The "Gradient Effect" in Federal Laboratory-Industry Technology Transfer Partnerships:
Which Collaborator Should Perform What R&D Role?

Pablo Saavedra
Georgia State University
and Georgia Tech

and

Barry Bozeman
Georgia Tech

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ABSTRACT

Based on data of 229 industry-federal laboratory projects, the chief objective of this research is to analyze combinations of technical roles and laboratory characteristics that have a positive effect on a measure of perceived "effectiveness" of the company. The findings show that a combination that follows a "gradient" where companies' roles, more product oriented, are just one or two steps ahead of laboratories', has a positive effect on that measure. The opposite happens when both partners undertake the same some role. Furthermore, the role combinations that are significant vary according to he company's objective.

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1. Introduction

In the United States, as elsewhere, public-private partnerships for technology transfer have grown steadily during the last fifteen years (Bozeman 2000). From the perspective of government policy for technology development and R&D, partnerships between companies and federal laboratories have been of particular interest. Federal laboratory-industry relationships are far from being simple to understand. Typically the partners have different research and technology management cultures, different technical and managerial strengths and weaknesses and, all too often, different and even conflicting motives for the technology partnership. One result is that, the evaluation of outcomes of these collaborations is inherently difficult.

Much of the research literature on federal laboratory-industry technical partnerships has focused on the “effectiveness” of technology transfer. Many purported determinants of effectiveness have been examined, including such factors as dollars invested in the partnerships, participation of top managers, geographic distribution of partners and medium of technology transfer (see Bozeman, 2000 for an overview). While the research on federal laboratory-industry technology transfer effectiveness is by this point extensive, few of the studies are truly comparable. Many different technology transfer effectiveness measures have been employed, in part because notions of effectiveness are quite varied among participants and in part because of the difficulties of measuring partners' returns as well as social returns. Some researchers have analyzed the number of patents as a chief outcome of these partnerships (Adams et al., 2002; Jaffe, Fogarty and Banks 1998). Others have focused on measuring the degree of commercial success (e.g. Kassicieh, S. K., H. R. Radosevich and J. Senker, 1996; Brown, 1997). However, as Ham and Mowery (1997) argue from their case studies, companies also obtain benefits that come rather indirectly from their partnerships with federal laboratories. In their case studies they found that companies benefit from enhanced technical capabilities even when there is no direct benefit to product development. Moreover, product development, patenting and commercial success depend on much more than technology transfer efforts, factors such as marketing skills and ability to manufacture products. Thus, it is extremely difficult separately to evaluate the impacts of technology transfer on commercial success and, of course, determining social impacts is even more daunting.

Our aims are more modest. Rather than focusing on the downstream impacts of technology transfer, we use a quantitative but perceptual measure of effectivness. While recognizing that myriad factors account for technology transfer effectiveness, even when effectiveness measures are stable, we focus primarily on the respective technical roles performed by the partners. Is there an optimal combination of technical roles? For example, is it better for the federal laboratory to perform basic research, while the industry partners perform applied research and technology development? Is it better for the partners to share technical roles or to specialize? In a related study, Bozeman and Wittmer (2001) found that increased technical range (i.e. more roles) performed on the part of the industry partner led to increased likelihood of product development. Few other studies have focused on technical roles.

Based on questionnaire data from 229 U.S. federal laboratories-industry joint projects, we focus on the perceived "cost-benefit" relationship from the point of view of the companies participating in the partnership. The research seeks to determine the relevance to effectiveness of the respective technical roles employed by both agents, companies and fed laboratories, including the *interaction* among roles. We feel that an understanding of the impact of technical roles on technology transfer effectiveness is particularly important because findings could be put to use by policy-makes and by companies seeking partnerships with federal laboratories. Many of the determinants of technology transfer effectiveness have limited strategic relevance. For example, if one finds that larger firms benefit more from federal laboratory technical partnerships, small firms cannot grow larger just to enhance their technology transfer effectiveness. But firms and federal laboratories have much more leverage on the technical roles they choose in their partnerships. In many instances it is a simply a matter of knowing which roles are most likely to provide benefit.

2. Conceptual Framework: A Strategic Perspective on Federal Laboratory-Industry Partnerships

Empirical evidence shows that most laboratory-industry partnerships are initiated not by the federal laboratories but by companies. Bozeman and Papadakis (1995) found that in 87% of projects were initiated either by companies' top management or by companies' research managers. Economic theory of the firm tells us that companies have strong motivations to seek information and make rational decisions about whether to engage in partnerships and, if so, with whom. Similarly, a strategic perspective tells us that firms are likely to give careful consideration to the role they play in the partnership and to finding a collaborative partner who can play a complementary role. Several studies (e.g. Eisenhardt and Schoonhoven, 1990; Pisano, 1991; Niosi and Bergeron, 1992; Niosi, 1995) indicate that companies typically understand the costs involved in technical partnerships, including opportunity costs.

