The Organization of Research Corporations and Researcher Ability[1]

by

Bruno Cassiman
Universitat Pompeu Fabra
Department of Economics and Business
Email: cassiman@upf.es

August 1998

Abstract

This paper analyzes the formation of Research Corporations as an alternative governance structure for performing R&D compared to pursuing in-house R&D projects. Research Corporations are private for-profit research centers that bring together several firms with similar research goals. In a Research Corporation formal authority over the choice of projects is jointly exercised by the top management of the member firms. A private for-profit organization cannot commit not to interfere with the project choice of the researchers. However, increasing the number of member firms of the Research Corporation reduces the incentive of member firms to meddle with the research projects of researchers because exercising formal authority over the choice of research projects is a public good. The Research Corporation thus offers researchers greater autonomy than a single firm pursuing an identical research program in its in-house R&D department. This attracts higher ability researchers to the Research Corporation compared to the internal R&D department. The paper uses the theoretical model to analyze the organization of the Microelectronics and Computer Technology Corporation (MCC). The facts of this case confirm the existence of a tension between control over the choice of research projects and the ability of researchers that the organization is able to attract or hold onto.

JEL: D23, L22, O32.
Keywords: Research and Development; Cooperation; Research Joint Ventures; Research Corporations; Monitoring; Ability; Organizational Design.

1. Introduction

The emergence of Research Corporations (RCs) or R&D Consortia as organizations where firms pool resources for research on projects which underlie their competitive position, is a recent phenomenon in the United States. RCs represent an alternative to internal R&D projects, technology licensing agreements, acquisitions and research joint ventures. With respect to their organizational design, RCs resemble research joint ventures. However, RCs usually have less focused goals than research joint ventures. Most of the RCs in the United States are actively involved in the generation of new ideas and they usually concentrate on more than one technical activity (Aldrich and Sasaki (1995), Sakakibara (1997)). Not surprisingly, then, there usually exists a strong relationship between Research Corporations and universities (Gibson, Kehoe and Lee (1994)). The difference between RCs and Industry/University Cooperative Research Centers (IUCRCs) lies in the fact that IUCRCs are typically initiated by the universities and get their initial funding from the federal government while most of the RCs are private initiatives where the member firms control the type of research conducted at the RC and contract with universities whenever desired (Evan and Olk (1990)).

The purpose of this paper is to explore why firms decide to form an RC instead of financing a similar research project internally. Several answers to this question have been proposed in the literature including the efficiencies of shared cost and risk, the pooling of scarce talent and capital, the desire for research synergy, setting standards, reducing duplication of effort, and accelerated technology development (Gibson and Rogers (1994), Ouchi and Bolton (1988), Peck (1986)). These traditional motivations for cooperation in R&D explain why firms would want to cooperate. However, they do not offer any insight as to how cooperation should be organized, i.e., whether cooperation should take the form of a RC or should be organized as a contractual agreement among independent firms. While the transaction cost literature does offer an explanation as to why a hierarchy might perform better than a contractual arrangement among independent firms, it does not provide a clear explanation as to why firms would prefer to form a RC—sharing authority with several partners—to performing the R&D project internally (see Kogut (1988), Hennart (1991), Parkhe (1993) and Robertson and Gatignon (1998)). In order for the RC to be the optimal governance structure, it needs to dominate both integration and a contractual arrangement. In the face of some contractual incompleteness related to the researcher's contract we find that RCs arise as the optimal governance structure.

The importance of attracting and retaining scarce research talent is often mentioned as an important reason for firms to cooperate in R&D, especially in the semiconductor industry. However, the role of researchers' ability and their influence over project choice, have never been directly related to the organizational form of R&D. This paper develops a model of RCs in which RCs must compete for high ability researchers with universities, research institutions and other firms within the industry. Universities are attractive to researchers because they typically allow researchers a great deal of autonomy in pursuing a research program. Private for-profit organizations often cannot offer the same degree of autonomy. Once a researcher has joined a private organization, it may be in the organization's best interest to channel the researcher's program in a specific direction in order to increase short-term profits. Anticipating such meddling by the management of the firms, researchers may opt for university employment rather than employment in the private organization. This creates the tradeoff for private organizations between control over research projects and attracting higher ability researchers. Economies of scale in R&D, i.e. a necessary critical mass of researchers, exacerbate this tradeoff and improves the performance of the RC because of these economies and the reduced competition for scarce resources by individual member firms.

In order to understand the nature of the problem, it is important to define the type of research RCs tend to perform. While R&D statistics often make the distinction between different types of research such as basic, applied and development research (Dosi (1988)), this distinction is rarely made explicit in the theoretical literature on research and development. What is important to note, is that different types of research projects, require different skills in terms of the researchers that perform the research. Research projects that could be classified as more basic research, require researchers with basic or academic research skills. For these research projects, the problem as well as the solutions are usually not well defined. The observable output of this research skill are for instance published articles in scholarly journals and the success of a basic research scientist is measured through peer acceptance rather than the utility created through social change or monetary rewards (Nason (1981), Powell and Smith (1996)). Reich (1985) defines the intermediate type of research that RCs tend to perform also as "Industrial R&D": "industrial laboratories set apart from production facilities, staffed by people trained in science and advanced engineering who work toward deeper understandings of corporate-related science and technology, and who are organized and administered to keep them somewhat insulated from immediate demands yet responsive to long-term company needs." We are especially interested in the organizational element of this type of research which requires researchers with basic research skills. Closer to development, the required skills of the researcher are development engineering skills (Bridenbaugh (1996)). The researchers on these projects need to find solutions to a known, usually more practical, but therefore not easier to solve problem. The observable output of these more applied projects are patent applications, new products and new processes and usually monetary rewards are tied to these. While at the development end, the firms compete with each other for qualified research personnel with development engineering skills, for the more basic research projects, the firms also compete with universities and research institutions for their researchers.

A key finding of this paper is that RCs will offer researchers greater autonomy than a single firm pursuing an identical research program. Given this, RCs will have an advantage over single firms in recruiting high ability researchers. The intuition for this result is that in a RC, exercising formal authority over the choice of research projects is a public good. The members of the RC free ride on each others' monitoring efforts. As a result top management of the RC ends up meddling less with the choices of research projects than would be the case in an in-house R&D department. Because it involves a sharing of formal authority among several principals, the organization of a RC effectively commits the organization to exert less control over project choice. The optimal loss of control over project choice which maximizes member firm benefits depends on the success probability of industrial R&D. The model predicts that the number of member firms of a RC is larger, the lower this success probability. This result is consistent with the fact that RCs are observed in some industries more than in others.

The theoretical model does not identify the boundaries of the organization. In this respect the model can also shed some light on issues relating to centralized R&D departments versus decentralized R&D efforts. Similar trade offs between control over the projects performed in the centralized R&D department and attracting high ability researchers exist. First, when the company headquarters reduces its authority over the research department and the different divisions of the firm jointly exercise formal authority over the research department, the model predicts that the maximum ability researcher that can be attracted to the research department decreases. Typically division management is better informed about which specific projects to perform and thus has a lower cost of information gathering and monitoring. Secondly, decentralizing R&D efforts completely increases the likelihood of intervention by management of the division because the free riding on information gathering between division managers is eliminated.

The model of RCs is applied to the specific case of the Microelectronics and Computer Technology Corporation (MCC), a well known RC devoted to research on computer technology and artificial intelligence. The model developed here sheds light on the organization of MCC as well as on the evolution of turnover of research personnel as a result of organizational changes. We find evidence in this case study that the flow of high quality researchers is directly related to the organizational design of an organization concerned with industrial research and development. The main findings are consistent with the existence of the trade off identified in the theoretical model between control over research projects and researcher ability.

