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Why do firms join consortial research centers? An empirical examination of firm, industry and environmental antecedents

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Abstract The purpose of this study was to test 10 hypotheses for why firms join research centers that are consortial in nature. We describe research centers with a formal arrangement for accommodating external membership as being consortial research centers (CRC). Although traditional analysis of why firms form collaborative research arrangements have tended to focus upon firm level variables, this study takes a broader view on antecedent factors. We derive hypotheses from resource dependence theory, market forces theory, and strategic behavior model explanations for such firm behavior. Panel data from 503 firms, in 104 industries from 1978 through 1996 were used to test the hypotheses. The decision to join a CRC was modeled using multivariate binomial probit analysis. Results showed that industry competitiveness, technological opportunities and the production of complementary innovations are all positively related to propensity to join a CRC. Slack resources are related to joining propensity in a non-linear fashion.

Keywords Research centers · Interorganizational relations · Cooperative R&D

JEL Classification M10

1 Introduction

It is now widely understood that the ability to form interorganizational relationships contributes to the development of organizational technical knowledge and capabilities and can be an important source of competitive advantage and financial performance

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(e.g., Gulati 1999; Hagedoorn and Schakenraad 1994; Kale et al. 2002; Sarkar et al. 2001). As a result, interest in organizational forms that arise to sustain collaborative research relationships has developed significantly in recent years (e.g., Vonortas 1997).

Cooperative R&D arrangements may take several distinct forms that vary in terms of the contribution of resources, the influence over goals and processes, and ownership of results by participants. In equity joint ventures two or more parties create a separate entity in which they have equity interests, and R&D results may or may not return to the parent firms (Lorange et al. 1992). In contrast cross-licensing agreements allow firms to share R&D results but not R&D costs. Then there are R&D consortia, which involve non-equity agreement between two or more firms where all participants share both costs and results of R&D (Hagedoorn 2002). Research centers may also possess characteristics of consortia. When they involve formal mechanisms for the inclusion of external members such as firms, universities, government agencies, military organizations, or individuals, research centers become consortial in nature. Such consortial research centers (CRC), like R&D consortia, are established to promote and/or pursue research activities across a defined domain, and to disseminate the results. These CRC have one or more external member who typically pay a membership fee or subscription, and in return receive access to some or all of the outputs of the research center activities. Membership may be long or short term; it may be for the purposes of a specific project, or ongoing. Centers may be not-for-profit, or formed for commercial purposes. Although often a part of a university, this is not a defining characteristic, and a research center may be based within a government agency or lab, a military organization, or a private business organization. Similarly, members may include government, universities, military, or private organizations and individuals. All of these characteristics of research centers overlap with the concept of the collaborative R&D consortium (e.g., Aldrich and Sasaki 1995; Hagedoorn 1993, 2006; Sakakibara 2002).[1] This research examines the antecedents of firm decisions to join CRC.

CRC are an important mechanism for sharing the risk inherent in the innovative process. They represent a form of inter-institutional networking that can include for-profit and not-for-profit organizations, private and public universities, and government agencies (Geisler 1995; Hagedoorn 2006). CRC are a font for the development of new knowledge and capabilities that are an important source of competitiveness for firms, industries and national economies, particularly in fast changing environments (e.g., Aldrich and Sasaki 1995; Child and Faulkner 1998; Doz et al. 2000; Gomes-Casseres et al. 2006; Hagedoorn 1993, 2002, 2006; Shan and Visudtibhan 1990).

The diversity of forms and purposes of cooperative research relationships has led to an equal diversity in the research literature (Barringer and Harrison 2000). This research includes analyses of causes (e.g., Sakakibara 2002), contexts (e.g., Hagedoorn 2006), and processes of formation (e.g., Doz et al. 2000). In the present research, we seek to contribute to knowledge of CRC by integrating and testing theories that are specific to why firms join

[1] Where they do occur, the differences between research centers and consortia are a matter of degree rather than a clear distinction. These differences include the extent of contribution of resources, influence over the focus or projects conducted by the organization (consortium or center) and extent to which members have ownership rights over products. Since these differences involve only the potential for greater contribution, influence and ownership, it is quite possible for entities referred to as consortia to have characteristics that are consistent with research centers and research centers that have characteristics consistent with R&D consortia. Perhaps the most famous example of research centers that are consortial in nature are those formed under the Industry-University Cooperative Research Center program established by the National Science Foundation. Members of such research centers may contribute resources beyond membership fees, including personnel and equipment, and may influence the research programs of the center.

such centers. In doing so, we use a multilevel approach to understanding CRC membership decisions which considers both environments and the internal characteristics of firms (e.g., Hagedoorn 2006; Osborn and Hagedoorn 1997; Sakakibara 2002). We present an empirical test of 10 hypotheses derived from three theoretical explanations of why firms join CRC and involving both firm and industry level variables. The hypotheses derived from each theoretical view are tested using panel data from 1979 through to 1996 for a sample of 503 publicly traded firms operating in 104 industries. We next present the literature review and our rationale for each hypothesis. This is followed by a description of our empirical study. We conclude with a discussion of the results, and their implications for both theory and for practice.

