Determinants of Successful R&D Cooperation in Japanese Small Businesses: The Impact of Organizational and Contractual Characteristics

Hiroyuki Okamuro *

Graduate School of Economics

Hitotsubashi University

Abstract:

Using original survey data on Japanese small businesses, this paper analyzes the impact of the organizational and contractual characteristics of cooperative R&D, such as membership structure, partner relationship, external support, and rules of cost and outcome sharing, on the probability of the technological and commercial success of the project. Empirical results suggest that cooperative R&D is more successful, the higher the quality and quantity of external resources available through cooperation, and the lower the transaction and coordination costs required for such arrangements. Moreover, we found that the determinants of technological and commercial success differ considerably.

JEL Classification: L24; O31; O32

Keywords: Cooperative R&D; Small Business; Small and Medium Enterprise (SME); Project Organization; Contract

* Graduate School of Economics, Hitotsubashi University, Naka 2-1, Kunitachi, Tokyo 186-8601, Japan

Tel.: +81-42-580-8792; Fax: +81-42-580-8882

E-mail: okamuro@econ.hit-u.ac.jp

1. Introduction

Cooperative R&D[1] has attracted considerable attention from both academics and practitioners. Important theoretical literature on this subject highlight the following advantages of cooperative R&D: better access to external business resources, achieving economies of scale and scope and synergy effects for R&D, reducing risk and wasteful duplication of R&D efforts, and increased incentive for R&D investment by the reduced appropriability problem (Katz, 1986; d'Aspremont and Jacquemin, 1988; Suzumura, 1992; Combs, 1993). On the other hand, cooperative R&D is also argued to have the negative effects of welfare loss or reduced R&D efforts if it leads to collusion in R&D and the product market (Jorde and Teece, 1990).

Cooperative R&D is a useful way to overcome the lack of internal business resources and to improve innovativeness and competitiveness, particularly for small and medium enterprises (SMEs). In fact, as pointed out by Kleinknecht and Reijnen (1992, p. 347), "R&D cooperation does not typically occur between big, high tech firms." A statistical survey carried out in Japan in 1991[2] revealed that 9% of SMEs (firms with 50–299 employees)[3] in the manufacturing sector were involved in cooperative R&D with other firms (Table 1). Compared to large firms, the ratio of SMEs with cooperative R&D is lower but is still too high to be neglected. It should be noted that, in absolute terms, more SMEs cooperate in R&D than large firms. Moreover, cooperative R&D is not concentrated in a small number of high-tech industries but is found in all manufacturing industries.

The aim of this paper is to analyze the impact of the organizational and contractual features of cooperative R&D on project performance by using original survey data of Japanese SMEs in the manufacturing sector. This paper contributes to the study of cooperative R&D in two major ways. First, few empirical studies have been conducted on

[1] Based on the aims and objectives of their studies, scholars of this topic refer to cooperation in R&D differently—cooperative R&D, research partnership, research joint venture (RVJ), and research consortia. In this paper, we mostly use the word "cooperative R&D."
[2] This is the first, and thus far, the last official statistics in Japan that shows the number of cooperating firms by firm size classes.
[3] Firms with less than 50 employees have been excluded from this survey.

the impact of the organizational and contractual characteristics of cooperative R&D thus far[4]. Second, previous empirical researches have concentrated on research consortia among large firms and paid relatively slight attention to SMEs. In particular, econometric studies based on Japanese data have primarily focused on government-sponsored research consortia among large corporations (Miyata, 1995; Branstetter and Sakakibara, 1998; Branstetter and Sakakibara, 2002; Sakakibara, 2001a, 2001b). This study is the first comprehensive empirical study on cooperative R&D projects of Japanese SMEs.

The remainder of this paper is organized as follows. The next section provides a review of previous empirical literature on the impact of cooperative R&D. Section 3 gives a detailed discussion of the data source and descriptive statistics of sample firms. Due to the lack of detailed information regarding the organizational and contractual features of cooperative R&D projects, especially pertaining to SMEs, it is worth describing the major findings of the survey. In Section 4, we present a basic model and some operational hypotheses for the empirical analysis. Section 5 shows and discusses the results of the analysis, and Section 6 consists of a summary of the main findings along with concluding remarks.

2. Impact of Cooperative R&D on Performance: A Review of Previous Empirical Literature

Major theoretical works on cooperative R&D predict various advantages of cooperation at least for participating firms. As a result, cooperative R&D would have a positive effect on participants' performance. A series of empirical studies have examined the impact of cooperative R&D on different measures of performance with different types of samples. Recently, this line of research has witnessed a remarkable increase.

Using Japanese data, Branstetter and Sakakibara (1998) provide evidence that due to increased knowledge spillovers, frequent participation in government-sponsored research consortia has a positive effect on research productivity in terms of patenting. Using micro

[4] See Hagedoorn et al. (2000) and Link and Siegel (2003), Chapter 11, for recent surveys of related theoretical and empirical literature.

data from official Japanese statistics, Okamuro (2004) and Okamuro (2005) demonstrate that cooperative R&D by Japanese SMEs has a positive and significant impact on profitability, productivity growth, and patenting. On the contrary, Vonortas (1997) reports that cooperative R&D in the USA has a negative impact on profitability. Link and Bauer (1989) demonstrate that cooperative R&D does not directly influence a firm's productivity growth but increases the productivity effect of internal R&D. Sakakibara and Branstetter (2003) obtained results that were similar to those of Branstetter and Sakakibara (1998) for the participants of government-sponsored research consortia in the USA. Becker and Dietz (2004) find that cooperative R&D in Germany increases both R&D input and output (number of new products).

While these studies primarily examined the impact of participation in cooperation, more recent studies explore the effects of different types of partners and other characteristics of the cooperative project.

Using data of large firms in the research consortia in Japan, Branstetter and Sakakibara (2002) analyze the impact of certain organizational characteristics of consortia (technological proximity and product market proximity of members, level of centralization, diversity of members, etc.). They conclude that the design of a consortium is more important than the level of R&D input in explaining technological performance.

Based on a sample comprising small manufacturers in the UK, Freel (2000) reveals that innovative firms are significantly more likely to have cooperated with their suppliers, customers, and universities. With regard to inter-industry personal networks of entrepreneurs in Japan, Fukugawa (2006) also reports that membership structure is of importance and cooperation with public research institutes has a positive impact on the technological success of innovation projects. On the other hand, using a dataset on French firms that received public finance for innovation, Bougrain and Haudeville (2002) show that cooperative R&D in itself does not increase the likelihood that innovation projects will succeed. In particular, they also show that cooperation with suppliers and public research institutes has negative effects.

Based on survey data of French manufacturing firms, Miotti and Sachwald (2003) analyze the impact of cooperative R&D with different partners on the performance of participating firms; they observed that patenting is positively influenced only by cooperation with public institutions, while the share of innovative products in sales is increased only by vertical cooperation (with customers and suppliers).

Bizan (2003) examines the performance of government-supported international research alliances and shows that the probability of technical success of the project increases with the duration of the project, ownership relation, and complementary abilities between the partners. Given this, the commercialization time decreases with the project budget, revenue of the larger partner, and ownership relation between the partners.

Based on a recent European database on research partnerships, Caloghirou et al. (2003) reveal that perceived success significantly depends on the closeness of the cooperative research to the in-house R&D effort of the firm, the firm's effort to learn from the partnership and its partners, and the absence of problems related to knowledge appropriation between partners.

