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Formation of R&D Consortia: Industry and Company Effects

ABSTRACT

This study investigates economic and strategic inducements of R&D cooperation. We focus on industry and company factors that affect a firm’s rate of participation in R&D consortia. These factors are analyzed in a dynamic context using a sample of 312 Japanese firms in 74 industries between 1969 and 1992. We find a firm in an industry with weak competition and appropriability conditions has a higher rate of consortia participation. A firm’s R&D capabilities, network formation through past consortia, encounter with other firms in product markets, age, and past participation in large-scale consortia also positively affect its tendency of consortia formation.

Key words: R&D consortia, alliances, industry and company effects, network, competition. appropriability

Running headline: Formation of R&D Consortia
INTRODUCTION

Who participates in R&D consortia? This issue has caught much attention from many perspectives. Firms are concerned because forming R&D consortia has become an important alternative to their R&D strategy. In organizational studies, growing attention is paid to the external network as the locus of innovation and organizational learning. This tendency reflects that firms increasingly rely on collaboration with other firms to conduct R&D activities (Gulati, 1995; Powell, Koput and Smith-Doerr, 1996; Osborn and Hagedoorn, 1997). Governments are concerned because they regard cooperative R&D as a tool for enhancing industry competitiveness. Since the late 1970s, governments throughout the developed world have adopted policies to spur the development of cooperative R&D, following the perceived success of Japan’s VLSI (Very Large Scale Integrated circuit) project in 1975. Governments want to know whether R&D consortia they support attract the right kind of firms from public policy perspectives. In economic studies, cases have pointed out that the formation of R&D consortia could suppress competition in product markets (Katz, 1986).

Studies have been made on motives of the formation of R&D consortia (Katz, 1986; Brockhoff et al., 1991; Hagedoorn, 1993), the relationship between motives and firm capabilities (Sakakibara, 1997a), and between motives and outcomes (Sakakibara, 1997b, Branstetter and Sakakibara, 1998, 2000). More broadly, the formation of strategic alliances has been studied from the perspective of transaction costs (Hennart, 1988, 1991; Pisano and Teece, 1989), strategy (Shan, 1990; Mitchell and Singh, 1992) and social factors (Kogut et al., 1992; Eisenhardt and Schoonhoven, 1996; Gulati, 1999).

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1 In this study, the words “formation of R&D consortia” and “participation in R&D consortia” are used interchangeably because in this study we rarely observe incidents that firms participate in an consortium after it is formed, and so formation and participation are synonymous here.
Building upon this line of literature, this study investigates a firm’s decision to participate in R&D consortia by taking industry and company factors into consideration. Our primary focus is economic and strategic inducements of R&D cooperation. We examine the longitudinal data of 312 Japanese firms that belong to 74 distinctive industries between 1969 and 1992. A unique feature of this study is that the data covers a large cross-section of industries, allowing us to investigate industry characteristics that induce the cooperation in R&D. By focusing on R&D consortia, we can concentrate on the issues beyond simple transaction costs because the formation of R&D consortia is typically influenced by long-term strategic considerations such as knowledge creation and learning (Kogut, 1988). Furthermore, the data covers the entire incidents of government-sponsored R&D consortia in Japan up to 1992. This data set has an advantage over the data collected through newspapers and trade journals, which are inherently subject to the sample selection bias. By analyzing panel data with a long time span in a dynamic context, we can investigate the process of a firm’s learning and how learning affects subsequent consortia participation.

We find that both industry and company factors affect the formation of R&D consortia. Firms in oligopolistic industries and in industries with weak appropriability conditions tend to participate more in R&D consortia. Firms with better R&D capabilities have a higher rate of participation in R&D consortia. Experience of past participation induces future participation. Especially, a measure of network formation through past participation has a stronger explanatory power than the simple count of the cumulative participation. A firm’s experience to meet with other firms in product markets and its age also positively affects its tendency to form R&D consortia. Finally, there is evidence that past participation in large-scale R&D consortia motivates further participation.
This article is organized as follows: The second section examines the existing literature to develop a model that captures the industry and company effects of the formation of R&D consortia. In the third section, the data on government-sponsored R&D consortia in Japan are described. The next two sections describe the research methods and the results obtained. In the final section, implications are drawn from the findings.

THEORY

Formation of Cooperative R&D

Firm motives to participate in cooperative R&D can be divided into two major classes: those related to R&D and those unrelated to R&D. In past economic theoretical research, two major R&D related motives have been emphasized: to enhance R&D productivity through cooperation on R&D inputs and to change the appropriability conditions of R&D outputs.\(^2\) Motives unrelated to R&D include improved market access through partners, risk sharing and the collection of government subsidies.