2 Theory

There are two sets of factors that influence the formation of any kind of interorganizational relationship: (a) environmental conditions; and (b) firm-specific contingencies (Oliver 1990; Sakakibara 2002). Environmental conditions influence the probability of relationship formation and may be categorized as either generalizable to all forms of interorganizational relationship or applicable only to specific types of relationship. Generalizable environmental conditions include resource scarcity, market concentration and domain consensus (Oliver 1990). In the context of CRC, whose primary purpose is the generation and dissemination of new technological capabilities (e.g., Geisler 1995), relationship specific conditions are those that may influence the availability and appropriability of knowledge (Baumol 1993; Levin et al. 1987; Sakakibara 2002). Firm specific contingencies include factors originating within the firm that either stimulate or inhibit firm membership decisions. Examples include the firm's current market power, it's resources available for R&D activities, performance (actual or expected) relative to competitors, the extent of slack resources, and the extent of diversification. We invoke three theoretical explanations (resource dependence theory; market forces theory; and strategic behavior models) for why these generalizable, relationship specific, and firm specific contingencies influence firm decisions to join CRC.

2.1 Resource dependence theory

Resource dependence theory (Pfeffer and Salancik 1978) suggests that as uncertainty and competition in an environment increase, firms look for ways to control uncertainty and secure access to needed resources. This is achieved in a number of ways, including the formation of interorganizational ties. With respect to CRC, the focal resource is knowledge and technological capabilities. As competition in an industry becomes more intense, competition for new knowledge resources increases. Consequently, firms are expected to seek mechanisms for acquiring, developing and appropriating that knowledge. CRC offer an important mechanism for achieving this goal. Therefore, we expect that firms within industries with lower market concentration will be more likely to join CRC for the purpose of acquiring new technological knowledge. This suggests the following hypothesis:

Hypothesis 1 Firms in more competitive industries are more likely to join CRC than their counterparts in less competitive industries.

The primary purpose of joining a CRC is acquisition of new technology or knowledge (e.g., Geisler 1995). Technological opportunity reflects the extent to which organizations

face an environment that is hostile or munificent with respect to the possibility of acquiring or creating new knowledge (Klevorick et al. 1995). The level of technological opportunity itself is broadly reflected in the distinction between high and low technology (Klevorick et al. 1995). In the case of technology or new knowledge, the greater the abundance of new knowledge or the greater the technological opportunity, the more likely a firm will need to join a CRC. This is because scientific knowledge is a collective resource that serves as an input into the industrial R&D process (Klevorick et al. 1995). Without access to this pool of resources a firm will fall behind its competitors. The significance of technological knowledge is far greater for firms in industries with greater technological opportunity. Therefore, we suggest the following hypothesis:

Hypothesis 2 Firms in industries with high technological opportunity are more likely to join CRC than firms in industries with low technological opportunity.

2.2 Market forces theory

Traditional economic models of innovation rely on the fundamental assumption that firms develop substitutable innovations (Schumpeter 1911). To secure positive economic profits, firms engage in patent races (attempt to reach the goal first) and in waiting games (let others bear the risks of pioneering and then imitate). Under these conditions, firms have a market incentive to closely guard their innovations.

In contrast, Baumol (1993) proposes a model where market forces actually motivate firms to externalize R&D through cooperative relationships such as CRC. According to this model, firms may also develop complementary innovations. Although both forms of innovation exist, the bulk of firms' innovations are incremental improvements rather than revolutionary new products or processes (Baumol 1993). Firms that produce evolving rather than mature products in an industry characterized by rapid technological change (short product lifecycle) have a market incentive to externalize R&D activities and maintain access to changing knowledge in spite of the increased risk of spillovers. According to this view, failing to join a CRC may lead to lower expected profits.

Market forces theory suggests several factors that may influence firm collaborative behavior. First, the extent to which firms engage in complementary innovations varies according to industry type (Baumol 1993). Kodama (1992) and Kotabe and Swan (1995) classify industries into two types: type M products, which are primarily assembled from electronic and mechanical components and have weaker patent protection; and type B products, which result from genetic engineering and biochemistry (biotechnology, pharmaceutical and chemical products), are created at the molecular level and have more effective patent protection (Levin et al. 1987). Firms producing type M products are more likely to engage in complementary innovations while firms producing type B products are more likely to engage in substitute innovations (Baumol 1993). For example, in photography, camera manufacturers (a type M product) can improve their product by combining their individual innovations such as an improved automatic focus device, an automatic light adjustment, and making the camera lighter and more compact (Baumol 1993). Pharmaceutical products (type B products) however, tend to substitute for one another, and it is rather doubtful that the good features of two new medications could be combined into a product representing an improvement over both of its predecessors (Baumol 1993). Market forces theory therefore suggests that the extent to which competitors produce competing or substitutable products will influence their propensity to join CRC. This suggests the following hypothesis:

Hypothesis 3 Firms operating in type M industries are more likely to join CRC than firms operating in type B industries.