Using a large dataset of Dutch firms, Belderbos et al. (2004) analyze the impact of cooperative R&D on firm performance, differentiating the types of partners. They observe that cooperation with suppliers and competitors has a significant impact on labor productivity growth, while cooperation with universities and research institutes positively affects productivity in innovative sales.

To summarize the previous empirical literature on the impact of cooperative R&D on performance, it can be concluded that not enough empirical research has been done on this subject, especially for SMEs. Moreover, even previous studies focusing on the characteristics of cooperative projects and partners do not provide an in-depth analysis of these characteristics, specifically with regard to organizational and contractual patterns[5]. In this paper, we will more comprehensively investigate the organizational and contractual features of cooperative R&D by Japanese SMEs and analyze the impact of these features on project performance in more detail than has been done thus far.

---

[5] Mora-Valentin et al. (2004) analyze the impact of various contextual and organizational factors of cooperative agreements. However, they do not focus on agreements between firms, but rather on agreements between firms and research organizations.

3. Data

3-1. Data Source

The data for the analysis were obtained from an original survey of 6,300 Japanese SMEs (with 50–300 employees)[6] in the manufacturing sector, carried out in 2002. The target of this survey was selected by random sampling from the *Tokyo Shoko Research* (TSR) database. After excluding incomplete or inappropriate answers, we obtained data on 1,577 firms, with an effective response rate of 25%.

The definitions of cooperative R&D in the previous literature are often not clearly stated and vary with data sources used. In our original survey, we defined inter-firm cooperation as any continuous joint activity among firms in the same industry or from different industries. Cooperation among firms in vertical relationships was included in this definition; however, business outsourcing, licensing and sales contracts, as well as very short-term and one-shot joint activities were excluded[7]. This definition follows a recent survey by the Japanese Fair Trade Commission (Fair Trade Commission of Japan, 2001).

Among the 1,577 respondents, 478 firms (30%) cooperate with other firms in the past 3 years and 315 firms (20%) participate in cooperative R&D. Within the latter, 255 firms consider the cooperation in R&D to be more important than any other types of cooperation (production, sales, etc.) in which they are involved. The description and empirical analysis in this paper is based on the sample of these 255 firms.

Firms can be simultaneously involved in more than one project of cooperative R&D. Therefore, the respondents were asked to focus on the most important project in which they were involved in the past 3 years. Thus, each firm in the sample reports on one project and

[6] The definition of SMEs used here is constructed as follows: Small firms with less than 50 employees use inter-firm cooperation to a negligible extent (less than 5% according to a statistics related to small businesses in Japan, *Shokogyo Jittai Kihon Chosa Hokokusho* for 1998 by METI. They were thus excluded from the sample The upper limit of this range was set according to the Basic Law of SMEs in Japan.
[7] Nakamura and Odagiri (2005) distinguish between joint R&D (cooperative R&D in this paper), commissioned R&D, and technology acquisition. In their definition of joint R&D, which we follow here, the partners share R&D work, while each of them contributes funds and often also personnel for R&D.

the characteristics of a firm and its project can be matched on a one-to-one basis.

3-2. Data Description and Findings

In this subsection, we provide a detailed description of the characteristics of the sample firms. The descriptive findings are summarized in Appendix 1 to facilitate understanding.

3-2-1. Size, Age, Industry, and R&D

The average number of employees of the sample firms is 126. Compared to the total respondents (115 employees on average), the sample firms are significantly larger. On average, these firms are founded 56 years and incorporated 41 years before the survey was carried out. The firms in the electrical machinery (15%), metal products (12%), and miscellaneous manufacturing (13%) industries are relatively highly represented in our sample.

With regard to R&D activities, the sample firms are more R&D intensive and innovative than the average firms: 64% of the firms budget their R&D expenses every year, 58% employ full-time R&D personnel, 73% have an R&D department, 62% developed a new product and introduced it into the market in the previous year, and 52% applied for a patent or utility model (minor patent) in the previous year. These percentages are significantly higher than those of the total respondents. Moreover, 61% of the sample firms have experience with cooperative R&D before the current or the last project.

3-2-2. Partners

Regarding the membership structure, approximately half (52%) of the sample firms cooperate with one firm only. In two-thirds of the cases (67%), firms cooperate with other firms from different industries. Apart from this, 66% of the firms cooperate with their business partners (customers or suppliers), and 61% cooperate with large firms having 300 or more employees.

In addition, 44% of the firms cooperate in R&D projects with universities or public research institutes. The most popular content of cooperation is to obtain technical advice from these institutions (18%), followed by outsourcing research tasks such as data analyses and tests (12%), direct participation of the personnel of these institutions in the project (11%), and utilization of the research facilities and equipments of these institutions (3%).

3-2-3. Organizations

Cooperative R&D is most frequently implemented through formal contracts but without assistance by formal organizations such as cooperative associations and joint ventures (61%). 26% of the respondents cooperate in R&D without formal organizations and contracts. Using new or existing associations (10%) or joint ventures (3%) is much less popular. These findings imply that cooperative R&D by SMEs is implemented primarily through informal organizations.

3-2-4. Rules of Sharing Costs and Outcomes

Typically, the costs for cooperative R&D are shared according to the assigned task (46%)[8]. This means that each member firm carries out its assignment and bears the corresponding costs. The other principles of sharing costs (equality, 19%; financial ability, 10%; R&D capability and input, 18%; expected shares of outcomes, 7%) are much less popular. A quarter of the firms (26%) obtain public subsidies for the cooperative R&D.

At the end of the cooperative R&D project, 49% of the firms complete the development of new products or processes, 38% apply for patents or utility models based on the project outcomes, and 43% consider the project outcomes to have contributed to an

[8] 8% of the respondents financed the project by public subsidies. These firms were excluded from the calculation of this percentage.

increase in sales. As a whole, most of the firms (86%) obtain some outcome from the cooperative R&D. However, only 17% of the firms apply for patents or utility models *and* achieve sales growth as a result of the cooperative R&D.

For one-third of the firms (34%), the direct outcome, such as the profit obtained from the developed products and the patent right, is shared among the participants according to technological contribution. For another one-third (31%), commercialization and patenting are left to the members, without ex ante agreements. Outcome sharing equally (22%) and according to financial contribution (13%) are observed less frequently[9].

Among a number of different combinations of the patterns of sharing costs and outcomes, the most frequent one is sharing costs according to assigned task and outcomes according to technological contribution, respectively (29 cases). Balanced contractual patterns (sharing costs and outcomes equally, according to financial capacity and contribution, and according to technological capability and contribution) are relatively less frequent (12, 2, and 11 cases, respectively).

The fact that less than half the cooperative R&D projects of the surveyed SMEs are successful (or regarded as such) brings us to the main question of this paper: what determines the success of cooperative R&D?

4. Analytical Models and Hypotheses

4-1. Basic Model

In this paper, we analyze the determinants of successful cooperation in R&D using the survey data described in the previous section. The basic model for the empirical analysis is given as follows:

Probability of Success

= f (Firm Characteristics, Industry Characteristics, Project Characteristics)

[9] 24% of the firms without any substantial outcome to be sold or patented were excluded from the sample in calculating these percentages.

Project success measures are critical to this model, and are explained in the next subsection. Special attention is paid to project characteristics including organizational structure and contractual features. The basic hypothesis to be examined is that the probability of the success of cooperative R&D depends on certain project characteristics, controlling for firm and industry characteristics. In this model, firm characteristics are represented by firm size, internal R&D activity, and past experiences with cooperative R&D. Industry characteristics include the different levels of technological opportunity, and are controlled for using industry dummies[10]. Project characteristics used in the model are explained in the subsection on independent variables.