This paper is related to the growing literature on endogenous organizational design where the firm commits to an organizational design either to influence some noncontractible decision by an agent or by the firm at a later point in time, or to change the renegotiation game which takes place after some investment decisions by the agent.

In Aghion and Tirole (1997), the paper most closely related to ours, the decision on the organizational design of the firm is whether formal authority to implement projects is allocated to the principal or to his agent. The optimal organizational design depends on the congruence between the principal's and the agent's objectives. Whenever congruence in objectives is high, the principal allocates formal decision rights to the agent in order to stimulate the agent's effort choice. There exists thus a general trade off between initiative by the agent and loss of control of the principal.

In Rotemberg and Saloner (1993) the choice of the CEO commits the firm to a certain leadership style, and as a result to an implementation policy for innovative projects. A more empathic leader cares about the employee's utility while an autocratic leader maximizes the profits of the firm. The shareholders prefer the former when the firm has the potential for exploiting numerous innovative ideas, and prefers the latter in the other case. In a similar analysis Rotemberg and Saloner (1994) show that under certain conditions a narrow focus of the firm might be preferable to a broad one. When considering which profit-enhancing innovation to implement, the firm selects the innovation that leaves the most rents to the firm after having paid incentive compensation to the innovative employee. With a broad business strategy it is more likely that implementing the innovation that leaves the most rents to the firm ex post does not provide the agent with the appropriate ex ante incentives to invest effort in finding profit-enhancing innovations. This could make the firm with a broad business strategy worse off compared to firms committing to a narrow business strategy.

In this paper the choice of organizational design, i.e. the number of principals and the amount of investment in infrastructure of the RC, commits the principals to a level of information gathering about R&D projects. This in turn determines the expected autonomy researchers will enjoy over the choice of research projects and as a result influences the ability of the researchers that can be attracted. The assumptions underlying this type of model, especially the noncontractibility of the level of autonomy researchers enjoy, of investment decisions of member firms, and of the final project value, have a natural interpretation in a research and development environment. As is the case with any monitoring effort, the decision to invest in gathering information about which research project to pursue, is hard to contract upon. Similarly, the exact nature of the outcome of a research project is ill-defined ex ante. The perceived benefits of these projects are typically rather intangible, such as researcher training, and increased awareness of R&D in general (Sakakibara (1997)). As a result the value of the research project is noncontractible ex ante (Aghion and Tirole (1997)).

The rest of the paper is organized as follows. In the next section we develop the basic theoretical model that focuses on the link between control over research projects and the ability of the researchers that can be attracted to the RC. Section 3 analyses the model and develops the key intuitions. In Section 4 the organization of MCC is described and the evolution of turnover of research personnel at MCC is explained as a result of the tension between control over research projects by the member firms at the RC and the ability of researchers within the organization. Section 5 concludes. Because of their simple nature, all proofs are relegated to the Appendix.

2. Model

This section develops the basic model for the organization of a RC interested in attracting high ability research personnel. The recruiting ground of the RC is common with the universities interested in high ability researchers. The main advantage of a RC over a university is the availability of funds and the latest technical equipment. The university is appealing to the researchers because of the guaranteed freedom in academic research. A private organization is unable to give its researchers such commitments.[2] The RC is considered as a commitment device that decreases the incentives of its member firms to interfere with the researcher's choice of research projects. As a result of this commitment the RC attracts higher ability researchers.

2.1 Notation and Timing

The idea for setting up a RC is launched by a leader and innovator in the field. This organizer determines the size, n, and the amount of the initial investment, F, of the RC by maximizing her share of profits from the RC where $n \in [1, \infty)$ and $F \in R^{+}$. The organizer invites n - 1 other firms to join the RC and they pay their share in the investment in infrastructure, $\frac{F}{n}$. Note that the principals in the RC are the top management of the n member firms. Next, the RC decides whether or not to offer a researcher with ability θ a research contract, where $\theta \in [0, \infty)$. The ability of the researcher implies his ability to perform academic type research and is assumed to be observable but not verifiable.[3] The researcher can either accept or reject the offer. Accepting the offer commits the researcher to the RC for the duration of the project. Rejection ends the game. If the researcher accepted the contract, he proposes a research project to work on. The member firms do not know the payoffs of any of the research projects ex ante but have the same preferences over project choices and individually invest in information gathering, K_i.[4] Their joint investment determines the probability that the board of directors of the RC actually knows which projects are the most profitable for the RC:

$$P(\sum_{i=1}^{n} K_i)$$

We assume that P(.) is increasing and concave with 0 ≤ P(.) ≤ 1, P(0) = 0 and P'(0) = ∞, P(∞) = 1, P'(∞) = 0. This ensures an interior solution with respect to the investment in information gathering. We also assume that the investment in monitoring is not contractible. The process of information gathering about which research projects would maximize the member firms' profits, is sufficiently complex that it cannot be specified completely in an initial contract between the member firms, which then could be observed by the researcher and other member firms. If the board of directors knows the payoff structure of the projects, they can overrule the proposal of the researcher, otherwise the researcher's suggestion as to which project to pick is accepted.[5] This set up is very similar to Aghion and Tirole (1997). The timing of the game tries to capture the fact that the management in the RC will meddle with the research project during the course of its development. This happens after the researcher accepted the contract of the RC. The researcher will be forward looking in anticipating this intervention by the board of directors. Finally, the project is selected and the payoffs are realized. The timing of the game is summarized in Figure 1.

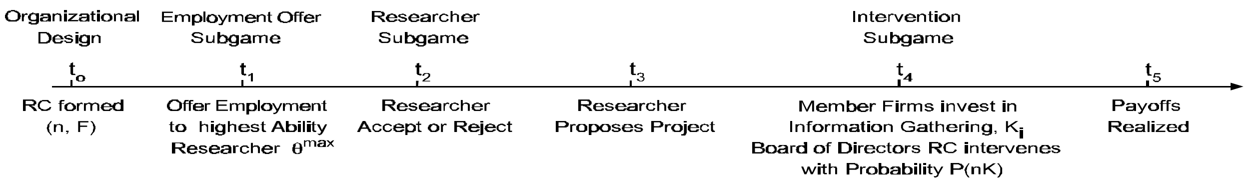

Figure 1: Timing of the Game

2.2 Preferences and Profits

The benefits of the member firms increase with the ability of the researcher that is attracted to the RC but depend on whether or not the board of directors chooses the project. The preferred project of the member firms has an expected gross benefit of $G(\theta)$, where $G(.)$ is increasing, concave and bounded in θ, and $G(0) = 0$ and $G'(0) = \infty$. This total value is equally divided between the member firms by allowing member firms to develop this technology in the specific areas of their expertise, or, the total value can be appropriated by the organizer of the RC by not inviting any other firms into the RC.[6] If the researcher is allowed to choose the R&D project, he will not necessarily choose the most preferred project of the member firms. The probability that the member firms' preferred project coincides with the researchers choice is α ($0 \leq \alpha < 1$). This "congruence" parameter is likely to be industry specific and is related to the distance of basic research to market. In some industries, basic research more readily leads to profitable products and processes.[7] We interpret this parameter α as the probability that academic type research eventually leads to a profitable business venture. If the board of directors follows the researcher's recommended project, the expected gross benefit of the RC is $\alpha G(\theta)$. It is important to distinguish the effects of α and θ. The parameter θ is related to the ability of the researcher to perform academic type research, while α indicates how likely this type of academic research translates into profitable business ventures. A brilliant mathematician will have a high θ. However, α, the probability that any project results in a profitable business venture is very low, whether you have a brilliant or not-so-brilliant mathematician. If, for some reason the mathematical research project turns out to be a profitable business opportunity, we assume that the expected value of the project by the brilliant mathematician, G(θ), is higher than the one for the not-so-brilliant researcher. The total expected payoff of the RC, gross of monitoring investment is:

$$RC(F,n,\theta,\sum_{i=1}^{n} K_i\ ;\alpha) = P\left(\sum_{i=1}^{n} K_i\right)G(\theta) + \left(1 - P\left(\sum_{i=1}^{n} K_i\right)\right)\alpha\, G(\theta) - F$$