A strategic perspective considers not just *whether* to engage in a partnership but also the allocation of technical tasks among partners (Roessner, 1993; Roessner and Bean, 1991). Often companies choice of technical partner is based on ideas or plans pertaining to technical task roles. Thus, for example, some companies come to specific laboratories because the labs have equipment that permits tests the company could not perform alone. Others hope to develop joint research. Still others plan to have the federal laboratory conducting basic research while the companies focused on development.

Decisions about technical roles are not made in isolation. Collaborative strategy is multi-faceted and includes, among other factors, issues pertaining to marketing (Piper, W. S. and S. Naghshpour 1996), R&D funding (Perchorowicz, Dakin, and Lindsey. 1991), intellectual property (Gillespie, 1988; Hertzfeld, Link and Vonortas, 2001), and alternative sources of scientific and technical information (Daghfous and White, 1994; Link and Zmud, 1987).

According to Ham and Mowery (1995: 72), "[e]xtended collaboration between labs and private firms will be needed to modify and apply most laboratory-developed technologies." This observation is counter to the "treasure chest" model (that federal labs have technology on the shelf ready for direct application to industry) and suggests that technology transfer effectiveness likely depends on viable technical strategy. Firms seem to know that federal laboratories' technologies are not immediately ready for the market and relatively few search for products that can be marketed with little or no modification (Bozeman and Papadakis, 1995). Further underscoring this point, Roessner (1993) found that firms' primary reason for interacting with federal laboratories is to develop “access to unique technical resources.” Similarly, a recent study of the National Science Foundation’s Engineering Research Centers (ERCs) concluded that “what firms appear to value in the ERCs is the availability of a flexible, multifaceted R&D supplier that permits them to buy into a capability to solve future problems” (Feller and Roessner, 1995: 83). In sum, business firms adopt various strategies and roles in generating and acquiring technical information and new technologies.

A few studies have specifically focused on the impact of technical roles and technical strategy on on innovation and commercialization of technology (Aram, Lynn, and Reddy, 1992; Gates, 1988, Roessner, 1984; Bozeman and Wittmer, 2001). These studies suggest that companies' choice of technical activity relates specifically thieir business strategies. Thus, companies competing on the basis of manufacturing quality may focus on process technology, whereas those focusing on innovation and first-to-market may have more interest in tracking the cutting edge of science and technology. These bases of competition have very different implications for companies’ choice of technology partners and for their respective technical roles.

Taking into account these assumptions, we present Figure One as a “conceptual model of technology partnering” for companies collaborating with federal laboratories. The model implies that the choice of technical partner (in this instance federal laboratories) depends upon the particularities of the company’s business strategy, the company’s choice of the technical role it wishes to perform, the role anticipated for the partner, and the availability of partners with particular configurations of technical resources and capacity. Like all models, this one is a simplification, not identifying the many types of technical activities possible (only the most familiar categories) and not focusing on the proactive role of federal laboratories in shaping the technical relationship. We feel this is an acceptable simplification because we are chiefly interested here in the companies’ technical choices, albeit constrained choices.

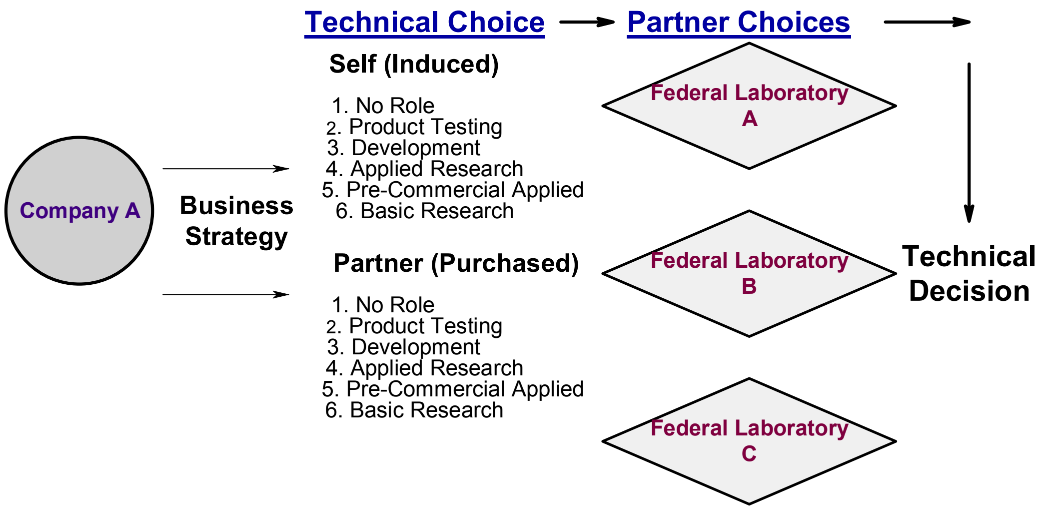

Figure One: Conceptual Model of Technical Partner Choice

3. Research Questions

Considering the model presented above, the implication is that companies seek to shape technical roles, both for themselves and their partners and, we hypothesize, some combinations of roles may prove more effective than others. . Using a cost benefit ratio as a measure of "perceived effectiveness" we consider the following research questions:

1. *Which interaction or combination of technical roles do companies and federal laboratories need to undertake in order to generate increased perceived effectiveness (a lower cost/benefit ratio) ?.*

2. If we take into account that companies pursuing partnerships with federal laboratories have different objectives or motivations, how do those interactions or combinations of technical roles affect their "perceived effectiveness" (cost / benefit ratio)?

3. Which federal laboratory characteristics or qualities have effects on the "perceived effectiveness?" More specifically, what are the effects on effectiveness of the following factors: laboratory personnel understanding of company's market place; skills and knowledge of laboratory scientists; and uniqueness expertise (personal or facilities of the laboratory)?.

Regarding technical roles, recent research using the same data set as we use in this study has examined the role of "basic research" and other technical roles in federal laboratories- industry partnership (Rogers and Bozeman, 1997; Bozeman and Wittmer, 2001). Rogers and Bozeman (1997). These studies found that often times basic research seems more suitable as a task for laboratories while companies should be more in command of more technical phases oriented to product development. Bozeman and Wittmer (2001) found that increased technical range or roles played by companies is positively associated with increased product development. A limitation of these studies is that they did not present simultaneous controls for potentially relevant variables, making difficult the task of clearly identifying significant relationships about specific patterns of interaction among technical roles. In the present study we address this limitation.

4. Hypotheses

The questionnaire used in this study and the ones cited immediately above e identifies five different technical roles, namely, basic research, pre-commercial applied research, commercial applied research, development and design product testing (exact wording and specifications are presented in Bozeman and Wittmer, 2001). In this context, a primary hypothesis is that there are sets of compatible technical roles assumed by the company and federal laboratory that help to enhance the perceived effectiveness discussed above. Our specific expectation, and the most important hypothesis for our study, is that, the most effective combinations of technical roles follow a gradient whereby companies' technical roles are just one step prior to the laboratories' role in the five phases or technical roles mentioned. That is, if company is performing "product testing", the federal laboratory should perform the role of "development and design". Similarly, if the if the company is performing the role of pre-commercial applied research, the federal laboratory should perform the role of "basic research".

The basis for the gradient hypothesis is a complementarity assumption. The argument is straightforward. If the company and the federal laboratory are performing exactly the same technical role (e.g. both primarily engaged in applied research) then there is less likelihood of comparative advantage and more likelihood of duplication and overlap. While duplication certainly is not always ineffective, it is more resource intensive and, by definition, less efficient. Since firms seek information within a range of cost, duplication generally is not preferred. At the same time, if the company technical role and the federal laboratory technical role are far removed from one another then there is a knowledge gap that is not filled, at least not in any obvious way.

Perhaps the best metaphor for the gradient hypothesis is a relay race in which two runners pass the baton. If the two are running the same stretch of the race there is an obvious problem, but if there is no one to pass the baton to at one leg of the race, there is also a problem. In short, there must be someone in place to move the baton (or the technical knowledge) to the next level.

One might well argue that the idea of a gradient effect assumes a linear model of technology. That observation is, strictly speaking, true. We do assume a set of stepwise technical roles. However, we are not assuming that the various technical roles must be performed in stepwise fashion, only that they must be performed at some point by someone. They may be performed in parallel, they me performed simultaneously, they may performed jointly- but the technical roles performed should be sufficiently close to one another, at any particular stage, to allow the communication and allow the movement of technical knowledge to the next level. We recognize that in today's world the time between basic research and commercialization often is compressed and the routes to technical products are may and varied. But we nonetheless suggest that technical roles that are "adjacent" may well work the best and, of course, that suggestion is falsifiable.

The following model is used to test our gradient hypothesis:

$$CBR_i = \beta_0 + \beta_1 Market + \beta_2 \ Technical\ roles\ interaction + \text{Control Variables} + \text{Ui}. \quad (1)$$

Additionally the same model but with a dependent variable that evaluates "overall experience" with the federal laboratory will be regressed to verify if the explanatory variables show the same pattern. The expectation is to have a similar pattern as the exposed in the first hypothesis.

$$labgood_i = \beta_0 + \beta_1 Market + \beta_2 \ Technical\ roles\ interaction + Control\ Variables + Ui. \quad (2)$$

Although it is the expectation that the technical roles performed by the company and the laboratory should be close to one another, there is a strong possibility of ineffectiveness when the company and the federal laboratory play the same technical role. (This is less likely to be problematical when there are multiple roles for both parties). Consequently, our second hypothesis is that interaction of the same technical roles between companies and federal laboratories will increase the cost/befit ratio. That is, it will reduce the perceived effectiveness for the company. In addition, it will be negatively correlated with a overall good experience of the company with the laboratory, tested through model (2). The rationale of this hypothesis is the overlapping of functions, which might decrease the opportunity of the company of learning from the laboratory. It might even create conflicts and ultimately the compatibility of laboratory and in-house might be absent under this interaction.