As mentioned above, SMEs can utilize external resources by cooperating with other organizations. In this way, they can enjoy economies of scale and scope and obtain synergy effects. They can also reduce the risk of innovation by sharing costs among the members and mitigating uncertainty through the acquisition of better information (Hagedoorn et al., 2000). However, cooperation also induces transaction costs and incentive problems among member firms (Weaver and Dickson, 1998; Becker and Dietz, 2004; Nakamura and Odagiri, 2005). Therefore, for cooperative R&D projects to succeed, it is important to design the organizational and contractual structure such that SMEs can take full advantage of the cooperation on the one hand and reduce transaction and coordination costs on the other hand, by enhancing incentives, increasing the commitment of participants, and preventing free-riding[11].

4-2. Measures of Project Success

Dummy variables are used as dependent variables for the "technological success" and

[10] The questionnaire contains questions pertaining to the personal characteristics of managing directors, such as age, level of education, and management experience; however, this model does not include these characteristics. No significant effect was observed with regard to these factors.

[11] This problem of conflicting objectives was explicitly dealt with in Kale et al. (2000). They argue that firms can achieve both objectives by building relational capital. Combs and Ketchen (1999) regard this as conflicting predictions of the resource-based view and the economics of organization.

"commercial success" of the project[12]. The former (TESUCCESS) takes on the value one if the firm applies the outcomes of cooperative R&D for patents or utility models and zero otherwise. The latter (COSUCCESS) takes on the value one if the firm considers the outcomes of cooperative R&D to have contributed to sales growth and zero otherwise.

Patent grants are a more suitable criterion than patent applications to measure the technological success, as the latter may include outcomes with little value. Despite this problem, we use patent applications as the measure of TESUCCESS due to the time lag between the application and grant of the patent, which is currently more than two years on average in Japan[13]. Since our questionnaire inquires about the outcomes of cooperative projects carried out in the past 3 years, using patent grants as the measure of TESUCCESS would lead to a considerable underestimation due to truncation effects.

Another problem with TESUCCESS is that a patent is not applied to every technological outcome, even though the outcome may be patentable and worth patenting. Firms may prefer hiding the outcome to patenting it because of the appropriation problem. Therefore, TESUCCESS may be underestimated. However, since the propensity for patent application differs significantly across industries, this problem can be mitigated by controlling for industry characteristics using industry dummy variables (Arundel and Kabla, 1998).

The commercial success of the cooperative project is measured by the contribution of cooperative R&D to sales growth, estimated by the participants. Therefore, this measurement depends on the subjective estimation of the participant. Despite this problem, we define and measure COSUCCESS in this manner because the objective data of sales growth are subject to numerous factors other than the outcome of the cooperative project; thus, we cannot distinguish the impact of cooperative R&D from the impact of the other factors.

[12] The reason for using different measures of success is to evaluate the project performance from different perspectives, thus taking into consideration the diversity of the aims of cooperative R&D. Fukugawa (2006) also uses these two success variables. Bizan (2003) uses technological success and, given this, time to commercialization as measures of project success.
[13] In the Japanese patent system, the Patent Office examines only those applications that are requested for examination. The current average time lag between this request for examination and the grant of the patent is approximately two years.

Similar to TESUCCESS, the concept of COSUCCESS is related to both product and process innovation. In other words, COSUCCESS includes both obtaining additional sales of new products and increasing the sales of existing products through reduced cost and price. Moreover, COSUCCESS does not necessarily depend on whether the project brought positive profits.

It should be noted that we do not define and regard TESUCCESS as a condition for COSUCCESS. This means that a cooperative R&D can be commercially successful without technological success, and vice versa. That is, participants of a cooperative R&D project can introduce a new product into the market, which is an outcome of the cooperative R&D, and thereby increase their sales without applying for a patent for the new technology. In this sense, in this paper, the concepts of technological and commercial success as well as the relationship between them are different from those in previous studies (Bizan, 2003; Fukugawa, 2006).

As explained in Section 3, 38% and 43% of the sample firms achieved technological and commercial success, respectively. Interestingly, the firms that achieved both accounted for only 17%; in other words, the majority of the technologically successful firms did not achieve commercial success, and the majority of the commercially successful firms did not achieve technological success. This implies that different factors can be associated with different measures of success. Thus, in the empirical analysis described in the next section, we will compare the results of the models of TESUCCESS and COSUCCESS in order to examine the differences in the determinant factors.

The determinants of successful cooperation are analyzed using probit models, regressing the probability of success on some variables of project characteristics, controlling for firm and industry characteristics. The definitions of the variables and the basic statistics of the sample are shown in Tables 2 and 3, respectively. In the following subsection, we explain the independent variables and present several hypotheses for examination, along with the expected signs of the coefficients of the related variables.

4-3. Independent Variables and Hypotheses

4-3-1. Availability of External Resources vs. Coordination Cost

One of the advantages of cooperative R&D is the availability of superior and complementary external resources, which is particularly important for SMEs due to limits on internal business resources. From this perspective, the number of participants (COOPSIZE), cooperation between firms in different industries (DIFFIND), cooperation with large firms (LARGE), cooperation with business partners (suppliers and/or customers) (BUSPART), and cooperation with universities or public research institutes (UNIV) are all expected to have positive effects on the success of cooperative projects[14]. These expectations are in line with the argument put forth in previous literature[15]. Further, we assume that UNIV is related to TESUCCESS, while BUSPART is related to COSUCCESS. See Table 2 for a more detailed explanation of these variables.

However, coordination costs will increase with the number and heterogeneity of the member firms. Coordinating a project efficiently would be difficult when many firms of different types are involved. In this regard, COOPSIZE and DIFFIND should be negatively related to the project success[16]. Depending on both the availability of external resources and the coordination costs, the signs of coefficients for COOPSIZE and DIFFIND could be positive or negative[17].

Based on these arguments, we derive the following hypotheses. The variables that correspond to each hypothesis and the expected signs of the coefficients of these variables are placed in parentheses.

---

[14] It is noteworthy that UNIV includes not only direct participation of their personnel in the project but also other types of technical supports.

[15] Becker and Dietz (2004) examine the positive impact of the number of partners on innovative behavior. Branstetter and Sakakibara (2002) show that the diversity of members increases research productivity. Miotti and Sachwald (2003) compare the relative efficiency of cooperative R&D with different partners (suppliers, customers, rivals, academic institutions, and foreign firms). According to Bougrain and Haudeville (2002), cooperation with public research institutes has an unexpected negative effect on project success.

[16] Another reason for the negative effect of COOPSIZE is that free-riding is more likely to occur with a larger number of participants.

[17] Sakakibara (2001b) argues that single-industry cooperation can increase R&D efficiency through economies of scale and the avoidance of wasteful duplication, while multi-industry cooperation provides its members easier access to necessary complementary resources.

Hypothesis 1a: The larger the number of participants, the more successful is the cooperative R&D (**COOPSIZE** +).

Hypothesis 1b: The smaller the number of participants, the more successful is the cooperative R&D (**COOPSIZE** –).

Hypothesis 2a: Cooperative R&D is more successful if the participants belong to different industries (**DIFFIND** +).

Hypothesis 2b: Cooperative R&D is more successful if the participants belong to the same industry (**DIFFIND** –).

Hypothesis 3: Cooperative R&D is more successful if a large firm participates in the project (**LARGE** +).

Hypothesis 4: Cooperative R&D is more successful if the business partner (customer and/or supplier) participates in the project (**BUSPART** +).

Hypothesis 5: Cooperative R&D is more successful if the personnel of a university or a public research institute participates in or provides technical support to the project (**UNIV** +).