In the examinations of how cooperation in the R&D input market enhances R&D productivity, three primary motivations for cooperation have been focused: sharing of fixed costs among R&D participants, realizing economies of scale in R&D, and avoiding “wasteful” duplication (Katz, 1986; d’Aspremont and Jacquemin, 1988; Choi, 1990; Katz and Ordover, 1990; Motta, 1992; Suzumura, 1992; Ziss, 1994; Salant and Shaffer, 1998). All three are scale-based motives, and they imply that the principal purpose of cooperative R&D is to share costs.

In the arguments of the effect of appropriability conditions on R&D outputs, industry factors are the center of considerations. Appropriability conditions are the means employed by

Nelson (1959) and Arrow (1962) argued that the existence of R&D spillovers makes it difficult for innovators to capture the full benefits of their innovative activity, which depresses the incentives to conduct R&D. Through R&D cooperation, firms internalize the externality created through spillovers, thus restoring the incentive for firms to conduct R&D (Spence, 1984). This argument implies that firms in industries that have weak appropriability conditions are motivated to participate in R&D consortia.

Katz (1986) pointed out, however, firms can use cooperative R&D to limit competition by restricting the level of R&D conducted. Firms might fear that the cost reduction achieved by the higher level of R&D could intensify the subsequent product market competition. Katz’s argument implies that firms which face intense competition might be motivated to participate in R&D consortia to ease a subsequent product market competition.

In managerial literature, on the other hand, firm-level factors have been the focus of the studies on motives of alliance formation. Firms in alliances are often recognized to possess heterogeneous capabilities, and they may or may not be direct competitors in the product market. The resource-based view suggests that a firm can be conceived as a portfolio of core competencies (Prahalad and Hamel, 1990). Alliances can be viewed as opportunities for one partner to internalize the skills or competencies of the other(s) to create next-generation competencies (Hamel, 1991). Firms possess a knowledge base, and this knowledge — particularly technological knowledge — is often “tacit” (Polanyi, 1958) and not easily diffused across firm boundaries. An organizational vehicle, such as an alliance, is required to effect this transfer (Kogut, 1988).

Similarly, in past managerial research on R&D cooperation, Brockhoff et al. (1991) found from his survey that the most important reason for cooperative R&D arrangements in
Germany is the possibility of developing synergy from the exchange of complementary technical knowledge. Hagedoorn (1993) found from his analysis of a journal-article database that technology complementarity is one of the most frequently cited motives for technology cooperation.

Based on these industry- and firm-level arguments, the purpose of our study is to examine both industry- and firm-level inducements of the formation of R&D consortia. There have been studies that focus on the characteristics of R&D consortia participating firms and the industries to which these firms belong. Link and Bauer (1987) conducted a study based on a survey of 92 U.S. companies, and found that firms in more highly concentrated industries, and those with larger market shares, are more active in cooperative research under the 1984 U.S. National Cooperative Research Act. This finding is contrary to the empirical implications of cost sharing and appropriability arguments because firms in more concentrated industries have less need to share costs and have fewer appropriability problems. Kleinknecht and Reijnen (1992), on the other hand, found from a survey of 1,929 Dutch firms that firm size, market structure, R&D intensity and high shares of product-related R&D have little impact on R&D cooperation between firms. They found that the presence of government subsidies to promote R&D (both generic R&D and R&D cooperation) and an affiliation with a group of companies enhance the probability that a firm will engage in cooperative R&D. All of these studies are simple cross-section analyses.

The formation of strategic alliance has also been studied from the strategic and social perspectives. Kogut et al. (1992) conducted a cross-section analysis of 87 new U.S. biotechnology firms and found that the number of new cooperative agreements is positively related to past alliance relationships. Eisenhardt and Schoonhoven (1996) found from their study of 102 entrepreneurial semiconductor firms between 1978 and 1985 that firms in competitive
industry segments and with top management teams, that are well connected with other firms, increased the rate of alliance formation. Gulati (1999) examined 166 firms in three industries between 1981 and 1989 and found that a firm’s connection to networks and the number of past alliances positively influences the propensity of alliance formation.

Building upon these contributions, we develop hypotheses regarding the formation of R&D consortia at the industry and firm level in the following subsection.