The third hypothesis is compatible with the first hypothesis is that these "gradient combinations" of technical roles work differently for companies with different objectives with resultant implications for perceived effectiveness. The questionnaire we employed depicts six different technical objectives, among which four seem to be the most important, at least in terms of response frequencies. These are: the objective to improve an existing product, process or service; the objective to pursue pre-commercial research in a company's strategic area; the objective to develop a new product; And finally the objective to gain access to information, expertise and facilities unique to the federal laboratory.

This set of goals show in a broad way that companies knowing their strengths and weaknesses have different expectations of the partnership. Bozeman, Papadakis and Coker (1995) argued that companies' objectives vary considerably when they look for a partnership and therefore there is no reason to believe that a determinate technical role's strategy will be equally effective for all. Consequently, we treat their expectations about cost and benefit, as one way to measure effectiveness, separately. The expectation is that having different objectives and even different stages of R&D, the explanatory variables in the model will vary from a set of companies with one objective to another.

The fourth hypothesis posed here is that "marketplace understanding" of the federal laboratory's personnel reduces the cost/benefit ratio of the companies regarding the partnerships. In other words, it is positive for the perceived effectiveness. Some of the background on this issue is provided by Mowery (1998). Based on case studies of cooperative research and development agreements (CRADAs), he argues that limited familiarity of laboratory's personnel about potential commercial users of the company's technology often times leads to more obstacles and less success in the collaboration.

Our fifth hypothesis asserts that the skills and knowledge of laboratory's scientists, and the unique expertise or facilities of the laboratory, enhance the perceived effectiveness of the companies' partnerships. Nevertheless, the positive effect of these variables is only significant depending on the objective originally pursued by the company in the partnership. Thus, skills and knowledge of laboratory's scientists will reduce the cost benefit ratio (improve effectiveness) of companies with the objective of improving an existing product, companies with the objective of pursuing pre-commercial research in a company's strategic area, and companies developing a new product. In the same way, unique expertise or facilities of the laboratory will reduce the cost benefit ratio of companies with the objective of gaining access to information, expertise and facilities unique to the federal laboratory.

The following models capture all the hypotheses proposed above except the first. Model (3) captures the cost benefit ratio of companies that pursued the objective of improving and existing product.

$cbrexist_i = \beta_0 + \beta_1 Market + \beta_2 Unique + \beta_3 skills + \ Technical\ roles\ interactions\ +$

Control Variables + Ui. (3)

Model (4) captures the cost benefit ratio of companies pursuing pre-commercial research in an area of its strategic interest:

$cbrstrategy_i = \beta_0 + \beta_1 Market + \beta_2 Unique + \beta_3 skills + \ Technical\ roles\ interactions\ +$

Control Variables + Ui. (4)

Model (5) captures the cost benefit ratio of companies pursuing the objective developing a new product.

$cbrnew_i = \beta_0 + \beta_1 Market + \beta_2 Unique + \beta_3 skills + $ *Technical roles interactions* + Control Variables + Ui. (4)

Model (6) captures the cost benefit ratio of companies pursuing the objective of gaining access to information, expertise or facilities unique to the federal laboratory.

3. Data and methods

This research is based on the data extracted from questionnaires sent to companies and organizations that had collaborative partnerships with Federal laboratories from the year 1989 to 1994 (Bozeman, Papadakis and Coker 1995). The data reflect 229 of these partnerships that includes a good portion, around 69%, of Cooperative Research and Development agreements (CRADAs). The rest of the partnerships are distributed in various groups that include R&D consortiums and other joint and cooperative R&D projects (1).

As commented in other studies based on the same survey (Rogers and Bozeman, 1997; Bozeman and Wittmer, 2001), the robustness of the data is not its best attribute. Nevertheless, it is apparently enough to show some robust relationships. The structure of the questionnaire generates many dichotomous and ordinal level variables. This is not the case of the dependent variables chosen for this study. The cost benefit ratio used divides the cost in dollar term for the partnership in dollar terms for the company over its perceived benefits.