Market forces theory also suggests that the length of the product lifecycle is relevant to the propensity for firms to externalize R&D activities. Under conditions of short product life cycles (i.e., rapidly evolving products), knowledge acquired from the environment through other non-collaborative means—e.g., reverse engineering or industrial espionage—is likely to be obsolete (Baumol 1993). This will increase the incentive to acquire new knowledge through collaborative means. Product lifecycles also are associated with the rate of industry growth. As industry growth rates increase, product lifecycles decrease. This suggests the following hypothesis:

Hypothesis 4 Firms in rapidly growing industries are more likely to join CRC than their counterparts.

Nevertheless, two firm-specific contingencies may discourage firms from joining CRC (Baumol 1993). First, firms with differentiated products may acquire a degree of market power sufficient to yield continuing and positive economic profits. Such firms may be unwilling to join CRC if they have already achieved a certain degree of market power through customer loyalty. Second, firms with very large R&D budgets and more productive R&D departments than those of their rivals may have both an incentive and a disincentive to join CRC.

On the one hand, since the membership fees for CRC are often allocated from R&D budgets, it is reasonable to expect a positive relationship between R&D expenditures and propensity to join. On the other hand, for firms with extensive resources and broad in-house R&D capabilities, joining CRC also may create costs in terms of signaling specific technological interests and potential commercial applications to competitors and triggering knowledge spillovers. Therefore, we propose a non-linear association between size of R&D budgets and propensity to join CRC:

Hypothesis 5 Firms with relatively unstable or declining market shares are more likely to join CRC.

Hypothesis 6 The likelihood that a firm will join a CRC increases at a decreasing rate as R&D expenditures increase.

2.3 Strategic behavior models

A third possible way to conceptualize the drivers of CRC membership is through a strategic behavior lens. Strategic behavior models attempt to identify the strategic motivations underlying cooperative arrangements (e.g., Kogut 1988). In general, these models postulate that firms select the mode of organization that maximizes long-term profitability through improving their competitive positions over time against rivals or consumers (Kogut 1988). Strategic cooperation is one option to increase market power, deter entry, and block competition. The general explanation takes two forms: (a) membership decisions represent a strategic response to current market positioning (e.g., Lorange et al. 1992); (b) membership decisions are the result of a search for synergies in response to environmental uncertainty or turbulence (e.g., Bolton 1993; Carney 1987; Hagedoorn 1993).

There have been several empirical studies that link interorganizational cooperation to competitive positioning. Lorange et al. (1992) report that firms form cooperative relationships when they are followers rather than leaders and the focus is on their core

business—i.e., the motive is to catch up. Ouchi and Bolton (1988) find that the most significant trigger events for forming collaborative R&D arrangements are substandard performance leading to market share erosion, especially for early joiners, as well as the threat of powerful foreign competitors. Shan (1990) provides evidence that the propensity to cooperate is positively correlated with the distance of firm's competitive position in relation to its rivals. In Shan's research, the follower was more likely to seek cooperative relations than the leader in commercializing new products. Shan and Visudtibhan (1990) also find that the decision to engage in cooperative relationships is a function of organizational characteristics, competitive position, and choice of strategy. In an investigation of how relative firm performance stimulates innovation, Bolton (1993) reports that firms experiencing declining performance tend to be early joiners, while firms experiencing improving performance tend to be late joiners. These results show that both high and low-performing firms join CRC; the difference resides mainly in the timing of the decision.

Strategic behavior models, therefore, suggest that the firm's current and expected performance and the firm's current competitive position will be predictive of the formation of CRC. Firms experiencing, or expecting to experience declining performance may join CRC as a strategic move to improve future performance (Bolton 1993). Some firms may adopt a proactive approach by innovating (in terms of organizational structure) in response to expected future decline in performance. Other firms may react to an actual decline in performance.

Hypothesis 7(a) and 7(b) Firms experiencing (7a) or expecting to experience (7b) a decline in performance are more likely to join CRC.

The decision to form a cooperative relationship may be constrained by the availability of slack resources (George 2005). The decision to join a CRC is a form of organizational innovation (Bolton 1993) and therefore a risky undertaking. In this case, slack resources will act as a buffer and increase the likelihood of joining (Bromiley 1991; Greve 2003). However, a large degree of slack resources in the firm may be indicative of inadequate management, and therefore a less innovative organization. There is evidence that resource constraints actually improve allocative efficiency (e.g., Baker and Nelson 2005; George 2005). Thus, a firm with a high degree of slack would be less likely to join a CRC. We incorporate the contradictory evidence from research into the influence of slack resources on performance, in the form of a non-linear relationship:

Hypothesis 8 The likelihood that firms will join CRC increases at a decreasing rate as slack resources increase.

Strategic behavior models also suggest that joining CRC is a strategy to improve the long-run competitive position of the firm. Lorange et al. (1992) have argued that a firms engage in R&D alliances in order to catch up with competitors. Since firms' evaluate their competitive position relative to their major competitors, we can expect firms that are followers to be more likely to join CRC than those that are leaders.