Industry conditions

*Competition.* The degree of industry competition will affect a firm’s propensity to participate in R&D consortia. As Katz (1986) discussed, firms in competitive industries might be more motivated to form R&D consortia to ease the subsequent product market competition. Also, R&D consortia allow firms to access complementary technology that enables firms to develop their R&D capabilities and improve their strategic position. These needs might be greater in competitive industries (Baum and Oliver, 1991; Eisenhardt and Schoonhoven, 1996). On the other hand, organizational economics and organizational theory document the difficulties involved in organizing cooperative ventures in general (Killing, 1983; Harrigan, 1985, 1986; Pucik, 1988; Borys and Jemison, 1989), and R&D consortia in particular (Doz, 1987; Hladik, 1988; Osborn and Baughn; 1990; Jorde and Teece, 1990). This literature emphasizes the organization costs associated with complex ventures, including costs to monitor opportunistic behavior of participants, and to align interests among participants. If firms are in highly concentrated industries, they might find the cooperation (or collusion) easier to achieve because these difficulties can be resolved in an oligopolistic understanding among rivals. Thus we develop the following competing hypotheses:
Hypothesis 1a: The more intense the industry competition, the greater the rate of R&D consortia formation.

Hypothesis 1b: The less intense the industry competition, the greater the rate of R&D consortia formation.

**Appropriability.** As discussed earlier, R&D consortia can be used as vehicles to internalize the externality created through spillovers of research outcomes (Spence, 1984). Cohen et al. (1998) found that, on average, intra-industry R&D spillovers are more extensive in Japan than in the United States, suggesting spillovers can be major issues determining the participation in R&D consortia. Thus we hypothesize:

Hypothesis 2: The weaker the appropriability conditions, the greater the rate of R&D consortia formation.

**Firm characteristics**

**R&D capabilities.** As discussed earlier, firms can use R&D consortia to gain access to technological capabilities of other firms to create next-generation technological competencies. This might imply that a firm that currently has disadvantageous R&D capabilities is motivated to form R&D consortia more than R&D-capable firms. However, Cohen and Levinthal (1989) demonstrated the possibility that a company’s own R&D increases its learning capability from others. Levin et al. (1987) also pointed out that independent in-house R&D is the most effective means to learn about rivals’ technology. Firms that already invested in R&D, therefore, can benefit more from R&D consortia than less R&D-capable firms, and so they might be more motivated to learn from others. Thus we hypothesize:
Hypothesis 3. The greater a firm’s R&D capabilities, the greater the rate of R&D consortia formation.

Experience of past participation. The network of prior alliances provides information of new alliance opportunities, potential partners and their quality (Kogut et al., 1992). With the formation of new alliances this network updates, it is the new network that becomes influential for subsequent firm behavior (Gulati, 1999). Furthermore, Baumol (1993) argued that cheating in the cooperative R&D game can be easily detected in a repeated game situation, and punishment to exclude a cheater from the following projects is very costly for a cheater. Therefore, firms that have repeatedly participated in R&D consortia can benefit from the sustained cooperation, which further motivate them to participate. Thus we hypothesize:

Hypothesis 4: The more extensive a firm’s experience of the participation in R&D consortia, the greater the rate of R&D consortia formation.

Cash flow. The free cash flow hypothesis by Jensen (1986) implies that managers with large cash flows are motivated to invest funds in R&D projects that could bring new business opportunities to maintain the growth of the firm. R&D consortia, or alliances in general, frequently serve as options on new markets distantly related to current knowledge by providing a vehicle by which firms transfer and combine their organizationally-embedded learning (Kogut, 1991). Thus we hypothesize:

Hypothesis 5: The greater a firm’s cash flow, the greater the rate of R&D consortia formation.

Encounter with other firms. The literature on networks stressed a firm’s access to external networks as an important source of capabilities that the firm can draw upon (Gulati,
1999; McEvily and Zaheer, 1999). Similarly, when a firm is diversified into many product markets, the firm might wish to draw on outside knowledge with a greater extent by combining in-house technological competencies and external technological acquisitions to serve these markets (Gtanstrand, Patel and Pavitt, 1997). When a firm is diversified, it is also likely that the firm has a better knowledge on potential partners in R&D consortia through contact with a large number of firms in many product markets, which further motivates the firm to form R&D consortia. Thus we hypothesize:

**Hypothesis 6:** The greater the degree of a firm’s encounter with other firms in product markets, the greater the rate of R&D consortia formation.

**Other factors.** A firm’s age will be considered since a firm with a long history has a better chance to develop formal and informal networks with other firms. We expect a positive relationship between these variables and the propensity to participate in R&D consortia.

The last issue to be considered is the involvement by government. Government subsidies can allow firms to conduct large-scale cooperative R&D projects, so participating firms can realize the economies of scale. Firms that have participated in large-scale projects might have unmeasured characteristics which induces further participation. The past involvement by the government will be therefore considered in the analysis. We expect a positive relationship between this variable and the rate of participation in R&D consortia.
DATA

The data set for this research consists of Japanese R&D consortia sponsored by governmental organizations. This form of cooperative R&D is chosen because these ventures are most frequently cited as being important to industry competitiveness, particularly among Western observers. It is also chosen because it provides a comprehensive and detailed data set.