The question about "cost" in the questionnaire says " Regardless of the amount of benefit received by your company from this project, approximately how much did this project cost your company in dollar term". The question about "benefit" in the questionnaire says "Considering all the possible benefits (e.g: training of personal; developing products or manufactured processes; receiving technical assistance) but not the costs, what is your estimate of the dollar value (if any) of your company's interaction with the lab on this project. As we can observe, both variables in the ratio involve a broader concept of perceived beneficial effects and ultimately "effectiveness". Bozeman and Wittmer (2001) used both measures to find the "net benefit", in terms of benefits minus the costs. The present research uses the ratio between both (cost/benefit) with the objective to normalize the data regarding the size of the projects, which varies sharply in the sample.

Model (1) uses the simple cost/benefit ratio as dependent variable for all observations. Model (2) uses a variable of perceived "overall experience" with the same set of explanatory variables of model (1) as a reinforcement to find out if the explanatory variables show the same pattern. Models (3), (4), (5) and (6) use as dependent variables the cost/benefit ratio multiplied by the variable of objective. Thus, each model only captures relationships by the particular objective that companies had when they joined the partnership. Since this study tries to analyze compatibility and interaction of technical roles. The model contains explanatory variables that are interaction terms of these roles. All five models were regressed using Ordinary Least Squares. The choice of this method is due not only to the characteristic of the dependent variables and the models *per se* used but as way to keep the regression analysis as simple as possible due the situation of the robustness of the data mentioned above. All models were tested changing control variables and other specifications. The coefficients were also tested for heterokedasticity.

All models have control variables to account for certain characteristics of firm. These control variables mainly control for size of the company and the ownership.

4. Findings

Technical roles interaction

Looking for the interactions that affect the cost/benefit ratio for the whole sample. That is, under the specification of model(1), the results show three interactions of technical roles between companies and federal laboratories that appear be statistically significant. First, the interaction between pre-commercial applied research undertaken by the company and basic research undertaken by the laboratory has a negative correlation with the cost/benfit ratio. This means that this combination of roles enhances the perceived "effectiveness" of the partnership for the company (see Appendix figure 1).

The same situation occurs for the interaction of the roles of development and design undertaken by the company and pre-commercial research by the laboratory. However, this last interaction was only significant at the 10% confidence level. These results are interesting not only because they seem to hold robust changing different control variables but also because the hypothesized "gradient" in the interaction of technical roles is observed. That is, laboratories performing roles one phase or two behind the company's, being the role of the laboratory towards the direction of basic research.

The third interaction of technical roles that appears to be significant is where companies have the role of development and design and laboratories the role of basic research. This interaction was positively correlated with the cost benefit/ratio, which means that the interaction decreases the perceived effectiveness. This could be explained by the argument of the roles being "too far" from each other discussed in section 2. That is, the role performed by the laboratory should be in a lower phase of the company's but not so far where it can not understand company's needs in terms of the specific stage of the research that is taking place.

Model (2) that involves an overall good experience of the company with the laboratory as dependent variable, confirmed with statistic significance one of the findings for model (1). The interaction between pre-commercial applied research undertaken by the company and basic research undertaken by the laboratory has a positive correlation with that overall good experience

There was yet another technical role interaction that appeared to be statistically significant in both models (1) and (2). However, the variable did not hold robust when alternating different controls. In any case, this interaction is the when the company has the role of product testing and the laboratory has the role of development and design. Again, this combination of roles holds the hypothesized "gradient", being both roles next to each other in the phases of technical activities.

Technical roles interaction geared towards companies' objectives

The interaction of technical roles that take into account the different objectives of the companies for the partnership also generated interesting results. Model (3), which considers the cost/benefit ratio only for companies that had the objective to improve an existing product showed one interaction that is statistically significant. When both companies and laboratories perform basic research as technical role there is a positive correlation with the cost/benefit ratio. This means that the perceived effectiveness measured with this ratio is negatively affected from the point of view of the company.

This support the second hypothesis presented that both partners with the same technical role in would harm the effectiveness of the partnership.

A somewhat similar result is brought by model (5), which considers the cost/benefit ratio only for companies that had the objective to develop a new product. Here, the interaction of both companies and laboratories with the role of pre-commercial research showed a statistically significant positive correlation with the cost/benefit ratio. In other words, the ratio grows with the affect of this variable, harming the perceived effectiveness of the partnership from the point of view of the companies. The same model (5) shows a negative correlation with the cost/benefit ratio of the variable that represents the interaction of the company in the role of product testing and the laboratory in the role of development and design. This was significant only at the 10% confidence level. In any case reinforces the same result obtained in model (2) discussed above.

Model (4), that considers the cost/benefit ratio only for companies that had the objective of pursuing pre-commercial research in a company's strategic area showed one interaction statistically significant. The interaction between pre-commercial applied research undertaken by the company and basic research undertaken by the laboratory has a negative correlation with the cost/benfit ratio. This also reinforces the result obtained in model (1). Apparently, this particular interaction enhances the companies' perceived effectiveness at this phase of the technical activities.