The researcher cares both about his research autonomy, a, and his research funding and infrastructure, F.[8] The researcher's utility is represented by: U(a, F), where $a \in \{0, 1\}$, $U_a \geq 0$, $U_F \geq 0$, $U_{aa} \leq 0$, $U_{FF} \leq 0$.[9] If a = 1, the researcher has the freedom to choose the project to work on. If a = 0, the researcher is told which project to work on. We will make the following assumption about the utility function of researchers:

$$\text{(A1)} \quad \forall F, \hat{F} \in \Re_o^+ : U(1, F) > U(0, \hat{F}).$$

This assumption implies that the researcher values the ***choice*** of research projects and can never be fully compensated for the loss of this freedom through monetary or material rewards. For the results of the model to hold, however, it is sufficient that any incentive scheme provided to the researcher cannot perfectly align the incentives of the researcher with those of the board of directors. This assumption is consistent with the observation that scientists are less likely to have an incentive contract compared to engineers. One explanation is that basic research types might be less responsive to financial incentives compared to development engineering types.[10] Alternatively this could be the result of the type of compensation contracts that are feasible between the RC and the researcher.[11] We will assume that the researcher has an outside option. We can think of this outside option as getting a job at the university where nobody will ever overrule any project choices (a = 1). The utility of the researcher doing research at the university is: $U(1, F^U)$, where F^U is the funding and infrastructure provided to the researcher by the university. The expected utility of the researcher at the RC depends on the available funding and up to date equipment, F, and on the expected autonomy in the choice of research projects. The expected utility of a researcher of ability θ, working at the RC is:

$$U^{RC}(F,n,\theta,\sum_{i=1}^{n}K_i) = P\left(\sum_{i=1}^{n}K_i\right)U(0,F) + \left(1 - P\left(\sum_{i=1}^{n}K_i\right)\right)U(1,F)$$

3. Analysis

3.1 Information Gathering by Member firms

To derive a subgame perfect equilibrium, we solve the game by backwards induction. In the last stage the member firms have to determine how much to invest in information gathering. Given that the investment in information gathering by an individual member firm is not contractible, each member firm chooses K_i to maximize her share in the RC:

$$\underset{K_i \in [0,\infty)}{\text{Max}} \quad \frac{RC(F,n,\theta,\sum_{i=1}^{n}K_i;\alpha)}{n} - \beta K_i$$

The first order conditions determine the optimal investment level of each member firm, for all $\alpha < 1$. We assume that the member firms are identical and solve for the symmetric equilibrium. Define $K^* \equiv K(n, \theta; \alpha, \beta)$ as the optimal investment in information gathering. We summarize the comparative statics with respect to K^* in proposition 1 and proposition 2:

<u>Proposition 1:</u> 1.1 Member firms gather more information, the higher the ability of the researcher in the RC: $\frac{dK^*}{d\theta} > 0$.

1.2 Researchers are monitored less, the more congruent the objectives between the board of directors and researchers: $\frac{dK^*}{d\alpha} < 0.$

1.3 Member firms that have lower costs of information gathering, monitor the researcher more: $\frac{dK^*}{d\beta} < 0.$

Proposition 1.1 states that the higher the ability of the researcher, the more a member firm invests in monitoring the project choice of the researcher. Given that the researcher accepted the contract, it is in the member firms' best interest to monitor with higher probability and let a higher ability researcher work on the member firms' most preferred project. The marginal benefit of intervention by the board of directors ($(1-\alpha)G(\theta)$) is increasing in the ability of the researcher.[12] If the objectives of the researcher are more aligned with the member firms' objective, or if research is more readily commercialized in the industry, proposition 1.2 reveals that the member firms are less likely to monitor the researchers' project choice because the expected benefit from not interfering increases. In proposition 1.3 the member firms invest less in information gathering as the marginal cost of information gathering increases.

Proposition 2: An individual member firm invests less in information gathering and the RC as a whole invests less in information gathering, the more member firms there are in the RC:

2.1 $\frac{dK^*}{dn} < 0.$

2.2 $\frac{d(nK^*)}{dn} < 0.$

Proposition 2.1 characterizes the public good aspect of the investment in information gathering. The more member firms there are in the RC, the less each member firm spends on monitoring. The free rider effect of gathering information becomes more severe as the number of firms in the RC increases.[13] Proposition 2.2 formalizes this stronger result, namely that the total investment in information gathering by the RC decreases as the number of firms in the RC increases. The loss of control over the research projects increases as the number of member firms increases.

3.2 Researchers' Pool

A researcher of ability θ needs to decide whether or not to accept an offer by the RC. Note that rejecting the offer returns the researcher to his reservation value, $U(1, F^U)$. We assume that the ability of the researcher is observable by the RC. Qualified researchers are scarce resources and the firms performing R&D in these specific areas usually have a good idea of the people available in the market. The highest ability researcher that the RC can attract is

$$\theta^{max} \equiv \theta(n, F; \alpha, \beta, F^U) \text{ where: } U(1, F^U) = U^{RC}(F, n, \theta^{max}, nK^*) .$$

The pool of researchers from which the RC can hire is $\theta \in [0, \theta^{max}]$. Given that ability is observable, the RC only attracts the highest ability researchers within the pool of researchers. Given the assumptions, $\forall\ \alpha < 1$: $U^{RC}(F, n, \theta, nK^*)$ is strictly decreasing and convex in θ, while $U(1, F^U)$ is constant. For any amount of funding strictly greater than the funding at the university, F^U, there will exist a strictly positive maximum ability researcher that the RC can attract. Propositions 3 derives the comparative statics related to the highest ability researcher that can be attracted to the RC.

Proposition 3: 3.1 If researchers and member firms are more likely to agree on the projects, higher ability researchers are more likely to accept a contract of the RC:

$$\frac{d\theta^{max}}{d\alpha} > 0.$$

3.2 If information gathering by the member firms becomes more difficult, higher ability researchers are more likely to accept a contract of the RC:

$$\frac{d\theta^{max}}{d\beta} > 0.$$

In proposition 3.1, the more aligned the objectives of researchers and member firms, the higher the ability of researchers attracted to the RC. The effect of an increase in α is that the member firms gather less information (Proposition 1), which reduces the probability that the board of directors meddles with the project choice of the researchers. The expected benefit of the researcher in the RC increases and as a result higher ability researchers are willing to accept a contract offer. An empirical prediction consistent with proposition 3.1 is that the average ability of researchers in the biotechnology industry, relative to the ability within the profession, is higher than the relative average ability of researchers in the microelectronics business. This is because we expect that α is higher in biotechnology than in microelectronics since the distance between basic research and the commercial application of technology in biotech is lower (see also footnote 7).

The same intuition for the effect of an increase in α of Proposition 3.1 underlies the effect of more costly information gathering in Proposition 3.2. An empirical prediction consistent with this proposition is that whenever formal decision authority over research projects is transferred from the central headquarters to the divisions, the high ability researchers are less likely to renew their research contract with the organization. This is because divisions usually have better access to information required to make such decisions, which lowers the cost of information gathering. As a result, intervention in the choice of research projects by the division level managers is more likely. The recent decision of IBM to reduce corporate headquarters share in the R&D budget in the T.J. Watson Research center in Yorktown Heights from 50% to 0% while increasing the divisions share to compensate for the reduction in funds, is likely to result in turnover of top academic type researchers. Sweet (1993) reports that as a result of these reorganizations at IBM, several top researcher have already traded their research positions at IBM for faculty positions at Harvard, Purdue, Wisconsin, Tsukuba and Hong Kong, while several other researchers accepted post doctoral positions at other universities.