Government-sponsored R&D consortia in the sample include all significant company-to-company cooperative R&D projects formed with a degree of government involvement. The nature of government involvement in R&D consortia varies. The government can have significant influence on the formation of consortia, including having input on the type of participants who will be involved and the directions the consequent research will take. One means by which the government wields this influence is through the provision of subsidies to the consortia that meet established criteria. It is not possible, however, for the government to force companies to participate in a particular consortium. There is evidence from interviews that companies which were asked to participate in some consortia chose not to participate (Sakakibara, 1997b). In some cases, companies took the initiative to form R&D consortia and asked the government for support. In this analysis, a principal criterion in the sample selection is that the projects of the R&D consortia involved cooperation among private companies, and firms showed the initiative to participate in these projects. In other words, projects which were primarily government procurement, and those in which government agencies simply allocated tasks without the private sector’s initiative, were excluded. Projects which were essentially the implementation of existing technology were also excluded.

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3 This data set was originally prepared for Can Japan Compete?, Michael E. Porter, Hirotaka Takeuchi and Mariko Sakakibara, forthcoming.

4 Projects organized not as cooperation among companies but as governmental projects without companies’ expenditure were also excluded.
A large number of government sponsored R&D consortia occurred between 1959 and 1992. All the identifiable projects, 237 in total, were documented in my sample. During this period, 1,171 companies participated in these consortia and many were involved in multiple projects. Inclusion of these multiple projects yields a data set with 3,021 company-project pairs. This data set was collected from each ministry through direct contacts after examining a wide range of government white papers and other government publications, and is as close as possible to an exhaustive list of all government-sponsored R&D consortia in Japan.

This data set was matched with firm- and industry-level data. Firm-level financial data are taken from the Japan Development Bank Financial Database, which covers all the listed companies on the Tokyo Stock Exchange. The matching process yielded the sample we use for this analysis. This sample covers 312 firms in 74 SIC three-digit manufacturing industries between 1969 and 1992. Among them, 267 firms have participated in R&D consortia at some point during the observation period. Some firms do not report financial figures for some years of the observation period, so the panel we constructed is unbalanced. The total number of observations becomes 5,753.

Figures 1 and 2 illustrate the heterogeneity among firms and industries in this sample. Figure 1 is an example of different patterns of consortia participation by two firms in similar industries. Both Toshiba and Sony operate in electronics-related industries. They are similar in terms of size and R&D intensity. One important difference between them is that Toshiba is a more diversified company than Sony. We observe that Toshiba has been a much more active participant of R&D consortia than Sony. Figure 2 illustrates how industry differences affect participation patterns. Both Canon and Yamanouchi Pharmaceuticals are similar in terms of R&D intensity and the degree of diversification, but appropriability conditions of the
pharmaceutical industry are much stronger than that of the optical equipment industry. This is one reason why Canon participates in R&D consortia more frequently than Yamanouchi Pharmaceuticals. There are many other differences among firms in these examples that drive different patterns of consortia participation, but the differences illustrated here demonstrate that both firm and industry factors influence a firm’s rate of participation in R&D consortia.

The use of government-sponsored consortia carries with it some disadvantages. First, the theoretical literature on which we build generally focuses on “private” consortia — there is no explicit role for a government as subsidy provider or project coordinator in the previous theoretical work. Second, there are a large number of research collaborations in Japan between private firms that take place without government involvement, but we do not examine these. We focus on only a part of the total distribution of research consortia in Japan, and some caution must be exercised in generalizing from our results to the rest of that distribution. Nevertheless, the disadvantages of working with government-sponsored research consortia are countered by some compelling advantages. First, the fact that these were government-sponsored projects means that they were extensively documented in publicly available sources and materials, providing us with the elements of our rich data set. Since this data set includes the entire incidents of government-sponsored R&D consortia, this has an advantage over the data collected through newspapers and trade journals, which are inherently subject to the sample selection bias. Also, government-sponsored research consortia are themselves an interesting object of study since this policy instrument has been so controversial and so widely emulated.

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Figures 1 and 2 about here

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**METHODOLOGY**

**Model**

We employ an event history technique, which takes into account both the occurrence and timing of events (Allison, 1984; Tuma and Hannan, 1984). We use Cox’s maximum-likelihood proportional hazard model (Cox, 1972), which has been widely used for event history analysis, including the analysis of alliance formation (Eisenhardt and Schoonhoven, 1996). We employ both time-variant and -invariant variables. The model was estimated by using the STATA package.