Finally, model (6) that captures the effects only for companies that had the objective to gain access to information, expertise and facilities unique to the federal laboratory show that none of the interactions has a significant effect on the cost/benefit ratio. It appear that when companies are not interested in a the creation or production of any particular product, the interaction of technical roles of the partners does not matter. However, interestingly enough a role of basic research undertaken by the laboratory enhances its perceived effectiveness (reduces de cost/benefit ratio). Maybe the explanation is in the fact that companies are most commonly weak in basic research and when their only interest is to gather some knowledge, the role of basic research for the laboratory seems appealing to them.

Market place understanding

The regression on model (1) showed that that the variable that measures market understanding of federal laboratory's personnel is statistically significant. It also showed the expected negative effect on the cost/benefit ratio, meaning that knowledge of the company's market in the federal laboratory increases company's perceived effectiveness. This result is in line with the study of Ham and Mowery (1998) that suggests that interactions between the laboratory staff and customers of the firms are as important as the interactions with the firm's research staff.

When regressed in model (2), with the alternative dependent variable that expresses overall good experience of the company with the laboratory, the market understanding variable showed again statistic significance. Apparently, this characteristic or quality of the researchers and laboratory staff enhances not only enhances perceived effectives but the overall experience of a company working such partnership.

Market understanding was statistically significant for the specific cost/benefit of companies pursuing pre-commercial research in an area of its strategic interest. This implies that even in early stages of product development this attribute of federal laboratories is important. The variable also showed significance for the specific cost/benefit of companies that pursued the objective of improving an existing product. This result was probably more expected. A company with a product in a stage that close to the marketing phase requires researchers in the laboratory that fully understand what is the product, its customers and the effect of redesign on those customers. However, here the variable was only statistically significant at the 10% confidence level. The variable was not statistically significant in the remaining two models. These last two models attempt to show the relationships that affect the cost benefit/ ratio of companies whose objectives were either developing a new product or gaining access to information, expertise and facilities unique to the federal laboratory.

Characteristics or qualities of the Federal Laboratory.

Regarding companies with the objective of improving an existing product, the regression showed that the skills and knowledge of laboratory's scientists evidently reduces the cost benefit/ratio of the company. In other words improves its perceived effectiveness. However, for companies with the objective of pursuing pre-commercial research in a company's strategic area, these special "skills" did not show statistical significance. The same happen with companies with the objective of developing a new product. Contrary to the expectation, the unique expertise or facilities of the laboratory seemed not to have any effect on reducing the cost/benefit ratio for companies gaining access to information, expertise and facilities unique to the federal laboratory.

5. Conclusion

Our search for "winning strategies" or "magic" combinations (Bozeman and Rogers, 1997) met with at least some modest success. Apparently, some combinations enhance the self-perceived effectiveness of the partnership from the point of view of the companies. Where companies and federal laboratory technical roles are just one or two steps away from each other, in a sort of gradient, a positive effect is measured.

When both partners perform the same role the opposite results were observed, that is, a negative effect in terms of the cost/benefit ratio. These findings complement Bozeman and colleagues' (1997 and 2001), despite that fact that in this study we use a different methodology and different dependent variables. Further we observed evidence that these interaction roles act differently with different company's objectives. This result is new in the literature although Bozeman and colleagues (1995) speculated about this possibility. Overall, different technical objectives seem to call for different strategies of interaction.

We also learned from the regressions performed in the models that some particular qualities of the laboratory are especially important for the company. The company's knowledge market place proved essential to enhanced effectiveness. This finding is consistent with evidence from case study-based research (Ham and Mowery, 1998; Mowery, 1998).

It seems that this is just the beginning of a puzzle that needs further work for its solution. Our research provides some evidence that interaction of technical roles is important, but further research needs to be performed on different sorts of partnerships and using different measures of technical success. There may, indeed, be optimal combinations of technical roles, but it seems likely optimality effects extend much beyond particular types of technical interactions or particular ideas about effectiveness. Indeed, there is some evidence that technical effectiveness constructs are not only distinctive, but success on one may lead to failure on the other (viz. Bozeman and Wittmer's [2001] findings about rates of commercialization vs. indicators of partner satisfaction).

Perhaps the most positive implication of our results is that policy and strategy matter. Choice of technical roles is often within the control of managers and, thus, the more we learn about technical role interactions and their impacts on various measures of technical effectiveness, the stronger the likelihood of improving technical partnerships.

Notes.

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References:

Adams, James D; Chiang, Erick P.; and Jensen, Jeffrey L. "The influence of Federal Laboratory R&D on Industrial Research". *Review of Economics and Statistics*. September 2002.

B. Bozeman and D. Wittmer. "Technical Roles and Success of US Federal Laboratory-Industry Partnerships." *Science and Public Policy*, 28, 4, June 2001, pp. 169-178.