Empirically we can try to discriminate between the effects of a change in α and β through analyzing industry versus firm specific effects. A change in α should affect the whole industry. In that case, we should observe similar effects with respect to all the firms within the industry. Firm specific effects can be interpreted as changes in β. For example, turnover of research personnel could be the result of a change in α. In this case, we should observe similar effects at other firms and RCs within the industry. This would also be reflected in the average ability of researchers in the industry. Turnover as the result of a change in β, would only affect that specific firm. These researchers could move within the industry, rather then between the industry and the university.

The effects of the number of firms and the amount of funding on the highest ability researcher are readily established. Higher funding attracts higher ability researchers by directly increasing the researchers expected benefits in the RC. Increasing the number of member firms exacerbates the free rider problem in the RC with respect to information gathering. Researchers anticipate being monitored less (Proposition 2). As a result higher ability researchers can be attracted at the margin. We turn to the determination of the optimal number of member firms and the optimal amount of funding next.

3.3 Size and Funding of the Research Corporation

In the first stage the organizer of the Research Corporation must decide on the number of member firms and the amount of investment in infrastructure of the RC. The organizer maximizes her share of the profits of the RC. On the one hand, the organizer can increase the initial investment in infrastructure, F. This attracts higher ability researchers, because it shifts the expected utility of the researcher in the RC upwards. As a result, the expected value of the research project increases. On the other hand, the organizer can increase the number of firms she invites to join the RC. This also attracts better researchers and enlarges the pie. However, the larger pie must now be split over more member firms.

The organizer solves:

$$\underset{F \in [0,\infty)\, n \in [1,\infty)}{\text{MAX}} \quad \frac{RC(F,n,\theta^{\max},nK^*;\alpha)}{n} - \beta K^*$$

The RC always provides a funding premium above what universities offer ($F > F^U$). Without this premium no researchers would be attracted to the private organization. We define the subgame perfect equilibrium of the game as (F^*, n^*, θ^*, K^*), where $\theta^* \equiv \theta^{\max} \equiv \theta(F^*, n^*; \alpha, \beta, F^U)$ and $K^* \equiv K(n^*, \theta^*; \alpha, \beta)$.[14] As the congruence between the researcher and the member firms increases, member firms decrease their monitoring investments (Proposition 1). We conjecture that the organizer of the RC will decrease the number of firms in the RC which dilutes her share less while the RC can still attract the same or higher ability researchers. Proposition 4 is consistent with this conjecture:

<u>Proposition 4:</u> Suppose that second order conditions are satisfied. Then there exists $0 \leq \alpha^* < 1$, such that $\forall\ \alpha \geq \alpha^*$, the Research Corporation collapses into a research project with a single member firm.

High congruence of objectives between the researcher and the member firms results in single customer R&D compared to a RC with multiple member firms. Increasing the number of member firms dilutes the profit share of the organizer. Given that the organizer can attract researchers with "high enough" ability to perform the type of research proposed, individual firm profits can be increased by decreasing the number of member firms in the RC. As the distance between fundamental research and its commercial application increases (α decreases), the RC will have more member firms in order to create a suitable research environment with sufficient autonomy in project choice to attract high ability researchers to perform this type of research. The commitment effect of the organization of a RC crucially depends on the noncontractibility of the investments in information gathering.

The result of Proposition 4 is consistent with evidence from a cross-sectional analysis of industries. We expect that α is industry specific. Hence, Research Corporations in different industries, should have a different number of members on average. The fact that most of the Research Corporations registered under the National Cooperative Research Act are from the microelectronics and telecommunications sectors and only few from the biotechnology industry (see Gibson et al. (1994), Link (1996) and Vonortas (1997)), suggests that while α is close to one for biotechnology, it is expected to be lower for microelectronics. Pisano, Shan and Teece (1988) confirm this intuition and state that "the technical distance between a basic discovery and a commercial product is distinctively shorter in biotechnology then in other technologies ... Basic biomedical and biochemical research can generate know-how with a direct and identifiable commercial application." This would explain the fact that while in biotechnology research projects are performed internally or for a single customer, firms in the microelectronics industry engage more often in joint projects. This result is confirmed more generally for the Research Joint Ventures in manufacturing industries (SIC 20-39) that have registered under the National Cooperative Research Act where the incidence of Research Joint Ventures in an industry is significantly negatively correlated with the number of R&D active firms that perform basic research in that industry.[15] This result is consistent with our theoretical result given that we expect the proportion of R&D active firms that perform basic research to be highly correlated with our measure of α. Furthermore, with respect to the number of member firms, the simple correlation between the average number of member firms of RCs of an industry and the percentage of R&D active firms that perform basic research is also significantly negative. Although we admit that other factors are certainly important in the determination of the exact number of member firms of the RC, the consideration of autonomy for researchers does seem important in the decision of an individual firm whether to go it alone versus forming a RC with more partners.[16] The ability to attract scarce high ability researcher features prominently in this decision. More in depth empirical analysis on RCs will be necessary, however, in order to distinguish the effect of the appropriability conditions of an industry on the average number of member firms of a RC from our explanation. One would expect that α is correlated with the appropriability conditions of the industry.[17]

Proposition 4 is also consistent with anecdotal evidence on longitudinal observations of specific industries. We conjecture that α changes over the life cycle of the industry, more specifically with the life cycle of the technological paradigm on which search and innovation is based in that industry (Dosi (1988)). In the development and growth phases of the industry, α is high and close to one. During the maturation and decline phases, α decreases over time. The evolution of α over time is consistent with the recent trend where large corporations in the microelectronics and computer technology industry shift effort away from central R&D laboratories toward division-level effort with greater emphasis on risk minimization to meet the needs of today's customers (National Science Board (1992)). At the same time these corporations are shown to cooperate increasingly with competitors for more basic research projects. With respect to the Biotech industry Pisano, Shan and Teece (1988) note that "...the distinction between basic research and applied development will likely become sharper as the technological paradigm matures and applied development becomes more focused on incremental innovation." As a result, we would expect to observe more cooperative ventures over time as the Biotechnology industry matures (see also Rosenberg and Nelson (1996)). Sakakibara (1997) finds evidence that for Japanese RCs more tangible merits of the RCs are recognized by R&D managers in the projects whose target industry is "emerging". This implies that these industries have a higher α given that innovation is still relatively easy. An empirical prediction of our model would be then that on average these RCs have fewer member firms.[18]

An alternative strategy to attract high ability researchers, is creating a reputation for respecting the autonomy of the researchers with respect to project choice with high quality industrial research as a result. Xerox is an organization that has been able to maintain such a reputation. The key feature of their organization of industrial research is that the budget for the research department is a line item on the budget to be approved by the CEO only. The CEOs of Xerox have been able to resist the pressures from the divisions to reduce corporate R&D spending in favor of increasing the divisional budgets. IBM that had an excellent reputation in encouraging industrial R&D, on the other hand, did succumb to these pressures, as evidenced by the reorganization of their Yorktown Heights T.J. Watson Research Center. In maturing industries, these pressures become more intense. As α decreases, it becomes more costly for the organization to maintain this research reputation. In addition, the scope of the research projects necessary to generate new and valuable research paths, widens, which, in turn, increases the cost of maintaining this reputation. Large corporations could also attempt to organize a RC internally by sharing formal authority over the research department between a group of managers. The credibility of this commitment to share authority however is lower because it can easily be reversed since the authority to change the design of the organization still resides with the CEO of the corporation. In contrast, in the RC this authority over the organizational design is also shared between the member firms which enhances the credibility of this commitment through organizational design.