Hypothesis 9 Firms that are followers in their core business are more likely to join CRC than their leader counterparts.

Cooperative arrangements also may be created to obtain synergistic effects that can result from the growing interrelatedness and intricacy of different technological fields—i.e., technology fusion (Hagedoorn 1993; Carney 1987). Carney (1987) proposed that cooperation is a necessary response to environmental turbulence, such as emergence of new organizations or technologies, which can threaten the resource base of the firm. One

strategic move for such organizations is to undertake an innovative approach to adapt to environmental changes. This includes seeking external sources of needed resources (Hamel 1991). For example, in industries characterized by rapid technological change, strategic cooperation accelerates the commercialization process. Firms are likely to pursue cooperative arrangements when the synergies resulting from pooling resources outweigh the externalities, such as potential technology spillovers and reputation erosion. The cost of sharing the rents to proprietary technology is outweighed by the long-term benefit of first mover advantage and successful preemption of competitors.

Potential synergies include risk reduction, economies of scale and scope that result from the sharing of complementary technology inputs, production rationalization, and convergence of technology (Child and Faulkner 1998; Contractor and Lorange 1988a, b; Hagedoorn 1993; Harrigan 1985; Mitchell and Singh 1996; Tripsas et al. 1995). CRC lower the cost of investment for each firm (Evan and Olk 1990; Fausfeld and Haklisch 1985; Gibson and Rogers 1988; Katz and Ordover 1990; Tripsas et al. 1995). Cooperation allows firms to increase the amount of effective R&D and to eliminate wasteful duplication thereby allowing the industry to be more diversified (Evan and Olk 1990; Fausfeld and Haklisch 1985; Gibson and Rogers 1988; Katz and Ordover 1990; Tripsas et al. 1995). Finally, CRC create unique 'brain-trusts' that are hard to imitate. Thus, they may become a source of sustainable competitive advantage for members (Dyer and Singh 1998; Harbison and Pekar 1998).

The 'search for synergies' strategic behavior explanation suggests that firms will join CRC to obtain synergies through technological fusion (Child and Faulkner 1998; Dyer and Singh 1998; Harbison and Pekar 1998; Hagedoorn 1993; Mitchell and Singh 1996). Thus, an important antecedent of joining is the range of capabilities that may be combined synergistically. In other words the diversity of technologies, products or markets in which a firm is engaged may be positively associated with the possibilities for finding synergies. This suggests the following hypothesis:

Hypothesis 10 Firms that are more diversified are more likely to join CRC than firms that are less diversified.

3 Method

3.1 Sample

The population of firms considered for this study was publicly traded firms in the United States between 1978 and 1996. This period was selected because publicly available data on CRC has been published in the *Federal Register* since 1984. Since the firm's decision to join a CRC depends on the value of the relevant variables prior to its making that decision, our sample consists of only those firms for which we have at least 4 years of data prior to their decision to join. The sampling frame is the Standard and Poors *Compustat* database, which includes over 10,000 individual firms that were publicly listed during the period. Those firms that do not have continuous R&D expenses during the period were dropped from the sample. Our final sample consists of 503 firms in 104 industries (when indicated by 4 digit SIC). Of these, 21% were consortium members.

3.2 Measures

The variables for this study were obtained from three sources. Standard and Poors *Compustat* database was the source for all independent variables. Two sources provided

information for the dependent variable. Membership data for CRC were obtained from the *Federal Register* (publisher of company filings with the Department of Justice under the National Cooperative Research Act of 1984; for a further description of this data source see Vonortas 1997) and from the National Science Foundation's Industry/University Research Center program.

3.2.1 Dependent variable

The dependent variable is membership of a firm in a CRC. As previously defined, a CRC is a formal organization, whose purposes is to conduct and/or disseminate research results, with explicit arrangements for managing external partners, who may be required to pay subscriptions, fees, or contribute resources, in exchange for access to the product of the center. The cooperative R&D arrangements filed with the US Department of Justice and published in the Federal Register under the terms of the NCRA are consistent with this definition of CRC. This variable is set equal to one if the firm is a member of a CRC in a given year, and to zero if it is not.

3.2.2 Independent variables

Industry competitiveness is indicated by the concentration ratio and the distribution of market shares. Following Soni et al. (1993), market share distribution is measured through the market share variance (MSV) of the four largest companies in the industry. When the four largest firms have relatively equal market shares, the market is more competitive and the MSV approaches one. When the market is more monopolistic, the MSV approaches zero.

Technological opportunity is indicated by the industry classification suggested by Hagedoorn (1993). Specifically, Biotechnology, New materials, Computers, Industrial automation, Microelectronics, Software, Telecommunications, Aviation/defense, Heavy electrical equipment/power, and Instruments and Medical technology are classified as high-tech sectors; Automotive, Chemicals, and Consumer electronics are classified as medium-tech sectors; Food and beverages, and Others are classified as low-tech sectors.