4-3-2. Public Subsidies

Public subsidies for cooperative projects (SUBSIDY) may also play an important role in determining the success of a project. With public subsidies, firms obtain additional financial resources that may increase the probability of project success. However, public subsidies may also have negative effects if they induce moral hazard problems. Namely, firms receiving public subsidies may reduce their own R&D expenses and efforts or select risky projects with a low possibility of success that they would otherwise not attempt without subsidies. Thus, the impact of public subsidies on the success of cooperative R&D may be positive or negative.

Hypothesis 6a: Cooperative R&D is more successful if the project obtains a public subsidy

(**SUBSIDY +**).

Hypothesis 6b: Cooperative R&D is less successful if the project obtains a public subsidy (**SUBSIDY –**).

4-3-3. Trust and Opportunism

Trust among member firms can reduce the risk of opportunistic behavior of those firms and thereby prevent conflicts, inducing higher levels of commitment to the project (Kale et al., 2000). Trust among participants is supposed to be high, and correspondingly low the risk of partner opportunism if the firms have experience of past cooperation (with the same members) (EXPER) and if they are familiar with each other beforehand (CONTACT) (Deeds and Hill, 1999; Bizan, 2003; Soh, 2003; Mora-Valentin et al., 2004). Thus, the coefficients of EXPER and CONTACT are expected to have positive signs[18].

Hypothesis 7: The more experience the participants have in cooperative R&D, the more successful is the project (**EXPER +**).

Hypothesis 8: The more familiar the participants are with each other beforehand, the more successful is the project (**CONTACT +**).

4-3-4. Formal and Informal Organizations

The coordination cost is further influenced by the organizational structure of the project. Formal organizations, such as cooperative associations (*Kyodo Kumiai*) and equity joint ventures for cooperative R&D, can prevent opportunistic behavior of member firms, thus saving transaction and coordination costs[19]; however, formal organizations may also

[18] There are other reasons for the positive effect of past experiences. Even if the participants in the current project are mostly different from those in past projects, the experienced firm can manage the project efficiently by learning from the past projects, as long as the subject of the current research is related to the subject of the past projects.

[19] Mora-Valentin et al. (2004) argue that a high level of institutionalization of cooperative agreements is a factor contributing to success, which is in line with our argument.

have negative effects as a result of lack of flexibility. Therefore, compared to informal organizations, formal organizations may lead to either better or worse performance. In this case, regarding informal organizations as the baseline reference, the coefficient of the variable of formal organizations (FORMAL) is expected to have either a positive or negative sign. In this paper, we consider cooperative associations and equity joint ventures as formal organizations, while informal organizations are defined as any organizations other than cooperative associations and equity joint ventures, both with and without written contracts.

Hypothesis 9a: Formal organizations are more favorable for project success than informal organizations (**FORMAL** +).
Hypothesis 9b: Formal organizations are less favorable for project success than informal organizations (**FORMAL** –).

4-3-5. Arrangements for Sharing Costs and Outcomes

Contractual agreements pertaining to the project, specifically the pattern of sharing costs and outcomes, may affect the incentives of the member firms, thus affecting the performance of the project[20]. In this regard, equal sharing of costs or outcomes does not seem to be optimal, given that the capability and contribution of each member is different. In this situation, equal sharing of costs per head would in fact be unfair and some parties would be discontent, and equal sharing of outcomes would encourage free-riding of the members.

However, what is more essential than the pattern of sharing costs and outcomes itself is the *combination* of these patterns. If the financial or technological capabilities of the members differ, it will be more efficient to assign a larger amount of tasks to a more

[20] Since the sample includes informal cooperative projects without written contracts, contractual agreements for sharing costs and outcomes include implicit ones. Moreover, it is not clear from the questionnaire survey if the rule of sharing project outcomes is agreed upon at the beginning of the project. Here, we make a rather strong assumption that the members had at least an implicit agreement on this rule at the beginning.

capable member, and thus a larger share of the costs, *and also* entitle him to obtain a larger share of the outcomes. Otherwise, incentive problems would occur. Similarly, it would be unfair to give members an equal share of or free access to the outcomes regardless of their different contributions. Therefore, certain balanced combinations of sharing costs and outcomes, such as equal sharing of costs and outcomes (RULE1) or the combination of sharing costs and outcomes according to technological capability and technological contribution, respectively (RULE2), are expected to be more efficient than the other, less balanced combinations, which are together regarded as the baseline reference[21].

Hypothesis 10: Cooperative R&D is more successful if the costs and the outcomes of the project are shared equally (**RULE1 +**), or according to technological capability and technological contribution (**RULE2 +**), compared to the other, less balanced patterns.

4-3-6. Control Variables

The above variables of project characteristics should be controlled for by firm and industry characteristics. As mentioned in Section 4.1, we control for inter-industry differences in the propensity of project success by using industry dummies[22]. Firm characteristics are represented by R&D capability (RDINPUT) and past experiences in cooperative R&D (EXPER). The latter is discussed with regard to Hypothesis 7 as part of the project characteristics; thus, we do not regard it as a control variable.

From the perspective of the internal resources of the firm, the higher the R&D capability of the members, the more successful is the cooperative R&D. The variable RDINPUT is calculated here as the sum of the following three dummy variables: (1)

[21] The combination of sharing costs and outcomes according to financial capacity and financial contribution, respectively, is also a fair and effective pattern. However, this combination is not considered in the following regression analysis because of its scarcity.

[22] Considering "miscellaneous products" as the baseline reference, we use 14 industry dummies, which roughly correspond to 2-digit SIC industries (food and beverages, textile and clothing, wood products and furniture, pulp and paper products, printing and publishing, chemical and pharmaceutical products, plastics and rubber products, ceramic products, steel and nonferrous metals, metal products, general machinery, electrical machinery, transportation equipments, and precision instruments).

budgeting R&D expenses every year = 1, (2) employing full-time R&D personnel = 1, (3) the existence of an R&D department = 1, and zero otherwise, respectively. Thus, this variable takes on values from 0 to 3. The firms with a high value of RDINPUT are characterized not only by their high innovative capability, but also by their distinct absorptive capacity of external technology and know-how (Cohen and Levinthal, 1989), which in turn improves the project efficiency[23].

We used two further variables of project characteristics in the models to control for the estimated weight of the cooperation project in the entire business activity of the firm (WEIGHT) and the level of R&D at the beginning of the cooperative project (ZEROSTART). The variable WEIGHT is measured as the score on a 5-point-scale, where the highest score (5) indicates the highest weight. ZEROSTART is a dummy variable that takes on the value one if the cooperative R&D started from the very beginning, identifying the subject of R&D, and zero otherwise. We thus distinguish this type from projects already started by at least a part of the participants. WEIGHT and ZEROSTART are expected to have a positive and negative impact on project success, respectively. A higher weight of the project implies a higher level of commitment of the firm toward the project, and the project is more likely to be successful if the related R&D has partly been carried out by member firms before the commencement of the project.

5. Empirical Results and Discussion

5-1. Determinants of Technological Success

Table 4 presents the estimation results on the determinants of TESUCCESS. All the models include 14 industry dummies, which are not shown in the table. In order to check the robustness of the estimation, we estimated 6 models with different combinations of variables controlled by the same variables (RDINPUT, WEIGHT, ZEROSTART, and

[23] In this sense, this variable should be the average value of the member firms. However, due to lack of such data, in this paper, we use the value of one of the member firms, namely the respondent to our survey, as a proxy, assuming that the other members have similar levels of R&D capability.

industry dummies).