4. The Microelectronics and Computer Technology Corporation

In order to strengthen the empirical validity of the theoretical model outlined in the previous sections, we need to show two things in the case of MCC. First, we need to show that the trade offs between control over the research projects and researcher ability are real and important. Secondly, we need to show that organizing a RC dominates other organizational forms such as internal R&D projects and funding university research.

In 1982, under the leadership and vision of William C. Norris, the Microelectronics and Computer Technology Corporation (MCC) was founded in order to restore U.S. industrial competitiveness and beat back the Japanese competition in microelectronics and computer technology. MCC would focus its research on mid-term to long-term research projects which would take projects from basic research to advanced development:[19]

> "Innovation is the process of transferring knowledge into meaningful products. Universities don't do that except rarely when staff leave to form their own company. We need what the universities have [high ability researchers] — but inside [an organization like MCC] so it gets a market focus." (Goldman, vice president of research at Xerox in Gibson and Rogers (1994)).

The member firms were responsible for bringing these technologies to market strength products. Out of 19 possible MCC research programs, four thrust areas with the most member firm support were withheld: CAD/CAM, packaging, software and advanced computer architecture. Member firms of MCC would fund at least one of these programs and get access to the results of the programs they sponsored.[20] Membership in MCC quickly increased from the 10 founders in 1982 up to an average of 20 member firms.[21] Murphy (1991) finds that the main motivations mentioned by member firms for joining MCC were scale economies and access to limited resources such as researchers, and, the noncompetitive nature of the expected output of MCC.[22]

MCC's organizational structure was designed as a flat hierarchy. MCC is governed by a board of directors which is composed of one representative from each member firm and MCC's CEO who serves as the chairman. A technical advisory board serves as an outside review group for long-term, industrial research by giving advice to the board of directors and research program directors. Only three hierarchical levels exist within MCC: executive managers, program managers and the researchers. This keeps bureaucracy down to a minimum and creates a climate for rapid decision making. The program directors also received broad authority for expenditures on equipment or other support. Although the organizational structure of MCC has remained very much the same over the years, MCC has gone through three distinct organizational phases to come full circle in its 13 years of existence.[23] Each phase is associated with the CEO of MCC at that time. At its conception, the member firms gave the CEO of MCC the authority to restructure the internal organization of MCC.

In the first phase, the start up under CEO Admiral Inman, MCC was championed by top level executives of 10 U.S. firms. MCC was envisioned to become an important source of long term industrial R&D. The member firms took responsibility for the ultimate commercialization of these research results. MCC's original organizational structure and resource allocation focused on research excellence. Inman realized that the key asset of the RC would be the ability of the researchers attracted to the RC:

> "Early on it was recognized by Inman and the small group of advisors and colleagues he had assembled to help set up an administrative structure for MCC that the success or failure of the organization would depend on the quality of the personnel they would be able to attract. Without first-class brainpower no amount of shareholder funding would insure attainment of MCC's ambitious goals." (Murphy (1991)).

However, within the microelectronics and computer technology industry, congruence between researchers'and member firms' objectives is not likely to be very high. This implies that it is not likely that enough suitable candidates will be found in the industry or within the member firms for the type of research MCC was envisioning:

> "Candidates from the shareholder companies were nominated and interviewed. The process...did not uncover enough people of sufficient quality to staff all the program director positions. As this became recognized, a modest parallel effort was under way that began looking outside the shareholders for suitable candidates...." (George Black, first Vice President for Human Resources of MCC, quoted in Gibson and Rogers (1994)).

The considerable amount of autonomy of MCC researchers and the availability of research funds combined with a state-of-the-art research facility attracted high ability researchers from all over the world. Ninety percent of the offers made to researchers were accepted once the researchers visited the MCC headquarters in Austin. The high quality of research life also explains the low turnover rate (3% compared to 10% on average in a U.S. corporation) in the first five years of MCC's existence:

> "By the mid-1980's, the world's perception of MCC's on-site research talent was generally quite favorable... In 1986, 46 percent of MCC's scientists had doctorates and possessed an average of 15 years' research experience. The remaining researchers (54 percent) had an average of 12 years' research experience, and over half of them had master degrees. About 65 percent came from non-MCC companies. About 20 percent came from universities and government laboratories. The rest came from shareholder companies." (Gibson and Rogers (1994)).

The organization of a RC such as MCC, allowed the member firms to attract a group of scarce researchers of a higher ability than that any individual member firm could ever hope to attract within their internal R&D departments while giving them more of a market focus than they would have in an academic position.[24]

In 1987 the threat from the Japanese fifth generation computer project had subsided and at the same time budgetary pressures forced the companies to reevaluate their participation in MCC. Given the long-term nature of the research projects, the collaboration had not yet produced any tangible results over this period. CEO Inman did not renew his contract after his four year tenure and Grant Dove, a Texas Instruments' veteran, became the new CEO. In an effort to involve the member firms' divisions more directly with MCC's operation, authority for matters related to MCC was transferred to division level managers in the member firms, in the hope that they would value and use the research they were paying for. However, this shift in authority resulted in the division management pushing MCC to deliver more near term (1-3 years) research output. This organizational shift also accentuated the competition for R&D funds between MCC and in-house (division) research. The divisions expected MCC to deliver packaged technology. As a result, MCC researchers lost their funding and autonomy in choosing projects, exactly the reasons why they came to MCC. Turnover of research personnel increased from 3% under CEO Inman to 20% in the second phase under CEO Dove. The division level managers have a lower cost of monitoring the choice of research projects within MCC. This is because division managers usually have better information on which to base any choice of research projects that would fit into their division. Alternatively, less potential projects would fit within a specific division, which reduces the search costs for suitable research projects of the division manager compared to a CEO. The effect of these reduced monitoring costs (lower β) is derived in proposition 1 and 3. The propositions predict that the researchers at MCC are more likely to lose their autonomy in choosing projects because of these lower monitoring costs of the division managers.

Researchers are unhappy about this change and high ability researchers leave MCC, increasing turnover during this phase and reducing average researcher ability at MCC.

In 1990, the third CEO of MCC, Craig Fields, took office. He started evaluating every MCC program as a separate profit center in order to increase the researchers' sensitivity towards the pressures of the business world. The result, however, was an all time high turnover rate of 30% in 1990: [25]

> "I don't know anybody who is still at MCC right now because they really like it, believe in its goals and think they are going to be there in five years," said former researcher Elaine Rich, who left the consortium last year after eight years there. "That wasn't true five years ago. People were there nights and weekends doing their work. Morale is low because workers believe some research programs are in jeopardy and because they dislike many of the changes Fields made." (Austin American-Statesman, March 7, 1994).

A decrease in the congruence parameter α could be the cause of this increase in turnover. The distance between the (new) objectives of the member firms and CEO on the one hand, and the researcher on the other hand, increased. As a result turnover increases dramatically (Proposition 3). To restore motivation, researchers at MCC were encouraged to spin off their technology whenever the member firms were not interested in commercializing the technology themselves. Turnover of research personnel stabilized around 17% after this policy change of allowing spin-offs in 1990. However, turnover did not drop to the low percentages as under Inman.

In June 1994 Fields resigned from MCC. The new CEO, John McRary wants MCC to return to its original mission of basic research and technology, the industrial research, which member companies should develop into market strength products. In order to refocus MCC, McRary is selling off several technology development projects started under CEO Fields to interested parties. In effect, with its fourth CEO, MCC came full circle in its organizational design. The question remains however: how will researchers be guaranteed sufficient autonomy? Did funding decisions revert back to member firm headquarters instead of division managers? According to the model outlined in the previous sections, this is the critical step for an optimal organizational design which attracts the highest ability researchers possible.[26] The delicate trade off highlighted by our model and faced by MCC is illustrated by the following quote:

> “McRary must overcome deep problems — the loss of faith by member companies and the departure of key researchers. Reviving its members’ enthusiasm and financial backing while attracting more top-level researchers won’t be easy” said David Smith, a consultant and former manager at MCC. (Austin American-Statesman, June 26, 1995.)