Product type is based upon the classification used by Kodama (1992) and Kotabe and Swan (1995). Type M products are primarily assembled from electronic and mechanical components and have weaker patent protection (Levin et al. 1987); type B products, resulting from genetic engineering and biochemistry (biotechnology, pharmaceutical and chemical products), are created at the molecular level, and have more effective patent protection (Levin et al. 1987). Industries not classified as either type M or type B, are classified as type O (Other).

Industry growth is measured by change in market share. This is calculated by subtracting the 3-year average market share from the current year's market share. Change in market share is standardized by industry.

R&D expenditure per employee is used to indicate the R&D intensity of each firm because R&D expenditures as a percentage of sales is prone to more distortions (Hill and Snell 1988). To model this nonlinear relationship, five dummy variables were created to represent different levels of R&D intensity.

There is no consensus as to what constitutes the best measure for firm performance (ROI, ROA, etc.). However, top management in many firms evaluates performance relative to recent accomplishments using earnings per share (EPS) as an index (Bolton 1993). We use both the change in EPS and the change in ROI, standardized by industry, to measure

firm performance. Management adjusts dividend payments according to expectations of long-term earnings of the firm. The change in dividend payments, standardized by industry, is therefore used as a proxy for firm's expected performance.

Slack resources are measured as the firm's current assets/current liabilities ratio. To model this nonlinear relationship, we created five dummy variables to represent different levels of slack resources. Competitive position is indicated by market share, which is measured as the proportion of the firm's sales to total industry sales.

Diversification strategy is measured using Varadarajan's (1986) SIC-based classification. Broad-spectrum diversification is defined by the number of two-digit SIC industries in which a firm operates (2-SIC). Narrow spectrum diversification is measured by the number of four-digit SIC industries in which a firm operates (4-SIC).

3.2.3 Control vriables

There is mixed empirical evidence concerning the influence of firm size upon CRC joining behavior (e.g., Boyle 1968; Shan 1990; Shan and Visudtibhan 1990). None of the theories reviewed above have clear implications for the influence of size upon joining behavior, but since it has been found to be associated with cooperative behavior, we wish to control for its effects. Firm size is measured as the number of employees.

3.3 Analysis

The decision to join CRC is modeled using a multivariate binomial probit analysis. A major complication for panel data analysis is the possible existence of heterogeneous responses among cross-sectional units over time. Heterogeneity could arise either from firm-specific effects fixed over time (fixed-effects specification) or random firm-specific effects (random-effects specification). Thus, we tested the data for heterogeneity and used the appropriate specification.

4 Results

Table 1 provides means and standard deviations and correlations for all the explanatory variables included in the study.

As preliminary check on the data we tested for heterogeneity. Using a Chi-square test, the hypothesis that responses are homogeneous was rejected at the 99% confidence level. Using a Hausman test, the hypothesis that using a random-effects specification does not lead to biased estimates was accepted at the 99% confidence level. Given that using a fixed-effects specification leads to inefficient estimation, the model is specified as random effects probit model. Table 2 presents the coefficient estimates from the random-effects probit regression model.

Our first hypothesis was that firms in more competitive industries are more likely to join CRC than their counterparts in less competitive industries. The coefficient estimate for the concentration ratio is negative and highly significant ($\beta = -6.392$, $p < .01$) and the coefficient estimate for market share variance is negative and significant ($\beta = -.0381$, $p < .10$). These results indicate that firms in less competitive industries are less likely to join CRC and therefore support our first hypothesis.

According to hypothesis 2, technological opportunity is positively related to joining CRC. The coefficient estimates on the dummies for high-tech ($\beta = 2.015$, $p < .01$) and

Table 1 Means, standard deviations, and correlations

Variable	*M*	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Concentration ratio	0.84	0.16																
2. Market share variance	1.55	25.14	.01															
3. High-tech	0.42	0.49	−.05	−.03														
4. Medium-tech	0.31	0.46	.03	−.02	−.58													
5. Type M	0.56	0.49	.04	−.04	.60	−.00												
6. Type B	0.18	0.38	−.09	−.02	−.19	.42	−.53											
7. Industry growth	1.49	1.23	−.02	.02	.21	−.15	.09	−.03										
8. Market share	−0.37	1.75	.11	−.01	−.06	.04	−.02	.01	−.24									
9. R&D	148.33	1388.25	−.04	−.00	−.04	.10	−.05	.13	−.04	−.03								
10. EPS	0.87	6.03	−.00	−.01	−.04	.01	−.05	.02	.03	.06	.01							
11. ROI	7.53	152.35	−.00	−.00	.00	−.00	−.00	.00	.02	.01	.00	.04						
12. Dividend	2.45	10.63	.02	−.01	−.07	.03	−.06	.03	−.06	−.01	.02	.12	.00					
13. Slack	2.53	2.24	.04	−.00	.10	−.09	.08	−.05	.02	−.00	−.05	−.01	−.00	−.03				
14. Competitive position	0.18	0.25	.11	−.03	−.17	−.01	−.11	−.09	−.09	−.01	.11	.06	−.00	.07	−.12			
15. 2-SIC	2.65	1.54	−.02	−.01	−.23	.07	−.24	.08	−.10	.00	.07	.05	.00	.06	−.15	.22		
16. 4-SIC	3.93	2.31	−.05	−.01	−.30	.14	−.28	.13	−.11	.01	.14	.07	.00	.06	−.18	.32	.73	
17. Size	23.72	67.49	.04	−.01	−.09	−.04	.06	−.01	−.00	−.00	−.04	.01	−.01	.01	−.05	.01	.09	.09