Model 1 comprises the variables of membership structure (COOPSIZE, DIFFIND, BUSPART, LARGE, and UNIV) and examines Hypotheses 1 to 5. Model 2 examines the effect of public subsidies (SUBSIDY), i.e., Hypothesis 6. Model 3 includes the variables of trust (EXPER and CONTACT) and examines Hypotheses 7 and 8. Model 4 investigates the combined effects of all the above variables. Model 5 examines Hypotheses 9 and 10 by estimating the effects of organizational formality (FORMAL) and the patterns of sharing costs and outcomes of the project (RULE1 and RULE2). Model 6 contains all the variables discussed in this paper. The estimation of Models 5 and 6 is based on a much smaller number of observations than the other models because of missing data of RULE1 and RULE2.

The results show that our estimation models have a sufficient explanatory power. Pseudo R-squares lie between 0.1 (Model 2) and 0.4 (Model 6). The comparison of the values of the pseudo R-squares between the estimation models suggests that the variables of contractual characteristics, especially RULE2, considerably increase the explanatory power of the model.

In Models 1 to 4, RDINPUT, DIFFIND, LARGE, CONTACT, and WEIGHT have positive effects[24]. This suggests that (1) intensive R&D, (2) cooperation with firms in other industries, (3) cooperation with large firms, (4) ex-ante familiarity between the members, and (5) the relative weight of the cooperative project, are important determinants of TESUCCESS. Among the additional variables in Models 5 and 6, only the coefficients of RULE2 are positive and significant, suggesting that a fair and balanced pattern of sharing costs and outcomes increases the possibility of TESUCCESS. The other variables, namely COOPSIZE, BUSPART, UNIV, SUBSIDY, EXPER, FORMAL, RULE1, and ZEROSTART, do not have a significant impact on TESUCCESS. Therefore, these results support Hypotheses 2a, 4, 8, and 10.

[24] There are at least two yet unmentioned reasons for the positive effect of LARGE. First, large firms tend to be more familiar with the patenting procedure and patent management than SMEs. Second, large firms are not interested in low-tech cooperation; they select technologically promising projects and firms. If this is the case, then R&D cooperation with large firms tends to have a good chance of achieving technological success right from the beginning.

With regard to industry characteristics, which are not shown in the table, the dummies for the textile and clothing industry and chemical industry (including the pharmaceutical industry) have negative and significant effects on TESUCCESS. It is interesting to observe that the probability of TESUCCESS of cooperative R&D is significantly lower in the chemical industry, which is characterized by a high R&D intensity and a high frequency of cooperative R&D (see Table 1)[25].

The estimation results for different models are robust. An important exception is UNIV, which has a positive and significant coefficient when all the variables are included in the estimation (Model 6). The signs and significance of the estimated coefficients of the independent variables do not change substantially even after excluding industry dummies or changing the combination of the variables[26]. The results of the robustness check imply that the estimation results are subject to the limitation of neither the degree of freedom nor the multicollinearity among several variables.

5-2. Determinants of Commercial Success

Table 5 shows the results on the determinants of COSUCCESS. All the models include industry dummies, which are not shown in the table. The estimation models have a sufficiently high explanatory power, as the pseudo R-squares lie between 0.19 (Model 5) and 0.35 (Model 6).

In Models 1 to 4, RDINPUT, COOPSIZE, BUSPART, EXPER, and WEIGHT have positive and significant effects, while UNIV, SUBSIDY, and ZEROSTART have negative and significant effects. DIFFIND, LARGE, and CONTACT do not have a significant impact on COSUCCESS. These results suggest that (1) intensive R&D, (2) cooperation with many firms, (3) cooperation with business partners, (4) *no* cooperation with universities and

[25] The reason for this result is unclear. Our sample comprises 22 firms in the chemical industry but we have no further information about their product programs. This unexpected result for the chemical industry may be attributed to an insufficient number of firms in this industry or to the heterogeneity within this industry, which includes even relatively low-tech industries such as inorganic chemistry and fertilizer industries.

[26] Cf. Appendix 2 for the coefficient of correlation between the dependent and independent variables, which largely corresponds to the signs and significance of the estimated coefficients.

public research institutes, (5) *no* public subsidy, (6) past experience in cooperative R&D, (7) the relative weight of the cooperative project, and (8) cooperation based on intermediate research outcomes of member firms, are important determinants of COSUCCESS.

The results of Models 5 and 6 suggest that neither organizational formality nor the rules of sharing costs and outcomes have a significant impact on COSUCCESS. Only the coefficient of FORMAL is negative and weakly significant in Model 6; however, it turns insignificant in Model 5, indicating that this result is not robust. In sum, the results on COSUCCESS support Hypotheses 1a, 3, 6b, and 7.

From among the industry dummies, which are not shown in Table 5, the textile and clothing industry and steel and nonferrous metal industry have positive and significant effects on the COSUCCESS.

Contrary to the hypothesis, the effect of UNIV is significantly negative. This unexpected result, which is similar to that by Hall et al. (2000) and Bougrain and Haudeville (2002), can be interpreted in different ways. Projects in need of technical support from university personnel may be at early stages and thus still far from commercialization. Further, firms are more likely to cooperate with universities in basic research projects that do not aim at commercialization. Hall et al. (2000) argue that universities tend to be involved in more difficult projects, namely those with a lower probability of early completion. However, an empirical analysis on the factors of cooperation with universities and public research institutes is beyond the scope of this paper and moreover is not feasible due to limited information from our questionnaire[27].

The estimation results for different models are robust. The signs and significance of the estimated coefficients of the independent variables do not change substantially even after excluding industry dummies or changing the combination of the variables. These results of the robustness check imply that the estimation results are subject to the limitation of neither the degree of freedom nor the multicollinearity among several variables.

Hypotheses 1a, 2a, 3, 4, 6b, 7, 8, and 10 are supported by combining the results on

[27] A further empirical analysis requires concrete information about the stage, purpose, and difficulty of the projects, which cannot be obtained from our questionnaire.

TESUCCESS and COSUCCESS (Table 6). In other words, all of our hypotheses but 5 (UNIV) and 9 (FORMAL) are empirically supported. Moreover, these results demonstrate that the determinants of TESUCCESS and COSUCCESS are considerably different, as summarized in Table 6. The determinants of TESUCCESS are RDINPUT, DIFFIND, LARGE, CONTACT, RULE2, and WEIGHT, while those of COSUCCESS are RDINPUT, COOPSIZE, BUSPART, UNIV (negative), SUBSIDY (negative), EXPER, WEIGHT, and ZEROSTART (negative). Thus, apart from the control variables RDINPUT and WEIGHT, the determinants of the dependent variables are different, though the results as a whole support our hypotheses.

These findings are consistent with the fact that the firms that achieved both technological and commercial success are in a minority (17%), and the probabilities of the two are statistically independent.[28] As suggested by Belderbos et al. (2004), the choice of cooperation partners is combined with particular measures of firm performance, and thus particular aims of cooperation. We argue that the optimal pattern of cooperative R&D depends on how project performance is measured, and therefore, the aim of the project members.

6. Concluding Remarks

In this paper, we investigated the organizational and contractual features of cooperative R&D of Japanese SMEs based on original survey data and analyzed the determinants of successful cooperation. We used two measures of success: TESUCCESS (project outcomes were applied for patents or utility models) and COSUCCESS (project outcomes contributed to sales growth). Particular attention was paid to the role of membership structure and supporting partners, degree of organizational formality, as well as the rules of sharing costs and outcomes. A number of studies have investigated cooperative R&D; however, neither the organizational structure of cooperation nor the effects of these

[28] The coefficient of correlation between TESUCCESS and COSUCCESS is lower than 0.05, which is not statistically significant.

features on project performance have been investigated and analyzed in detail. Moreover, this is the first econometric analysis pertaining to Japanese SMEs.