What we learn from this story of organizational evolution at MCC is that the loss of control over research projects by the member firms in an R&D consortium is not necessarily bad since tighter control forces higher researcher turnover and lower average researcher ability. Frustration with this loss of control is readily documented throughout MCC’s history and in similar cases where firms cooperate in R&D. But the loss of control by member firms guarantees autonomy for researchers, which together with funding, are the most important elements in attracting high ability research personnel. These high ability researchers distinguish themselves from low quality researchers through the payoffs of research projects to the member firms. The expected payoff of a research project to the member firms increases with the ability of the researcher working on the project. The case of MCC clearly demonstrates that the trade off between control over the choice of research projects and the ability of the researchers attracted, is real and important. Setting up the RC commits the firms to less meddling with the choice of research projects compared to an internal R&D project. At the same time, being in a private organization compared to at a university stimulates a market focus of the project choices of the researchers.[27]

5. Conclusion

Since the enactment of the National Cooperative Research Act in 1984, Research Corporations have become a more familiar organizational form where firms pool their R&D resources in order to improve the technology that underlies their competitive position. In many industries the link between technology advancement and actual business success has weakened considerably when these industries mature. One firm cannot finance this advancement by itself anymore and at the same time higher quality researchers are necessary to create this technological advancement. The main argument of this paper states that the organization of Research Corporations allows firms to commit to interfere less with the research projects of their researchers compared to funding an identical project as an internal R&D project. The result of this commitment is the ability of the Research Corporation to attract higher ability research personnel compared to the internal R&D departments of the firms. The organization of the Microelectronics and Computer Technology Corporation (MCC) and the evolution of turnover at MCC is consistent with the existence of this trade off between control over research projects, and researcher ability, possibly resulting in superior performance of Research Corporations in industrial R&D.

An important next step in the analysis of Research Corporations is the relation between this organizational form and its performance. Support for this model, namely that the number of member firms matters, could be found along two lines of further research. First, one could use qualitative data on the perceived performance of research corporations by member firms. This data could be obtained through questionnaires as in Olk (1997) and related to the number of member firms in the Research Corporation carefully controlling for industry effects. A second approach is related to the finance literature. Yermack (1996) and Eisenberg et. al. (1998) have found a significant negative relation between board size and firm value in a large sample of US and Finish firms respectively. An interesting partial test of this model would be to check whether firms that are more innovative also show this negative relationship. The model would predict that a larger board of directors provides the CEO with more autonomy to chose the direction of the company. This might be more important for innovative companies, where choice of the (research) projects is of strategic importance, compared to less innovative companies, which are managed based on financial criteria. Related to Rotemberg and Saloner (1993), the choice of the CEO would be more important for these innovative companies relative to less innovative ones. The size of the board of directors would then determine how much of a commitment the choice of the CEO is for the firm. Small boards tightly control the CEO, while larger ones leave the CEO some more autonomy.

Appendix: Proofs of Propositions

Proof of Proposition 1

We know that the optimal investment by an individual member firm, i, is determined by:

$$\frac{P'\left(K_i + (n-1)K\right)(1-\alpha)G(\theta)}{n} = \beta$$

From the implicit function theorem we get:

$$\frac{dK^*}{d\theta} = -\frac{P'G'}{nP''G} > 0.$$

P is increasing and concave, G is increasing in θ.
Similarly:

$$\frac{dK^*}{d\alpha} = \frac{P'G}{nP''(1-\alpha)G} < 0.$$

and

$$\frac{dK^*}{d\beta} = \frac{1}{nP''(1-\alpha)G} < 0.$$

Proof of Proposition 2

As in Proposition 1, we find from the first order condition that:

$$\frac{dK^*}{dn} = -\frac{nP''K - P'}{nP''} < 0.$$

$$\frac{d(nK^*)}{dn} = \frac{P' - (n-1)P''K}{P''} < 0, \ \forall n \geq 1.$$

Proof of Proposition 3

$\theta^{max} \equiv \theta(F, n; \alpha, \beta)$ is implicitly defined by $U(1, F^U) = U^{RC}(F, n, \theta^{max}, nK^*)$

Using the implicit function theorem, we find that:

$$\frac{d\theta^{max}}{d\alpha} = -\frac{\frac{dK}{d\alpha}}{\frac{dK}{d\theta}} > 0.$$

Since from Proposition 1: $\frac{dK}{d\theta} > 0$ and $\frac{dK}{d\alpha} < 0$.

$$\frac{d\theta^{max}}{d\beta} = -\frac{\frac{dK}{d\beta}}{\frac{dK}{d\theta}} > 0.$$

Since from Proposition 1: $\frac{dK}{d\theta} > 0$ and $\frac{dK}{d\beta} < 0$.

Proof of Proposition 4

Let $\alpha = 1$.

The solution in this case is:

$$\lim_{\alpha \to 1} \theta^*(\alpha) = \infty$$
$$\lim_{\alpha \to 1} K^*(\alpha) = 0$$
$$\lim_{\alpha \to 1} F^*(\alpha) = F^U$$

The profits of the RC are $RC(F^U, n, \theta^*, K^*; \alpha) = \frac{\overline{G} - F^U}{n}$, where $\lim_{\theta \to \infty} G(\theta) = \overline{G}$.

Thus, at $\alpha = 1$, the optimal number of firms is $\lim_{\alpha \to 1} n^*(\alpha) = 1$. We are at the boundary of the feasible set $[1, \infty)$, where $dRC/dn < 0$. Given the continuity of the problem, in a neighborhood of $\alpha = 1$, increasing F has only a second order effect on the value of the objective function, while increasing the number of firms, n, has a first order effect. This implies that there exists an $\alpha^* < 1$, such that $\forall\ \alpha > \alpha^*$ the optimal number of member firms in the RC is one.

References

Aghion, P. and J. Tirole, 1997, “Formal and Real Authority in Organizations,” Journal of Political Economy, 105, p.1-29.

Aghion, P. and J. Tirole, 1994, “The Management of Innovation,” Quarterly Journal of Economics, November, CIX, p.1185-1210.

Aldrich, H. and T. Sasaki, 1995, “R&D Consortia in the United States and Japan,” Research Policy, 24, p.301-316.

Anderson, E., 1990, “Two Firms, One Frontier: On Assessing Joint Venture Performance,” Sloan Management Review, 19, Winter, p.19-30.

Bailyn, L., 1985, “Autonomy in the Industrial R&D Laboratory,” Human Resource Management, 24, p.129-146.

Bridenbaugh, P., 1996, “The Future of Industrial R&D, or Postcards from the Edge of the Abyss”, in Engines of Innovation: U.S. Industrial Research at the End of an Era, R. Rosenbloom and W. Spencer (eds). (Cambridge, MA: Harvard Business School Press).

Browning, L., Beyer, J. and J. Shetler, 1995, “Building Cooperation in a Competitive Industry: SEMATECH and the Semiconductor Industry,” Academy of Management Journal, 38, p.113-151.

Cassiman, B., 1996, “Cooperation in Research and Development,” unpublished PhD dissertation, Northwestern University.

Dosi, G., 1988, “Sources, Procedures, and Microeconomic Effects of Innovation,” Journal of Economic Literature, XXVI, p.1120-1171.