$N = 6989$

Table 2 Random-effects probit estimation: R&D consortium membership decision

Variable	Estimate	Standard error
Intercept	1.530***	0.331
Concentration ratio	−6.392***	0.313
Market share variance	−0.381*	0.200
High-tech	2.015***	0.246
Medium-tech	1.907***	0.243
Type M	−1.970***	0.246
Type B	−2.360***	0.257
Industry growth	−0.041	0.027
Market share	−0.070	0.021
R&D1	1.478***	0.119
R&D2	2.168***	0.133
R&D3	3.393***	0.153
R&D4	4.896***	0.199
EPS	0.026***	0.007
ROI	0.000	0.001
Dividend	−0.137***	0.012
Slack1	−0.812***	0.113
Slack2	−1.191***	0.099
Slack3	−1.558***	0.123
Slack4	−1.667***	0.116
Competitive position	−1.748***	0.162
2-SIC	−0.470***	0.032
4-SIC	0.355***	0.023
Size	0.010***	0.001
Y84	−2.835***	0.176

$N = 6989$

Model Chi-squared: 3733.031; $df = 1$

*** $p < .01$, * $p < .10$

medium-tech ($\beta = 1.907$, $p < .01$) are both positive and highly significant. Furthermore, the coefficient for high-tech is larger than the coefficient for medium-tech. These results support our second hypothesis that the higher the degree of technological opportunity, the more likely the firm is to join.

Hypothesis 3 stated that firms producing complementary innovations are more likely to join than firms producing substitutable innovations. The estimated coefficients on the dummy variables Type M and Type B have to be interpreted relative to the omitted dummy Type O. Both coefficient estimates are negative and highly significant, but the magnitude of the coefficient estimate on Type B ($\beta = -2.360$, $p < .01$) is larger than the magnitude of the coefficient estimate on Type M ($\beta = -1.970$, $p < .01$) indicating that firms producing substitutable products are less likely to join than those producing complementary innovations. These results support hypothesis 3.

Hypothesis 4 stated that industry growth rate is positively related to joining CRC. The coefficient estimate for industry growth is negative but insignificant ($\beta = -0.041$, n.s.). These results indicate that industry growth does not affect the firm's decision to join. Thus, there is no support for hypothesis 4.

Hypothesis 5 stated that firms with relatively unstable or declining market shares are more likely to join CRC. The coefficient estimate of the variable for market share is negative but not significant ($\beta = -0.070$, n.s.), failing to support hypothesis 5.

According to hypothesis 6, the relationship between the size of a firm's R&D budget and its likelihood to join an CRC increases at a decreasing rate and eventually becomes negative. The results show all coefficient estimates for R&D1 through R&D4 are positive and significant (R&D1: $\beta = 1.478$, $p < .01$; R&D2: $\beta = 2.168$, $p < .01$; R&D3: $\beta = 3.393$, $p < .01$; R&D4: $\beta = 4.896$, $p < .01$). The likelihood that a firm will join an CRC increases at a rapidly increasing rate as R&D intensity increases. Thus, hypothesis 6 was not supported.

We hypothesized that firms experiencing (hypothesis 7a) or expecting to experience a decline in performance (hypothesis 7b) are more likely to join CRC. The coefficient estimate of the variable EPS ($\beta = 0.026$, $p < .01$) is positive and highly significant, while the coefficient estimate of the variable ROI ($\beta = 0.000$, n.s.) is positive but not significant. These results suggest that firms experiencing improved performance are more likely to be joiners, which does not support hypothesis 7a. In terms of expected performance, the coefficient estimate on the variable Dividend ($\beta = -0.137$ $p < .01$) is negative and highly significant indicating that firms expecting to experience a decline in performance are more likely to join CRC. This result provides support for hypothesis 7b.

Hypothesis 8 suggested that firms with relatively more slack resources are more likely to join CRC at low levels of slack and firms with relatively high levels of slack are less likely to be joiners. The results show support for our 8th hypothesis. The coefficient estimates of the variables Slack1 through Slack4 are all negative and highly significant (Slack1: $\beta = -0.812$, $p < .01$; Slack2: $\beta = -1.191$, $p < .01$; Slack3: $\beta = -1.558$, $p < .01$; Slack4: $\beta = -1.667$, $p < .01$). This means that relative to firms with low levels of slack resources, firms with high levels of slack are less likely to join, and the likelihood of joining decreases at a slowly increasing rate as the degree of slack increases.