There are both left and right censoring in the data during the period of 1969—1992. Since there are few R&D consortia before 1969, left censoring does not pose a serious problem. There is no correction in the specification. Right censoring, caused by truncating the observation period at 1992, is routinely and robustly handled within event history analysis (e.g., Tuma and Hannan, 1984).

Alternatively, we employed random-effects panel-data logit models and logit models on pooled data, which focus on the instantaneous probability of consortia formation. We obtained qualitatively similar results as presented here. These results are available from authors upon request.

**Dependent variable**

The dependent variable in a hazard model is a hazard rate that denotes a likelihood of a firm to form an R&D consortium (or R&D consortia) at each time period. Its value for firm i in year t, denoted by $h_i(t)$, is given as:

$$
\hat{h}_i(t) = \hat{h}_0(t) \exp \left( \sum_{k=1}^{m} \beta_k x_{ik} \right)
$$

(1)
where \( h_0(t) \) is the baseline hazard function when \( x_1 \ldots x_m \) are set to 0, \( x_{it}(t) \) is the value of the \( k \)th explanatory variable for firm \( i \) in year \( t \), which may or may not depend on time, and \( \beta_k \) is the \( k \)th regression coefficient. The baseline hazard function is common for all firms. The Cox model provides estimates of \( \beta_1 \ldots \beta_m \), but provides no direct estimate of \( h_0(t) \). The dependent variable in this analysis takes 1 if firm \( i \) forms an R&D consortium (or R&D consortia) in year \( t \), and 0 otherwise.⁵

**Explanatory variables**

*Competition.* The best measure of the degree of industry competition is to measure market conduct directly. Mobility statistics, such as market share instability, have been used and yielded satisfactory results (Caves and Porter, 1978; Sakakibara and Porter, forthcoming). Alternatively, measures of market structure, such as the number of firms, the four-firm industry concentration ratio, and the Herfindahl Index have been traditionally employed. Due to data constraints, the number of establishments in the three-digit industry classification is used as a proxy for the degree of industry competition.

It is necessary to assign each company to a three-digit SIC industry category. Participants in these R&D consortia tend to be large, listed companies, though many smaller companies also participated. Many of these larger participants are diversified companies, which makes this industry assignment difficult. In order to obtain an objective measure to identify the primary industry, we use *Kaisha Kigyo Meikan* (Company Almanac) edited by the Japanese Statistics Bureau of the Management and Coordination Agency. This source lists companies that are

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⁵ The STATA package can handle data with multiple “failures”. In this analysis, it is specified that all firms become at-risk in year 1959 when the first government-sponsored R&D consortia scheme was introduced. The hazard remains unchanged as events occur (i.e., the hazard may change with time, but time is measured from 1959 and is independent of when the last failure occurred). Alternatively, when we specify a firm becomes newly
covered by the Census of Establishments, an official census by the Japanese government. In the Company Almanac, each company reports the SIC three-digit level industry codes to which its establishments belong. As a result of this reporting, my basis for industry classification is the firm’s own identification of its primary activity. We use the SIC code the firm reported as the primary industry for its headquarters to assign each company to an industry. When the firm reports the function of headquarters (such as wholesaling) instead of the industry, we use the industry to which the largest factory of the firm was assigned as the primary industry.

In order to control for the industry size effect (since large industries can accommodate many firms without intensifying competition), industry sales, deflated by using the GDP deflator in 1985 prices, is included as a control.

Appropriability. As the measure of appropriability conditions, we use survey data collected by the Carnegie Mellon group (Cohen et. al., 1997). The Carnegie Mellon survey, administered in 1994, asked about patents and other mechanisms firms use to appropriate returns from their innovations. A total of 1,164 useable responses were received from the U.S. manufacturing sector, aggregated to 31 U.S. industry categories, which are mapped to corresponding Japanese industry classifications. Cohen et. al. (1998) found that there are significant differences between Japan and the United States regarding effective mechanisms to protect innovations. In Japan, patents are recognized to be the most effective mechanism. While there are differences between the systems in Japan and the United States, the level of effectiveness of patent systems is perceived to be the same in both countries, justifying the use of the U.S. patent-based appropriability measure for the Japanese analysis. Based on a similar survey conducted by the Yale group, Cockburn and Griliches (1988) found a simple patent-based

at-risk after every failure event (i.e., whenever a firm forms an R&D consortium), essentially the same results are obtained.
measure worked best as the measure of appropriability. From these observations, we use the average of the scores to question “how effective are patents to protect a firm’s product innovations” and “how effective are patents to protect a firm’s process innovations” in percentage reported in Cohen et. al. (1997) as appropriability conditions of industries. This measure is similar to what was used in Cockburn and Griliches (1988). We use the measure in 1994 for the whole period.