Eisenberg, Th., Sundgren, S. and M. Wells, 1998, “Larger Board Size and Decreasing Firm Value in Small Firms,” Journal of Financial Economics, 48, p.35-54.

Evan, W. and P. Olk, 1990, “R&D Consortia: A New U.S. Organizational Form,” Sloan Management Review, Spring, p.37-46.

Fischetti, M., 1986, “A Review of Progress at MCC,” IEEE Spectrum, March, p.76-82.

Gatignon, H. and E. Anderson, 1988, “The Multinational Corporation’s Degree of Control over Foreign Subsidiaries: An Empirical Test of a Transaction Cost Explanation,” Journal of Law, Economics and Organization, 4, p.305-336.

Gibson, D., Kehoe, C. and S-Y. Lee, 1994, “Collaboration Research as a Function of Proximity, Industry, and Company: A Case Study of an R&D Collaboration,” IEEE Transactions on Engineering Management, 41, 3, p.255-262.

Gibson, D. and E. Rogers, 1994, R&D Collaboration on Trial, (Cambridge, MA: Harvard Business School Press).

Hennart, J.F., 1991, "The Transaction Cost Theory of Joint Ventures: An Empirical Study of Japanese Subsidiaries in the United States," Management Science, 37, p.483-497.

Kogut, B., 1988, "Joint Ventures: Theoretical and Empirical Perspectives," Strategic Management Journal, 9, p.319-332.

Kogut, B., 1991, "Joint Ventures and the Option to Expand and Acquire," Management Science, 37, p.19-32.

Kornberg, A., 1995, The Golden Helix: Inside Biotech Ventures, (Sausalito, CA: University Science Books).

Levin, K., Klevorick, R., Nelson, R. and S. Winter, 1987, "Appropriating the Returns from Industrial Research and Development," Brookings Papers on Economic Activity, p.783-831.

Link, A., 1996, "Reseach Joint Ventures: Patterns from Federal Register Filings," Review of Industrial Organization, 11, p.617-628.

Link, A.N., Teece, D. and W. Finan, 1996, "Estimating the Benefits from Collaboration: The Case of Sematech," Review of Industrial Organization, 11, p.737-751.

Murphy, W., 1991, R&D Cooperation among Marketplace Competitors, (New York: Quorum Books).

Nason, H., 1981, "Distinction between Basic and Applied in Industrial Research," Research Management, May 1981, p.23-28.

Olk, P., 1997, "The Effects of Partner Differences on the Performance of R&D Consortia," in Cooperative Strategies: North American Perspectives, Beamish, P.W. and J.P. Killing, eds. (San Francisco: The New Lexington Press)

Ouchi, W. and M. Bolton, 1988, "The Logic of Joint Research and Development," California Management Review, Spring, p.9-33.

Parkhe, A., 1993, "Strategic Alliance Structuring: A Game Theoretic and Transaction Cost Examination of Interfirm Cooperation," Academy of Management Journal, 36, p.794-829.

Peck, M, 1986, "Joint R&D: The case of Microelectronics and Computer Technology Corporation," Research Policy, 15, 219-231.

Powell, W.W. and J.D. Smith, 1996, “Commercialism in Universities: Life Sciences Research and the Interface with Industry,” working paper University of Arizona, mimeo.

Reich, L., 1985, The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926, New York: Cambridge University Press.

Ritti, R., 1968, “Work Goals of Scientists and Engineers,” Industrial Relations, p.118.131.

Robertson, T. and H. Gatignon, 1998, “Technology Development Mode: A Transaction Cost Conceptualization,” Strategic Management Journal, 19, p.515-531.

Rosenberg, N. and R. Nelson, 1996, “The Roles of Universities in the Advance of Industrial Technology”, in Engines of Innovation: U.S. Industrial Research at the End of an Era, R. Rosenbloom and W. Spencer (eds). (Cambridge, MA: Harvard Business School Press).

Rotemberg, J. and G. Saloner, 1993, “Leadership Style and Incentives,” Management Science, November, 39, p.1299-1318.

Rotemberg, J. and G. Saloner, 1994, “Benefits of Narrow Business Strategies,” American Economic Review, December, 84, p.1330-1349.

Sakakibara, M., 1997, “Evaluating Government-Sponsored R&D Consortia in Japan: Who Benefits and How?,” Research Policy, 26, p.447-473.

Spencer, W. and P. Grindley, 1993, “SEMATECH after Five Years: High-Technology Consortia and U.S. Competitiveness,” California Management Review, Summer, p.9-32.

Sweet, W., 1991, “IBM Cuts Research in Physical Sciences at Yorktown Heights and Almaden,” Physics Today, 43, p.75-79.

Vonortas, N.S., 1997, “Research Joint Ventures in the US,” Research Policy, p.577-595.

Wallich, P., 1986, “U.S. Semiconductor Industry: Getting it Together,” IEEE Spectrum, p.75-78.

Yermack, D., 1996, “Higher Market Valuation of Companies with Small Board of Directors,” Journal of Financial Economics, 40, p.185-211.

Endnotes

[1] I would like to thank my advisors David Besanko and Pierre Regibeau, and Jim Dana, Ann Gron, Morton Kamien, Kathy Spier and Asher Wolinsky for the many useful comments and discussions. This paper is a revised version of Chapter 3 of my dissertation at the Department of Managerial Economics and Decision Sciences of the J.L. Kellogg Graduate School of Management, Northwestern University and received the “Young Economists Award 1996” of the European Association for Research in Industrial Economics. Financial Assistance of the National Fund for Scientific Research of Belgium, DGES PB96-0302 and CIRIT 1997SRG00138 is gratefully acknowledged.

[2] RCs will also compete with other firms in the industry for high ability researchers. In the model we restrict attention to competition between the RC and universities given that in the model it is always dominant for the researcher to accept a contract from an optimal RC compared to accepting a contract from an individual firm. In addition to receiving better funding, which also avoids the continuous hassle of grant applications, researchers in private organizations are free of teaching and administrative duties. A university position, in addition to autonomy to choose research projects, puts no restrictions on the dissemination of research findings.

[3] The model could easily be extended to include the case where ability is not observable. The qualitative results would be the same as the ones derived in this case. However, this would not reflect the stylized facts of for example the microelectronics industry where it is clear to everybody in the field who the top researchers in a certain area of expertise are.

[4] The member firms' interests are assumed to be perfectly aligned. In order for the results to hold more generally, it is sufficient that the objectives of the different member firms are more aligned than the objectives of any individual member firm and the researcher. This assumption seems reasonable, given that the firms are interested in the business opportunities of the research project, while the researchers care about the private benefits they derive from performing the research per se.

[5] This proposal reveals no useful information to the board of directors about which type of project should be performed. They are unable to evaluate this project without any investment in information gathering.

[6] The model does not analyze the motives of an individual firm for joining the RC. It is assumed that the RC creates some value which is independent of any ongoing activity within the industry. As such, the model abstracts from any competitive reasons for joining the RC as well as ex post competition in development. Sakakibara (1997) finds that her sample of Japanese RCs contains participants from a range of industries. The expected degree of ex post competition for these consortia in likely to be low.

[7] We would, for example, expect that α is higher in biotechnology compared to microelectronics. Shan, Walker and Kogut (1994) quote that "After their recent acquisition of a majority stake in Genentech, Hoffman-Laroche increased its membership on Genentech's board by only two seats, leaving the majority vote to scientists, managers and investors closer to the mores and practices of biotechnology." This is suggestive of a high α.

[8] It is possible to reinterpret the funding decision, F, as the wage of the researcher. Any feasible incentive scheme where the researcher shares in the benefit of the RC could be factored into F. As a result we can restrict attention to the choice of F. The question however is whether such an incentive scheme is feasible (see also footnote 11).