The basic idea of this research is that the organizational and contractual features of the cooperative project affect the success of the project. The results of the regression analyses generally support this. It should be noted that the probability of commercial success of the project is positively influenced by cooperation with business partners but negatively influenced by cooperation with universities and public research institutes. The results also provide evidence that the technological success of cooperative R&D depends on the combination of the rules of cost and outcome sharing. Specifically, the project is more likely to be successful when the costs and outcomes are shared according to technological capability and contribution, respectively. Moreover, we found that, as a whole, the determinants of technological and commercial success of cooperative R&D are almost entirely different. Note that, however, this research focuses on SMEs, and therefore the results cannot be directly applied to large firms.

Our empirical results suggest as a whole that cooperative R&D projects should be designed to provide the participants with optimum access to complementary external resources on the one hand and to reduce transaction and coordination costs on the other hand, by inducing higher incentive and commitment of the participants and preventing free-riding.

To sum up the most important results, we would emphasize that whether or not cooperative R&D is successful depends on the structure and contents of the cooperation. The optimal design of cooperative projects depends on the goals of cooperation (Belderbos et al., 2004):Cooperation with large firms and familiar firms in other industries is more likely to contribute to technological success, while cooperation with many firms and business partners without public subsidy is favorable for commercial success.

Firms can select an optimal pattern for the cooperative project based on their aims (patents, new products or process, etc.) and conditions (internal resources, technological characteristics of the industry, etc.). In this analysis, the organizational and contractual characteristics are regarded as exogenous but they can also be determined endogenously.

However, this issue exceeds the scope of this paper and is left for further research[29].

In conclusion, some factors that are not covered in this research should be mentioned as areas for future research. First, the characteristics of the technological field of cooperative R&D may affect both the organization and performance of the project. Such characteristics were not explicitly considered in our questionnaire, though they have been party controlled for with industry dummies. Future research should focus on a specific industry or technology[30]. Second, and related to the first point, the technological proximity of cooperating partners may also play an important role in determining project success (Branstetter and Sakakibara, 1998; Sakakibara and Branstetter, 2003). Third, project success may also depend on the closeness of the subject of cooperative R&D to in-house R&D (Caloghirou et al., 2003). Fourth, the geographical proximity of the participants may also be an important factor in project success (Mora-Valentin et al., 2004). Finally, aims, membership, and the organizational and contractual structure of the cooperative project may change over time. In our research, we implicitly assumed that the project characteristics—particularly the organizational and contractual structure—are determined at the beginning of the project and remain unchanged over time. To address this issue, the dynamic process of cooperation should be considered explicitly (Cf. Reuer et al,, 2002; Dvir and Lechler, 2004).

Acknowledgments:

The author is grateful to the *Japan Society for the Promotion of Sciences* for providing financial support for this research project (Grant-in-Aid for Scientific Research 2001–2002, Basic Research C (2), project number 13630135). Additional support from *The 21st Century Center of Excellence (COE) Project on "Normative Evaluation and Social Choice of Contemporary Economic Systems"* of Hitotsubashi University is also gratefully

[29] There are only a few empirical studies on the determinants of the contract of cooperative R&D projects. See Cicotello and Hornyak (2000) for an analysis of R&D agreements with government agencies and Bönte and Keilbach (2005) for the choice of formal and informal cooperation.

[30] Cf. Deeds and Hill (1999) as an example for biotechnology.

acknowledged. Earlier versions of this paper were presented at the 29th International Small Business Congress (ISBC) in October 2002 in Amsterdam, the Netherlands; the Annual Meeting of the Japanese Economic Association in June 2003 in Oita, Japan; the 48th International Council for Small Business (ICSB) World Conference in June 2003 in Belfast, UK. The author thanks the participants of these conferences and two anonymous referees of this journal for helpful comments and suggestions. Any remaining omissions or errors are mine.

References:

Arundel, A., Kabla, I., 1998. What percentage of innovations are patented? Empirical estimates for European firms. *Research Policy* 27, 127–141.

Becker, W., Dietz, J., 2004. R&D cooperation and innovation activities of firms–evidence for the German manufacturing industry. *Research Policy* 33, 209–223.

Belderbos, R., Carree, M., and Lokshin, B., 2004. Cooperative R&D and firm performance. *Research Policy* 33, 1477–1492.

Bizan, O., 2003. The determinants of success of R&D projects: evidence from American-Israeli research alliances. *Research Policy* 32, 1619–1640.

Bönte, W., Keilbach, M., 2005. Concubinage or marriage? Informal and formal cooperations for innovation. *International Journal of Industrial Organization* 23, 279-302.

Bougrain, F., Haudeville, B., 2002. Innovation, collaboration and SMEs internal research capacities. *Research Policy* 31, 735–747.

Branstetter, L., Sakakibara, M., 1998. Japanese research consortia: a microeconometric analysis of industrial policy. *Journal of Industrial Economics* 66, 207–233.

Branstetter, L., Sakakibara, M., 2002. When do research consortia work well and why? Evidence from Japanese panel data. *American Economic Review* 92, 143–159.

Brouwer, E., Kleinknecht, A., 1999. Innovative output, and a firm's propensity to patent. An exploration of CIS micro data. *Research Policy* 28, 615–624.

Caloghirou, Y., Hondroyiannis, G., Vonortas, N.S., 2003. The performance of research partnerships. *Managerial and Decision Economics* 24, 85–99.

Cicotello, C.S., Hornyak, M.J., 2000. Cooperation via contract: An analysis of research and development agreements. *Journal of Corporate Finance* 6, 1–24.

Cohen, W.M., Levinthal, D.A., 1989. Innovation and learning: Two faces of R&D. *Economic Journal* 99, 569–596.

Combs, K., 1993. The role of information sharing in cooperative research and development. *International Journal of Industrial Organization* 11, 535–551.

Combs, J.G., Ketchen, D.J., 1999. Explaining interfirm cooperation and performance: Toward a reconciliation of predictions from the resource-based view and organizational economics. *Strategic Management Journal* 20, 867–888.

d'Aspremont, C., Jacquemin, A., 1988. Cooperative and non-cooperative R&D in duopoly with spillovers. *American Economic Review* 78, 1133–1137.

Deeds, D.L., Hill, C.W.L., 1999. An examination of opportunistic action within research alliances: evidence from the biotechnology industry. *Journal of Business Venturing* 14, 141–163.

Dvir, D., Lechler, T., 2004. Plans are nothing, changing plans is everything: the impact of changes on project success. *Research Policy* 33, 1–15.

Fair Trade Commission of Japan (JFTC), (2001). *Survey Report on Business Alliances and Inter-firm Competition*, Tokyo, in Japanese.

Freel, M., 2000. External linkages and product innovation in small manufacturing firms. *Entrepreneurship and Regional Development* 12, 245–266.

Fukugawa, N., 2006. Determining Factors in Innovation of Small Firm Networks: A Case of Cross Industry Groups in Japan. Small Business Economics 27, 181-193.

Hagedoorn, J., Link, A.N., Vonortas, N.S., 2000. Research partnerships. *Research Policy 29*, 567-586.

Hall, B.H., Link, A.N., Scott, J.T., 2000. Universities as Research Partners, *NBER Working Paper* No. 7643.