R&D capabilities. As a measure of a firm’s R&D capabilities, we use the difference between a firm’s R&D intensity (R&D expenditure/sales) and the R&D intensity of the industry to which the firm belongs.

Experience of past participation. We construct two kinds of variables that summarize the experience of a firm’s participation of past R&D consortia. One is the Net number of firms met, which is the net number of firms a firm has met in the past R&D consortia. This variable is a proxy for the extent of the network a firm forms through its participation in R&D consortia. The other is the Cumulative number of participation, which is the cumulative number of R&D consortia a firm has participated. This variable is a proxy for the depth of a firm’s experience in R&D consortia. For both variables, one-period lagged variables are used to avoid simultaneity.

Cash flow. Our cash flow measure is a firm’s net income plus depreciation minus dividend payments. In some specification, alternatively, a firm’s sales is used. These financial figures are deflated by using the GDP deflator in 1985 prices.

Encounter with other firms. Our measure of the degree of encounters with other firms in product markets is calculated from Market Share in Japan (1990) of the Yano Research Institute. This private Japanese market research firm tracks the market shares of the top Japanese firms in 591 distinct, disaggregated product markets. We use these data to count the number of firms a particular firm encounters in these product markets. Our data tracks 387 listed manufacturing
firms and their encounters with each other.\(^6\) From these numbers, we can construct the “net” number of firms each firm meets in product markets, which is a proxy for the extent of a firm’s network in product markets, or the degree of diversification. Ideally, we would like to obtain these data for each year, but the cost to process the data for multiple periods is prohibitively high, and so the data in 1990 are used for the entire analysis.

**Age.** As the age of a firm, we use the number of years passed after the establishment of the firm.

**Project budget.** In order to address the issue of government involvement, we use the sum of budgets of R&D consortia a firm participates in a given year. While we know the official total budget of each consortium and the official duration of each consortium, we do not know how the expenditures are allocated across participating firms and over time. We therefore assume that expenditures are divided equally across participating firms and across years of the consortium’s operation. After this allocation, we can sum all the budgets of R&D consortia for each firm for each year.\(^7\) We use one-year lagged variables to avoid simultaneity. These figures are deflated by using the GDP deflator in 1985 prices.

Descriptions of variables and their predicted signs are shown in Table 1. Table 2 presents summary statistics. Data sources are summarized in Appendix 1, and the correlation matrix is presented in Appendix 2.

\(^6\) These data were originally prepared for Branstetter and Sakakibara (2000). These data were optically scanned, electronically processed, then matched to our other information by name of the participating firm. We are grateful to Natasha Hsieh and Kaoru Nabeshima for their efforts in helping us accomplish this.
**RESULTS**

Table 3 presents the results of the event history analyses. Column 1 shows the estimation results with the base model. The results show that the degree of industry competition strongly and negatively affects the rate of R&D consortia formation (Hi). As predicted, the weak appropriability conditions of industries have a strong influence on the R&D consortia formation (H2). The findings on firm characteristics overall support our prediction. R&D intensive firms tend more to form R&D consortia (H3). Among two measures of the experience of past participation, the coefficient of *Net number of firms met* is positive and highly significant, while the coefficient of *Cumulative number of participation* is negative and significant (H4). This is due to the high correlation between two variables. Firm cash flow has a positive effect on the rate of R&D consortia formation, but the coefficient is not significant (H5). The net number of firms a firm encounters in product markets has a strongly positive effect on the formation of R&D consortia (H6). The age of a firm and the amount of project budgets both have positive influences on the rate of consortia formation.

In Columns 2 and 3, we drop one of the measures of the experience of past consortia participation. Column 2 presents a model with *Net number of firms met*, and Column 3 includes *Cumulative number of participation*. The comparison of these two models shows that, though the coefficients of both variables are positive, the net number of firms a firm has met in the past R&D consortia has a stronger predictive power than the cumulative number of R&D consortia a firm has participated. The fit of the model with this variable is better than the other model. It is

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7 Alternatively, we can use the total amount of government subsidies allocated to each firm for each year, but this measure is highly correlated with the project budget we use here, and so we chose to use the project budget.
8 One might argue that the participation in R&D consortia might have been already determined in a year before a firm actually participated. We tested the same specifications by using the one-year lagged independent variables, and obtained qualitatively very similar results as presented here.
the extent of the network a firm forms through the participation in R&D consortia, not a mere frequency of participation, which affects the rate of formation of R&D consortia.