Bozeman, Barry. "Technology Transfer and Public Policy: A reveiew of research and theory". *Research Policy*, 20 (2000) 627-655.

Bozeman, B. and M. Papadakis, "Company Interactions with Federal Laboratories: What They Do and Why They Do It," Journal of Technology Transfer, 20, 3-4 (December, 1995), 64-74.

Bozeman, Barry; Papadakis, Maria; and Coker, Karen (1995). "Industry Perspectives On Commercial Interactions With Federal R&D Laboratories: Does The Cooperative Technology Paradigm Really Work?"; National Science Foundation, Research on Science and Technology Program.

Brown M. A. 1997. "Performance metrics for a technology commercialization program." International Journal of Technology Management, 13(3): 229-244.

Carr, Robert K. "Measurement and Evaluation of Federal Technology Transfer". *Procedings* from the 20th Annual Meeting of the Technology Transfer Society. Washington Dc, July 1995.

Daghfous, A. and G.R. White, "Information And Innovation: A Comprehensive Representation," Research Policy, Vol. 23, No. 3, (May 1994), pp 267-293.

Eisenhardt, K., Schoonhoven, C., 1990. Organizational growth: linking founding team, strategy, environment, and growth among US semiconductor ventures, 1978–1988. Administrative Science Quarterly 35, 504–529.

Gillespie, George C. 1988. "Federal Laboratories: Economic Development and Intellectual Property Constraints." Journal of Technology Transfer, 13 (1): 20-26.

Ham, Rose M and Mowery, David C. " Improving the effectiveness of public-private R&D collaboration: Case studies at the US Weapons laboratory". *Research Policy*, 26 (1998) 661-675.

Hertzfeld, Henry R., Albert N. Link, and Nicholas S. Vonortas, 2001. *Intellectual Property Protection Mechanisms and Research Partnerships*, Paper Presented at the Workshop on Intellectual Property Protection Mechanisms in Research Partnerships, Center for International Science and Technology Policy, George Washington University, Washington, D.C., October 2001

Jaffe A. B., M. S. Fogarty and B. A. Banks 1998. "Evidence from patents and patent citations on the impact of NASA and other federal labs on commercial innovation." *Journal of Industrial Economics*, 46(2): 183-205.

Kassicieh, S. K., H. R. Radosevich and J. Senker 1996. "From Lab To Market--Commercialization Of Public-Sector Technology" *Research Policy*, 25(3): 482-484.

Link, A. and B. Zmud, "Additional Evidence on the R&D/Marketing Interface," *IEEE Transactions on Engineering Management*, (February 1986).

Link, A. and B. Zmud 1987. "External Sources of Technical Knowledge." Economic Letters, July.

Mowery, David. "Collaborative R&D: How effective is its?". *Issues in Science and Technology*. Fall 1998

Niosi, J., 1995. *Flexible Innovation*. McGill-Queen's University Press, Montreal.

Niosi, J. and M. Bergeron, "Technical Alliances in the Canadian Electronics Industry: An Empirical Analysis," *Technovation*, 12, 5, (July 1992), p. 309.

Perchorowicz, J. T., K. J. Dakin, & J. Lindsey. 1991. "Technology Transfer - Financing and Commercializing the High Tech Product or Service from Research to Roll Out." *Journal of Technology Transfer*, 16 (3): 62.

Piper, W. S. and S. Naghshpour 1996. "Government technology transfer: The effective use of both push and pull marketing strategies." *International Journal of Technology Management*, 12(1): 85-94.

Pisano, G., 1991. The governance of innovation: vertical integration and collaborative agreements in the biotechnology industry. *Research* Policy 20, 237–249.

Roessner, J.D., (1993) "What Companies Want From the Federal Lab," Issues in Science and Technology, V10, 1, 37-42.

Roessner, J. D. and A. Bean, (1991) "How Industry Interacts with Federal Laboratories," Research Technology Management, 34, 4, (July/Aug. 1991), p. 22.

Rogers, Juan and Bozeman Barry. "Basic Research and the Success of Federal Lab-industry Partnerships". *Journal of Tchnology Transfer*. Vol.22 (3):37-48. 1997.