Jorde, T.M., Teece, D.J., 1990. Innovation and cooperation: Implication for competition and antitrust. *Journal of Economic Perspectives* 4, 75–96.

Kale, P., Singh, H., Perlmutter, H., 2000. Learning and protection of proprietary assets in strategic alliances: Building relational capital. *Strategic Management Journal* 21, 217–237.

Katz, M.L., 1986. An analysis of cooperative research and development. *Rand Journal of Economics* 17, 527–543.

Kleinknecht, A., Reijnen, J.O.N., 1992. Why do firms cooperate on R&D? An empirical study. *Research Policy* 21, 347–360.

Link, A.N., Bauer, L.L., 1989. Cooperative Research in U.S. Manufacturing. Lexington (Lexington Books).

Link, A.N., Siegel, D.S., 2003. *Technological Change and Economic Performance.* London (Routledge).

Miotti, L., Sachwald, F., 2003. Co-operative R&D: why and with whom? An integrated framework of analysis. *Research Policy* 32, 1481–1499.

Miyata, Y., 1995. An economic analysis of cooperative R&D in Japan. *Japan and the World Economy* 7, 329–345.

Mora-Valentin, E.M., Montoro-Sanchez, A., Guerras-Martin, L.A., 2004. Determining factors in the success of R&D cooperative agreements between firms and research organizations. *Research Policy* 33, 17–40.

Nakamura, K., Odagiri, H., 2005. R&D boundaries of the firm: An estimation of the double-hurdle model on commissioned R&D, joint R&D, and licensing in Japan. *Economics of Innovation and New Technology* 14, 583–615.

Okamuro, H., 2004. The Effects of Inter-firm Cooperation: A Comparative Analysis of Small and Large Firms Using Micro Data, *COE/RES Discussion Paper* No. 66, Hitotsubashi University, in Japanese.

Okamuro, H., 2005. Cooperative R&D by SMEs and Intellectual Property, *Proceedings of the Japan Academy of Small Business Studies*, 24, Tokyo (Doyukan), 3-16, in Japanese.

Reuer, J. J, Zollo, M., Singh, H., 2002. Post-formation Dynamics in Strategic Alliances.

Strategic Management Journal 23, 135-151.

Sakakibara, M., 2001a. Cooperative research and development: who participates and in which industries do projects take place? *Research Policy* 30, 993–1018.

Sakakibara, M., 2001b. The diversity of R&D consortia and firm behavior: Evidence from Japanese data. *Journal of Industrial Economics* 49, 181–196.

Sakakibara, M., Branstetter, L., 2003. Measuring the impacts of US research consortia. *Managerial and Decision Economics* 24, 51–69.

Soh, P.-H., 2003. The role of networking alliances in information acquisition and its implications for new product development. *Journal of Business Venturing* 18, 727–744.

Suzumura, K., 1992. Cooperative and non-cooperative R&D in oligopoly with spillovers. *American Economic Review* 82, 1307–1320.

Vonortas, N.S., 1997. *Cooperation in Research and Development*, Boston (Kluwer).

Weaver, K.M., Dickson, P., 1998. Outcome quality of small- to medium-sized enterprise-based alliances: The role of perceived partner behaviors. *Journal of Business Venturing* 13, 505–522.

Table 1: Japanese Firms Conducting Cooperative R&D in 1991
(Units: number of firms)

	(A) All Firms	(B) Firms Conducting Cooperative R&D	B/A
All Manufacturing Industries	13,688	1,634	0.119
50—99 employees	4,080	311	0.076
100—199 employees	4,325	404	0.093
200—299 employees	1,906	202	0.106
300—499 employees	1,401	190	0.136
500—999 employees	1,089	191	0.175
1000—4999 employees	746	255	0.342
5000 and more employees	141	81	0.574
SMEs (50—299 employees)	10,311	917	0.089
Large Firms (300+ employees)	3,377	717	0.212
Food	991	77	0.078
Beverages, Tobacco, and Feed	171	21	0.123
Textile	539	32	0.059
Clothing	430	23	0.053
Lumber and Wood Products	166	16	0.096
Furniture and Fixtures	193	18	0.093
Pulp and Paper Products	342	7	0.020
Printing and Publishing	517	29	0.056
Chemical Products	643	102	0.159
Petroleum and Coal Products	38	5	0.132
Plastic Products	487	49	0.101
Rubber Products	99	6	0.061
Leather Products	53	3	0.057
Ceramic, Stone, and Clay	529	50	0.095
Iron and Steel	357	24	0.067
Nonferrous Metals	257	18	0.070
Metal Products	825	67	0.081
General Machinery	1,209	134	0.111
Electrical Machinery	1,268	131	0.103
Transportation Equipment	719	61	0.085
Precision Instruments	260	31	0.119
Miscellaneous Products	218	13	0.060

Source: Ministry of Economy, Trade and Industry, "Results of the Basic Survey of Japanese Business Structure and Activities 1992" Vol. 1, own calculation.

Table 2: Definitions of the Variables

TESUCCESS	The outcomes of cooperative R&D were applied for patents or utility models = 1, otherwise 0.
COSUCCESS	The outcomes of cooperative R&D contributed to sales growth = 1, otherwise 0.
RDINPUT	Internal R&D activity (sum of 3 dummy variables) 1)
COOPSIZE	Number of participants (scores from 1 to 4) 2)
DIFFIND	Cooperation between firms in different industries = 1, otherwise 0
BUSPART	Cooperation with customers or suppliers = 1, otherwise 0
LARGE	Cooperation with large firms = 1, otherwise 0
UNIV	Cooperation with universities and public research institutes = 1, otherwise 0 3)
SUBSIDY	The project received public subsidy = 1, otherwise 0.
EXPER	The respondent has past experience of cooperative R&D = 1, otherwise 0.
CONTACT	The respondent was familiar with other members beforehand = 1, otherwise 0.
FORMAL	The project was organized as a cooperative association or joint venture = 1, otherwise 0.
RULE1	Costs and outcomes of the project were shared equally = 1, otherwise 0.
RULE2	Costs and outcomes of the project were shared according to technological ability and contribution of the members = 1, otherwise 0.
WEIGHT	Relative weight of the project in the entire business activity of the respondents (5-point Likert scale; 5 indicates the highest weight).
ZEROSTART	The project started with looking for a research subject = 1, otherwise 0.

1) Sum of the values of the following 3 dummy variables: Budgeting R&D expenses every year = 1; Employing full-time R&D personnel = 1; Existence of R&D department = 1 (otherwise 0)

2) Score 1: 2 firms; Score 2: 3—5 firms; Score 3: 6—10 firms; Score 4: 11 or more firms

3) Including direct participation of the personnel of universities etc., consulting with the personnel of universities etc., outsourcing of research task to universities etc., and utilizing research facilities and equipments of universities etc.

Table 3: Sample Statistics and Hypotheses (n = 255)

Variables	Hypotheses	Mean	Stand. Dev.	Max.	Min.
TESUCCESS		0.376	0.485	1	0
COSUCCESS		0.427	0.496	1	0
RDINPUT		1.953	1.060	3	0
COOPSIZE	1a (+), 1b (–)	1.583	0.695	4	1
DIFFIND	2a (+), 2b (–)	0.672	0.470	1	0
BUSPART	3 (+)	0.681	0.467	1	0
LARGE	4 (+)	0.610	0.489	1	0
UNIV	5 (+)	0.445	0.498	1	0
SUBSIDY	6a (+), 6b (–)	0.255	0.437	1	0
EXPER	7 (+)	0.610	0.489	1	0
CONTACT	8 (+)	0.650	0.478	1	0
FORMAL	9a (+), 9b (–)	0.127	0.334	1	0
RULE1	10 (+)	0.079	0.271	1	0
RULE2	10 (+)	0.073	0.261	1	0
WEIGHT		2.478	1.236	5	1
ZEROSTART		0.197	0.398	1	0

Notes: Expected signs of coefficients in the regression analyses are in parentheses.
RDINPUT, WEIGHT, and ZEROSTART are regarded as control variables.