Columns 4 and 5 show the same models as Columns 1 and 2, with firm sales variables replacing firm cash flow variables. Our overall findings are robust to these specifications, and the firm sales variable is positive and significant in Column 4.

One might argue that the above results are driven by the selection of certain firms to participate in government-sponsored R&D consortia. We dropped all the non-participants and conducted the same analysis by using the sample of participants only. This analysis yielded essentially the same results.

One might also argue that the results above are driven by the overall increase in the formation of R&D consortia, since many of explanatory variables also tend to increase over time. In some specifications we included a time trend variable and obtained qualitatively similar results as presented here.⁹

CONCLUSION

Our findings show strong support that industry and company factors affect the rate of participation in R&D consortia. Firms in oligopolistic industries tend to form R&D consortia at a greater rate than those in competitive industries. This is consistent with the findings by Link and Bauer (1987), but contrary to results by Eisenhardt and Schoonhoven (1996). Perhaps the maturity of the firms might be driving these results: this study, as well as Link and Bauer (1987),

⁹ In some models we were not able to obtain convergence. We suspect this is due to the high correlation between the trend variable and some other variables (notably Age).
tends to focus on established firms, while Eisenhardt and Schoonhoven (1996) studied entrepreneurial firms. It seems to suggest that the firms in different stages of life act differently in the formation of R&D consortia to cope with industry conditions. The interaction between the maturity of firms and industry conditions in the decision of alliance formation would be an interesting future research agenda.

Appropriability conditions, which have been a major focus of past economic theoretical analyses of R&D consortia, do have a strong explanatory power on the formation of R&D consortia. This finding, as well as the findings on industry competition, suggests that the important role industry conditions play on the formation of R&D consortia, which managers should take into consideration when they form their alliance strategy. Other industry conditions should be investigated further in the future research on the formation of alliances.

We find some firm characteristics strongly influence the rate of formation of R&D consortia. Firms with better R&D capabilities have a higher rate of participation in R&D consortia. Experience of past participation induces future participation. Especially, a measure of network formation through past participation has a stronger explanatory power than the simple count of the cumulative participation. A firm’s experience to meet with other firms in product markets and its age also positively affects its tendency to form R&D consortia. Finally, there is evidence that past participation in large-scale R&D consortia motivates further participation. It is especially interesting to observe that a firm’s tie with both market and non-market networks affect the formation of R&D consortia. The relative importance of these networks is an important issue that deserves further investigation.

There are limitations to this study. As already explained, the generalization of the results based on the data of government-sponsored R&D consortia requires some caution. Also, due to
the data constraints, some of the important variables in this analysis are only available for a particular year. This study, however, incorporates new variables which have not been operationalized before in the analysis of alliance formation, and so we hope this study stimulates further research.

An issue that remains unexplored is how specific these findings are to the Japanese context, and how they generally apply to the United States. It has been documented that the industry distribution of the frequency of participation in the Advanced Technology Program, a scheme of the U.S. government-sponsored R&D consortia, shows a similar pattern to that in Japan (Sakakibara and Branstetter, 1999). Differences in firm-level factors have not been explored and need further analysis.

Overall, we find this is a fruitful line of research. The results of this study suggest that ‘further investigation in the effects of industry and firm characteristics on a firm’s formation of R&D consortia is soundly warranted.
Figure 1. Number of Participation in R&D Consortia: Different Firms in Similar Industries

Figure 2. Number of Participation in R&D Consortia: Similar Firms in Different Industries
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Predicted Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D consortia participation</td>
<td>1 if firm i participated in an R&amp;D consortium (or consortia) in year j, 0 otherwise</td>
<td></td>
</tr>
<tr>
<td>Competition</td>
<td># of establishments in an industry</td>
<td>+/-</td>
</tr>
<tr>
<td>Appropriability</td>
<td>Average of two patent-based appropriability measures by Cohen et al. (1997)</td>
<td>-</td>
</tr>
<tr>
<td>R&amp;D capabilities</td>
<td>Differences between firm R&amp;D intensity and industry R&amp;D intensity</td>
<td>+</td>
</tr>
<tr>
<td>Net number of firms met</td>
<td>Net # of firms firm i has met in the past R&amp;D consortia, one-period lag</td>
<td>+</td>
</tr>
<tr>
<td>Cumulative number of participation</td>
<td>Cumulative # of R&amp;D consortia firm i has participated, one-period lag</td>
<td>+</td>
</tr>
<tr>
<td>Real cash flow</td>
<td>Cash flow (net income+depreciation-dividend payments) in 1985 billion yen</td>
<td>+</td>
</tr>
<tr>
<td>Real sales</td>
<td>Sales in 1985 billion yen</td>
<td>+</td>
</tr>
<tr>
<td>Encounter with other firms</td>
<td>Net # of firms firm i has encountered in product markets</td>
<td>+</td>
</tr>
<tr>
<td>Age</td>
<td># of years passed after the establishment of firm I</td>
<td>+</td>
</tr>
<tr>
<td>Real project budget</td>
<td>Sum of R&amp;D consortia budgets allocated to firm i in 1985 billion yen, one-period lag</td>
<td>+</td>
</tr>
<tr>
<td>Real industry sales</td>
<td>Industry sales in 1985 billion yen</td>
<td>Control</td>
</tr>
</tbody>
</table>
Table 2. Summary Statistics