We expected that firms that are followers in their core business are more likely to join CRC than their leader counterparts (hypothesis 9). The coefficient estimate on the measure of competitive position ($\beta = -1.748$ $p < .01$) is negative and highly significant. This result indicates that firms that are leaders in their core business are less likely to join CRC. Thus hypothesis 9 is supported.

We hypothesized that more diversified firms are more likely to join CRC than their less diversified counterparts (hypothesis 10). The coefficient estimate on the variable 2-SIC is negative and highly significant ($\beta = -0.470$ $p < .01$), while the coefficient estimate on the variable 4-SIC is positive and highly significant ($\beta = 0.355$, $p < .01$). These results indicate that more diversified firms in closely related activities are more likely to join CRC, while more diversified firms in broadly related activities are less likely to join. There is therefore, partial support for hypothesis 10.

5 Discussion

Resource dependence theory, market forces theory and the strategic behavior explanations for why firms join CRC focus on different aspects of firm behavior under different conditions (Barringer and Harrison 2000; Osborn and Hagedoorn 1997). When combined, these explanations provide a treatment of short- and long-run economic factors that compel firms to form collaborative relationships. The results of our empirical analysis strongly support the value of simultaneously testing multiple diverse explanations for why firms join CRC. We found that using such an integrative approach provides a richer explanation for the firm's behavior than provided by traditional firm level analyses (Barringer and

Harrison 2000; Hagedoorn 2006; Oliver 1990). In this study we find some support for all three theoretical explanations for factors motivating firms to join CRC.

Environmental contingencies such as the competitiveness of the industry, and the degree of technological opportunity were, as expected, significantly associated with the probability of joining CRC. Two forms of environmental contingency were examined: general and relationship specific. A general environmental contingency is expected to be influential across all forms of interorganizational arrangement (Oliver 1990). The level of competition in an industry is one example of such a generalizable contingency. Our study supports the significance of industry concentration as a strong and significant driver of membership decisions with respect to CRC. This provides clear support for resource dependence theory (Pfeffer and Salancik 1978), which suggests that organizations act to control their environment when facing uncertainty. In fact, these results suggest that, of all the different contingencies investigated, at firm and environmental levels of analysis, the environment (specifically the level of industry concentration) has a greater effect than any of the other factors.

A second generalizable environmental contingency that we influences firms to join CRC is the effect of technological intensity—operationalized in our study as high- versus low technology industries. Our study supports the influence of this environmental contingency. Furthermore, although its effect is smaller than that of industry concentration, the influence is still among the greatest of all of the contingencies investigated in this study. This finding then provides further support for the propositions of the resource dependence theory (Pfeffer and Salancik 1978). While the level of competition constrains firm behavior, forcing organizations to attempt to control external resources such as technological knowledge, the level of technological intensity increases the opportunity to obtain such knowledge externally. Together, the environment creates both necessity and opportunity, which, in combination increase the propensity of firms to join CRC.

Relationship specific environmental contingencies are only salient to particular forms of interorganizational relationship (Oliver 1990). We proposed that with respect to CRC, the availability and appropriability of new technological knowledge would be significant relationship specific contingencies. Our results are supportive of the significance of the regime of technological appropriability (Levin et al., 1990) for membership decisions. This supports the proposition from market forces theory, that the type of product innovation that is taking place is highly significant for determining whether or not firms will compete or collaborate in their innovative inputs (Baumol 1993). When the industry produces complementary innovations, there will be higher propensities to partner in R&D than when the innovations are substitutes. These findings add to the weight of environmental influences on firms' membership decisions. We find that industry type—our proxy for the type of innovation that is taking place—is the second strongest predictor of membership decisions that is consistent with our hypotheses. We may even consider the market forces explanation as a special consideration within the broader resource dependency arguments of Pfeffer and Salancik (1978). After all, Baumol's (1993) explanation for why firms engaging in complementary innovations are more likely to partner than those engaging in substitutable innovations rests on the extent to which the regimes of appropriability lean towards control versus spillovers in knowledge (Levin et al. 1987). In the original formulation of the resource dependency arguments, firms use external arrangements such as alliances, joint ventures, and by extension collaborative research agreements and research centers, to exert control over the environment and ensure supplies of critical resources. In an environment where technological knowledge tends to spillover very easily (e.g., mechanical–electrical innovation) and is not easily controlled by secrecy or patenting, it

becomes more effective to control by collaboration. In such an environment, control is achieved through remaining at the cutting edge of a technological field, and having broader knowledge of technological possibilities. In summary, we find very strong support for explanations of membership decision making that rely on environmental contingencies.

Our results also provide good support for the effect of firm specific contingencies. According to the strategic behavior literature, firm specific contingencies influence membership decision making through considerations of competitive positioning. In our empirical study, we find that the propensity to join CRC is positively related to both being a follower, and the extent of diversification. In general, however, we find much smaller effect sizes for the influence of firm specific factors than we do for the effect of the environmental contingencies.