[9] Note that $U(a,F;\text{q}) \equiv U(a,F)$. We do not make any assumption on the effect of ability on how a researcher values autonomy and funding.

[10] Ritti (1968) views differences between scientists and engineers as matters of basic personality. Among engineers, 69% say it is very important to have the opportunity to help their company increase profits. Among research scientists, only 28% find this very important. In contrast, 88% of the scientists view publication in technical journals as very important (Rotemberg and Saloner (1993)). Powell and Smith (1996) note: “For scientists priority of discovery is the goal, and publication the means through which new knowledge is shared in a timely fashion. The public nature of scientific knowledge encourages its use by others, and in doing so, increases the reputation of the researcher. In contrast, patents are the coin of realm in the technologist’s world. Rewards are pecuniary and the incentives to divulge new information quickly are not as potent.” Arthur Kornberg, who won the Nobel Prize in medicine for his laboratory synthesis of DNA, mentiones in his account of the successful creation of the biotech venture DNAX that “Neither Alex (CEO DNAX), nor the scientists and founders had ambitions for sudden wealth, such as that created by the Genentech’s initial public offering…” The key to develop a first class research institute were (1) attract the best young scientists, (2) keep them by providing good facilities, full freedom to publish, exchange

ideas and to focus on problems in depth, and (3) insure property rights protection (Kornberg (1995)).

[11] Given that the RC performs a more basic type research for which it hires scientists, it might be impossible to write incentive contracts contingent on the benefits of the research projects. This might be due to the non-contractible nature of the outcomes given the higher level of uncertainty or because of the time lag between effort of the scientists and the outcome, so that it is hard to attribute the outcome itself to the scientists involved. In more applied research, usually performed by engineers, it is often more feasible to write this type of incentive contracts. In the model it might be possible to interpret the parameter α as a measure related to the contractability of the outcomes of research. If α is close to 1, meaning that the objectives of the member firms and the researcher are more aligned, contractability might at the same time be less of an issue. As a result the RC is less likely to occur as an optimal organizational design, which is consistent with our results. Link et. al. (1996) mention for the case of Sematech that it was clear to all the parties involved that the intangible benefits of Sematech, such as benefits from research management, research integration and spillovers, were more important than the tangible direct benefits flowing from the research results. See also Anderson (1990) on the difficulties of assessing the performance of joint ventures in general and the inability to apply typical financial criteria and Sakakibara (1997) for a related account on Japanese RCs.

[12] If the probability that academic research creates business opportunities increases in the academic ability of the researcher, $\alpha'(\theta)>0$, this result could be reversed. However, we do not

believe that brilliant academic researchers necessarily have a better business sense but the value of their projects, in case of a hit, G(θ), is assumed to be higher.

[13] If the objectives of the member firms diverge, each individual member firm might have a stronger incentive to get informed about what the best project for its purpose would be in order to influence the decision of the board of directors. However, given that there is more than one member firm and each member firm has equal weight, the board has to vote on any change in project choice. The fact that the opinion of one member firm is only weighted according to her voting power, reduces the incentive of the member firm to invest in monitoring compared to the case where this member firm would be the sole participant in the project. The organization of a RC thus creates the same loss of control over the choice of research projects where the objectives of the member firms are not perfectly aligned.

[14] We assume that second order conditions for the problem are satisfied so that there exists an optimal number of firms and an optimal amount of investment for the RC (see Cassiman (1996) for details).

[15] I would like to thank Albert Link for generously providing this updated data set on firms that registered under the National Cooperative research act. This data set is described in more detail in Link (1996). The number of firms performing R&D in an industry and the number of firms performing basic R&D in that industry were taken from the National Science Foundation Survey of Industrial Research and Development, 1996.

[16] Gatignon and Anderson (1988) find more generally that the key decision for multinationals' organizational entry mode for foreign subsidiaries is not the degree of control, but whether or not to share control with partners.

[17] Levin et. al. (1987) provide measures of appropriability at the industry level (see Table 2 p.797). On the one hand we find indeed that the percentage of R&D active firms performing basic research in the industry is positively correlated with their measure of appropriability. On the other hand other measures of appropriability (or rather lack of appropriability) such as the percentage of Research Joint Ventures that include a university or a government agency as a partner are positively correlated with the average number of member firms, but not correlated with the percentage of R&D active firms performing basic research in the industry.

[18] It is interesting to note that the perceived higher incidence of RC activity in Japan (Sakakibara (1997)) could be explained by the relative rigid labor market for researchers in Japan, in particular the university system that does not provide the necessary flexibility for researchers. Odagiri et. al. (1997) in their account of the fifth generation computer project (ICOT) in Japan mention that the RC attempted to recruit researchers from the universities but ran into serious obstacles caused by the Japanese university system. ICOT went so far as to find positions with the member firms of ICOT for newly recruited researchers who just finished their doctorates and were interested in pursuing further research at ICOT. The Japanese experience leads us to believe that in addition to the effects of autonomy created by the RC, economies of scale, i.e. a critical mass, can be realized by the RC. At the same time the RC reduces competition between individual firms for top researchers.

[19] MCC has a very similar organizational structure as SEMATECH, a second widely publicized joint research effort in microelectronics. The distinction between MCC and SEMATECH, however, is the type of researchers they want to attract. The goal of SEMATECH is to improve manufacturing practices, which requires more development

engineering skills, and as a result, another type of researcher. Hence, the critical difference between MCC and SEMATECH lies in their Human Resource Management. MCC hires most of its own researchers, while SEMATECH, in contrast, receives most of its researchers on assignment from the member companies.

[20] Although the mission of MCC was clear at the time of its founding—cooperate at the basic-technology level and leverage R&D to provide long-term benefits to the microelectronics and computing industry and the nation—no project details had been decided on at the time when member firms were deciding to join. The specific project details would be filled in by the board of directors, assisted by the technical advisory board, the program directors and the researchers. The board of directors, however, remained in charge of the progress and direction of the research performed at MCC.

[21] The semiconductor and computer companies were the ones that originally helped set up MCC. The major aerospace companies and conglomerates joined later. And, finally, the telecommunications companies signed up (Murphy (1991)).

[22] In a recent press release by MCC (March 9, 1998), a Texas Instruments' representative mentions that the main reason for TI to become a shareholder is that MCC has proven an effective way to complement their internal R&D resources.

[23] The period we consider in this case is from 1983 until 1995.

[24] Four out of nine of the program directors that started at MCC were recruited from university positions: Stanford University (2), University of Minnesota and University of Texas (Defense Electronics (June 1984), Gibson and Rogers (1994)).

[25] By 1990 only two of the nine program directors mentioned before remained at MCC and by 1991 all of the nine program directors had left MCC. One of the researchers and vice president for strategic development at MCC is quoted in Gibson and Rogers (1994) saying: "If everybody is a profit center, why stay at MCC?" He left MCC in the fall of 1993.

[26] An MCC press release of November-December 1995 notes key staff additions: Erik G. Mettala who will serve as MCC's executive vice president, was the associate dean of engineering for research and professor of computer science and engineering at the University of Texas at Arlington. Marek E. Rusinkiewics is now director of the InfoSleuth Project launched in January 1995 and comes to MCC from the University of Houston where he was professor in the computer science department and director of undergraduate studies. The Austin American-Statesman (June 26, 1995) reported that MCC's board of directors warmly received a revamped research plan presented this month. And employee morale reportedly is on the rise as new projects are being put together. A few companies are ready to become new members, and several current members say they are ready to increase their financial support.

[27] The complexity of the case does not allow us to determine what the optimal organizational design for MCC is. This analysis is also not intended to form an opinion on which organizational changes introduced by the different CEOs was right or wrong, but merely to focus attention on an important trade off in the organization of industrial research.