<table>
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<tr>
<th>Variable</th>
<th># of obs.</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<th>Max</th>
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<td>.369</td>
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<td>1</td>
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<tr>
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<tr>
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<td>6.348</td>
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<td>40675.16</td>
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### Table 3. Proportional Hazard Modeling of Participation Decision in R&D Constoria

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<tr>
<th>Variable</th>
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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
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<td>(-3.60)***</td>
<td>(-3.67)***</td>
<td>(-3.15)***</td>
<td>(-3.34)***</td>
</tr>
<tr>
<td>Appropriability</td>
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<td>-.0232</td>
<td>-.0264</td>
<td>-.0220</td>
<td>-.0233</td>
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<tr>
<td></td>
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<td>(-3.74)***</td>
<td>(-4.28)***</td>
<td>(-3.58)***</td>
<td>(-3.79)***</td>
</tr>
<tr>
<td>R&amp;D capabilities</td>
<td>.0418</td>
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<td>.0447</td>
<td>.0387</td>
<td>.0398</td>
</tr>
<tr>
<td></td>
<td>(2.42)***</td>
<td>(2.45)**</td>
<td>(2.57)**</td>
<td>(2.25)**</td>
<td>(2.30)**</td>
</tr>
<tr>
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<td>.00455</td>
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<tr>
<td></td>
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<td>(4.24)***</td>
<td>(4.91)***</td>
<td>(3.34)***</td>
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<td>.00839</td>
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<td></td>
<td>(-2.58)**</td>
<td>(1.38)</td>
<td>(-3.36)***</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>(.757)</td>
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<td>(.717)</td>
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</tr>
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<td>.000111</td>
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<td>(2.42)**</td>
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<td>.0153</td>
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<td>(4.94)***</td>
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<td>(4.79)***</td>
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<td>(3.89)***</td>
</tr>
<tr>
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<tr>
<td></td>
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<td>(1.85)*</td>
<td>(2.36)**</td>
<td>(2.29)**</td>
<td>(2.25)**</td>
</tr>
<tr>
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<td>.141</td>
<td>.141</td>
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</tr>
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<td>(3.41)***</td>
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<td>(3.44)***</td>
<td>(2.894)***</td>
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<td>Real industry sales</td>
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<td>.0000129</td>
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<td>.00000772</td>
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<tr>
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<td>(.986)</td>
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<td>5689</td>
<td>5753</td>
<td>5753</td>
</tr>
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<td>Log likelihood</td>
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<td>-5037.28</td>
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</tr>
<tr>
<td>Chi-squared</td>
<td>345.85***</td>
<td>339.15***</td>
<td>323.64***</td>
<td>359.33***</td>
<td>348.05***</td>
</tr>
</tbody>
</table>

T-statistics in parentheses. *** Significance at the 1% level, ** significant at the 5% level, * significant at the 10% level, using a two-tailed t-test.
REFERENCES


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Appendix 1. Data Sources

<R&D consortia data>
*The 30 Year History of the Mining and Industry Technology Research Associations*, the Council of the Mining and Industry Technology Research Association, 1991, brochures of each project type, issued by MITI and its affiliated organizations, and white papers, brochures, and hearings from each governmental organization.

<Industry-level data>
Number of establishments and shipments. *Census of Manufacturers*, Ministry of International Trade and Industry, Japan, various years.


<Firm-level data>
R&D expenditure, sales, net income, depreciation and dividend. Japan Development Bank Financial Database.


## Appendix 2. Correlation Matrix

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
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<tbody>
<tr>
<td>R&amp;D consortia participation</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competition</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Appropriability</td>
<td>-0.02</td>
<td>-0.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D capabilities</td>
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<td>-0.18</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net number of firms met</td>
<td>0.37</td>
<td>-0.03</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative number of participation</td>
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<tr>
<td>Real cash flow</td>
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<td>0.06</td>
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<td>0.57</td>
<td>0.17</td>
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<td>0.07</td>
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