Appendix 1: Variables codes and names

Variable Code	Variables names
CBR	Cost benefit ratio (Costs and benefits derived from the partnership with the federal laboratory in dollar terms)
labgood	Indicates if on balance working with the federal laboratory proved to be a good use for the company.
cbrexist	Cost benefit ratio of companies that had the objective of improving an existing product, process or service, when entered into the partnership with the federal laboratory.
cbrstrategy	Cost benefit ratio of companies that had the objective of pursuing pre-commercial research in an area of strategic interest for them, when entered in the partnership with the federal laboratory.
Cbrnew	Cost benefit ratio of companies that had the objective of developing a new product, process or service, when entered into the partnership with the federal laboratory.
Market	Good marketplace understanding of federal laboratory personnel.
Private	Ownership of the company- private.
rdemratio	Ratio of R&D employees to total number of employees in the company.
Sales	Amount in dollar terms of annual sales of the company.
Crada	Indicates if the company is a participant of Cooperative Research and Development Agreement Program (CRADA)
Noprev	Indicates none previous experience of the company with the specific federal laboratory in partnership.
Lbenchi	Indicates if federal laboratory's bench level scientists and engineers played a significant role as initiators and participant in the interaction.
Bcbl	Interaction term of technical roles performed during the partnership: basic research role performed by the company and basic research role performed by the federal laboratory.
Pcpl	Interaction term of technical roles performed during the partnership: pre-commercial applied research role performed by the company and pre-commercial applied research role performed by the federal laboratory.
Acal	Interaction term of technical roles performed during the partnership: applied commercial research role performed by the company and applied commercial research role performed by the federal laboratory.
dcdl	Interaction term of technical roles performed during the partnership: development and design role performed by the company and

	development and design role performed by the federal laboratory.
Variable Code	**Variables names**
Tctl	Interaction term of technical roles performed during the partnership: product testing role performed by the company and product testing role performed by the federal laboratory.
Pcbl	Interaction term of technical roles performed during the partnership: pre-commercial applied research role performed by the company and basic research role performed by the federal laboratory.
Acbl	Interaction term of technical roles performed during the partnership: applied commercial research role performed by the company and basic research role performed by the federal laboratory.
Dcbl	Interaction term of technical roles performed during the partnership: development and design role performed by the company and basic research role performed by the federal laboratory.
Acpl	Interaction term of technical roles performed during the partnership: applied commercial research role performed by the company and pre-commercial applied research role performed by the federal laboratory.
Dcpl	Interaction term of technical roles performed during the partnership: development and design role performed by the company and pre-commercial applied research role performed by the federal laboratory.
Dcal	Interaction term of technical roles performed during the partnership: development and design role performed by the company and applied commercial research role performed by the federal laboratory.
Tcal	Interaction term of technical roles performed during the partnership: product testing role performed by the company and applied commercial research role performed by the federal laboratory.
Tcdl	Interaction term of technical roles performed during the partnership: product testing role performed by the company and development and design role performed by the federal laboratory.
Unique	Indicates that a reason for the company's decision to work with a specific federal laboratory was the laboratory's unique expertise or facilities.
Skills	Indicates that a reason for the company's decision to work with a specific federal laboratory was the laboratory's scientists and engineers' skills and knowledge.
Basicl	Laboratory performs a basic research role during the partnership.
precoml	Laboratory performs a pre-commercial applied research role during the partnership.

Appendix 2: Regressions Results

	Model(1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
market	-8.836659 (-3.25) ***	.4256281 (6.51) ***	-.4815488 (-1.77) +	-2.542931 (-2.03) **		
private	12.47245 (2.23) **	.2216821 1..37				
rdemratio	2727211 (0.49)	-.0068465 (-0.51)				
sales	-.3619923 (-0.21)	.0149071 (0.28)	-.3201357 (-2.01) **			
crada	6.928375 (1.60)	.2468145 (1.80) +				
noprev	2.663066 (0.60)	-.0008561 (-0.01)				
lbenchi	7.609606 (1.66)					
bcbl			1.23865 (2.40) **			
pcpl	6.495909 (1.13)	-.1843902 (-1.30)		6.252724 (1.20)	.9239176 (2.05) **	
acal	-2.129611 (-0.24)		.5929484 0.61			
dcdl	-14.38233 (-1.20)	-.0059664 (-0.03)				
tctl	-1.516758 (-0.28)	.0844789 (0.50)				
pcbl	-12.19163 (-2.09) **	.3612647 (2.56) **		| -6.118131 (-1.71) +	-.0518732 (-0.11)	
acbl	-8.27754 (-1.23)	-.1591451 (-0.83)				
dcbl	15.37413 (2.55) **	-.0059664 (-0.03)				
acpl	7.491801 (0.99)					
dcpl	-10.65097 (-1.76) +	.0836665 (0.41)				
dcal	21.86771 (1.51)					
tcal	-19.5137 (-1.35)		0.1353919 (0.15)	1.017673 (0.16)		
tcdl	.2246311 (0.02)	.3281778 (2.05) **			-.7744732 (-1.64) +	
unique					-.253641 (-0.55)	1.295655 (0.99)
skills			-1.007906 (-2.17) **		.6200354 (1.35)	.2013448 (0.15)
basicl						-2.635727 (-2.18) **
precoml						-2.015078 (-1.73) +

Number is parenthesis are t-test (t)

\+ Statistically significant at the 10% confidence level

** Statistically significant at the 5% confidence level

*** Statistically significant at the 1% confidence level