Not all resources are unimportant. In particular, our finding for the non-linear influence of slack resources supports recent arguments that slack is not always a positive benefit for a firm (Baker and Nelson 2005). Resource constraints can force management to more efficient allocation of assets (George 2005). In this case, some slack helps provide the resources needed to buffer the firm as it engages in risky, innovative activities (Bolton 1993). However, as slack increases its effect on joining diminishes, suggesting that firms may find other uses, or may not consider it necessary to externalize R&D when they have a large endowment of slack resources. The non-linear contribution of slack to explaining CRC joining behavior is particularly significant when we consider how many other forces are included in our test of the multiple diverse explanations for such behavior. In sum, while we provide evidence in support of the strategic behavior explanations, we do note that this evidence is not as strong as that for the resource dependency perspective, which prioritizes the effect of the environment on organizational behavior.

Not all of our results were in the expected direction. Contrary to market forces theory we find that firms in fast growing industries, and therefore those with shorter product lifecycle, are not significantly more likely to form CRC. However, this result should be interpreted in light of the fact that two other indicators of product lifecycle–the level of competition and the level of technology–were positively related to joining CRC.

The surprising finding is that on average, the extent of market power and the investments made in R&D does not appear to be related to joining CRC. This finding is interesting as it is contrary to expectations. It may be that in the face of environmental and competitive forces, firm resources are not a significant deciding factor. On the other hand, the relationship between these factors and joining behavior may be more complex. Even though we have included a number of controls, it is possible that other factors serve as contingencies for when and how firm resources may influence the probability of joining an CRC. Another possibility is that the variance explained by market power is accounted for by a combination of industry competitiveness and relative competitive position of a firm, which are both significant explanations for why firms join CRC. Similarly, the variance explained by R&D expenditures may already be captured by technological opportunities, as we expect these to be closely related. However, the relatively small correlations among these variables do not provide strong support for these alternative explanations.

Taken together, our analysis shows that the decision to join a CRC reflects the influence of a number of distinct factors. The most interesting is the strong and consistent support for the influence of environmental conditions. Some of these conditions may be generalizable across all forms of interorganizational relationship, and others may be specific to CRC. Traditional analyses of why firms join cooperative R&D arrangements have tended to focus upon firm level variables (e.g., Hagedoorn 1993; Hamel 1991; Prahalad and Hamel, 1990). However, consistent with Sakakibara (2002) we found that environmental factors

associated with knowledge demand and availability have a more important influence even after firm level factors are included in analysis.

By finding considerable support for hypotheses derived from theory we avoided the common problem of post-hoc rationalization of joining behavior. The use of panel data over 18 years with a large sample of firms allows us to place some degree of confidence in our results. Yet, more research needs to be conducted before these results can be generalized to the population of firms. This is because our sample was limited to only those firms with continuous R&D expenditures. Firms that joined CRC but did not report continuous R&D expenditures over the period covered by our data were not included in this study. Likewise, firms are not mandated to register their membership, thus the CRC behavior of many firms is not captured in the *Federal Register*. It is also possible that fluctuations in joining rates can exert an influence on the results. Over the years of the study we see a steadily increasing rate of joining behavior, and the effects of imitation or institutionalization of CRC are not considered by out empirical model, neither are any temporal fluctuations in membership rates (Vonortas 1997). Therefore, we should point out that our results using discrete dependent variables models must be replicated in future research to eliminate the possibility of specification error influencing our outcomes.

Nevertheless, our use of integrating knowledge from diverse explanations of why firms join CRC clearly supports the need for considering the multi-level influences on firm partnering behavior. Future research, using various statistical models, may consider which of these drivers are associated with superior performance in the relationship. Additional considerations would be the integration of patterns of relationship creation and dissolution over time, geographically, and across industries, to determine if this type of embeddedness is an important factor leading to the formation of new relationships (Hagedoorn 2006). Another important issue to explore is whether the presently used firm and environmental variables act in consistent ways in all research centers, or whether they may differentially influence research centers that are formed through different organizational processes (Doz et al. 2000).

There are several practical implications that emerge from this empirical study. The evidence presented here suggests that policy makers, research center directors and managers, and any concerned with the growth or survival of CRC, should be aware of the significant role that environmental forces play in determining the propensity of firms to join. It is apparent that if resources for starting research centers are scarce, then one consideration would be the characteristics of the industries which are to be served or connected with. The greatest effectiveness (in terms of joining rates) is most likely to be found in more concentrated industries in high technology fields, and specifically within industries that may be classified as engaging in complementary innovations, or more simply, using mechanical and/or electrical technologies. Here, the combinations of competitive constraints, technological resource availability, and the high rates of knowledge spillover combined to provide the greatest motivations to firms to sign up for membership in scientific centers that are consortial in nature. Given the difficulty of targeting possible members based upon their internal characteristics, which are naturally hard to observe, the strong influence of generic, easily identifiable, environmental forces may in fact be good news for center managers and policy makers.

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