Table 4: Determinants of "Technological Success"

Probit Models; Dependent Variable = TESUCCESS

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	–1.05 b	–1.02 a	–0.952 a	–1.03 b	–1.05 c	–1.27
RDINPUT	.254 a	.277 a	.273 a	.251 b	.449 a	.539 a
COOPSIZE	–.00220			–.0530		–.178
DIFFIND	.485 b			.558 b		.564 c
BUSPART	–.239			–.314		–.332
LARGE	.577 a			.593 a		1.02 a
UNIV	.147			.152		.613 b
SUBSIDY		.282		.0559		–.428
EXPER			–.104	–.0640		–.600 c
CONTACT			.331 c	.448 b		.878 a
FORMAL					–.214	.189
RULE1					–.131	–.538
RULE2					1.48 a	1.68 a
WEIGHT	.164 b	.174 b	.155 b	.149 c	.123	.136
ZEROSTART	.169	.0458	.0800	.113	–.0920	.135
Industry Dummies	included	included	included	included	included	included
Log likelihood	–134.0	–146.2	–144.8	–131.4	–81.3	–65.2
Pseudo R-square	.152	.102	.109	.176	.253	.398
No. of observations	228	237	236	228	149	144

Note: Level of significance: a, 1%; b, 5%; c, 10%.

Table 5: Determinants of "Commercial Success"

Probit Models; Dependent Variable = COSUCCESS

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	–1.87 a	–1.21 a	–1.58 a	–2.15 a	–.0429	–.882
RDINPUT	.235 b	.178 c	.139	.242 b	.00847	.0359
COOPSIZE	.287 c			.367 b		.518 c
DIFFIND	.164			.222		.414
BUSPART	.650 a			.583 a		624 c
LARGE	–.243			–.297		–.811 b
UNIV	–.594 a			–.434 b		–.598 b
SUBSIDY		–.689 a		–.587 b		.481
EXPER			.568 a	.503 b		.441
CONTACT			–.0565	–.0876		–.247
FORMAL					–.354	–.953 c
RULE1					.148	–.0379
RULE2					.261	.567
WEIGHT	.285 a	.315 a	.294 a	.262 a	.172 c	206 c
ZEROSTART	–1.13 a	–.990 a	–.943 a	–.888 a	–1.36 a	–1.49 a
Industry Dummies	included	included	included	included	included	included
Log likelihood	–117.8	–128.5	–128.7	–112.4	–82.9	–68.2
Pseudo R-square	.305	.238	.244	.348	.188	.320
No. of observations	228	237	236	228	149	144

Note: Level of significance: a, 1%; b, 5%; c, 10%.

Table 6: Summary of the Empirical Results

Variables	TESUCCESS	COSUCCESS	Supported Hypothesis
RDINPUT	+	+	(control)
COOPSIZE		+	1a
DIFFIND	+		2a
BUSPART		+	3
LARGE	+		4
UNIV		–	
SUBSIDY		–	6b
EXPER		+	7
CONTACT	+		8
FORMAL			
RULE1			
RULE2	+		10
WEIGHT	+	+	(control)
ZEROSTART		–	(control)

Note: "+" or "–" in the columns suggest that the coefficients of the variables have positive or negative significant signs.

Appendix 1: Summary of the Findings from the Survey
(sample size = 255 firms)

1. Basic Firm Characteristics	
average number of employees	126
average firm age (years since foundation)	56
R&D activity	
1) budgets R&D expenditure every year	64%
2) employs full-time R&D personnel	58%
3) has an R&D department	73%
4) introduced a new product into the market last year	62%
5) applied for a patent last year	52%
experience of cooperative R&D before the last project	61%
2. Partners	
cooperation with one firm only (cooperation between two firms)	52%
cooperation with firms in different industries	67%
cooperation with large firms (with more than 300 employees)	61%
cooperation with business partners (customers and/or suppliers)	66%
cooperation with universities and public research institutes	44%
1) direct participation of the personnel	11%
2) utilization of research facilities and equipments	3%
3) outsourcing research tasks	12%
4) technical consultation	18%
3. Project Organization	
1) formal organization (cooperative association or joint venture)	13%
2) informal organization with contract	61%
3) informal organization without contract	26%
4. Rules	
Cost sharing	
1) equal sharing	19%
2) according to financial ability	10%
3) according to research capability	18%
4) according to assigned tasks	46%
5) according to expected shares of outcomes	7%
public subsidies received	26%
Project outcomes	
1) new product or process developed	49%
2) outcomes were applied for patent or utility model	38%
3) outcomes contributed to sales growth	43%
Outcome sharing	
1) equal sharing	22%
2) according to financial contribution	13%
3) according to technological contribution	34%
4) no agreements; free access and utilization	31%

Source: Original survey data

Appendix 2: Correlation Matrix

Variables	*TESUCCESS*	*COSUCCESS*	*RDINPUT*	*COOPSIZE*	*DIFFIND*	*BUSPART*	*LARGE*	*UNIV*
TESUCCESS	1.000							
COSUCCESS	0.049	1.000						
RDINPUT	0.188	0.143	1.000					
COOPSIZE	0.014	0.018	-0.165	1.000				
DIFFIND	-0.159	0.027	-0.001	-0.227	1.000			
BUSPART	-0.059	0.201	-0.076	-0.122	0.101	1.000		
LARGE	0.207	0.106	0.143	-0.085	-0.061	0.215	1.000	
UNIV	0.065	-0.250	-0.018	0.197	-0.128	-0.095	0.001	1.000
SUBSIDY	0.048	-0.262	-0.015	0.317	-0.176	-0.233	-0.180	0.406
EXPER	0.040	0.295	0.120	-0.137	0.102	0.115	0.127	-0.156
CONTACT	0.111	0.055	-0.004	-0.008	0.175	0.209	0.074	-0.037
FORMAL	-0.075	-0.089	-0.100	0.368	0.061	-0.124	-0.181	0.129
RULE1	0.029	-0.024	-0.036	0.260	0.008	-0.065	0.031	0.111
RULE2	0.258	0.008	0.149	-0.200	0.026	-0.023	0.071	0.003
WEIGHT	0.139	0.284	0.083	-0.087	0.149	0.197	0.173	-0.142
ZEROSTART	0.011	-0.251	-0.042	0.161	-0.045	-0.132	-0.132	0.165

Variables	*SUBSIDY*	*EXPER*	*CONTACT*	*FORMAL*	*RULE1*	*RULE2*	*WEIGHT*	*ZEROSTART*
TESUCCESS								
COSUCCESS								
RDINPUT								
COOPSIZE								
DIFFIND								
BUSPART								
LARGE								
UNIV								
SUBSIDY	1.000							
EXPER	-0.281	1.000						
CONTACT	0.086	0.147	1.000					
FORMAL	0.301	-0.114	0.019	1.000				
RULE1	-0.061	-0.090	0.079	0.194	1.000			
RULE2	0.087	0.005	-0.049	-0.104	-0.082	1.000		
WEIGHT	-0.140	0.209	0.184	-0.032	0.118	0.056	1.000	
ZEROSTART	0.266	-0.283	0.033	0.190	0.216	0.022	-0.104	1.000