may indicate a different set of requirements for the appropriating and applying than the supplying of knowledge.

The findings provided here have some implications for possible approaches for accelerating the conversion of science to technology. A fundamental finding is that the choice, at the outset of a project, of complementary technical roles is likely to lead to a shortened technology path. This study has shown that some specific combinations of roles work better than others and the knowledge developed here may be applied as a first step in accelerating technology development.

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