Determinants of R&D cooperation in Japanese start-ups

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Abstract

This paper explores the determinants of R&D cooperation in Japanese start-ups. Using a sample from an original survey conducted in 2008, we examine the effects of founder-, firm-, and industry-specific characteristics on R&D cooperation by type of partners. Our findings indicate that founder-specific characteristics such as educational background, prior innovation output, and affiliation to academic associations are fairly important in determining R&D cooperation with academic institutes (universities and public research institutes). We also provide evidence that founders' prior innovation output and work experience have positive and significant effects on R&D cooperation with business partners. With respect to firm-specific characteristics, it is found that firms investing more in R&D tend to engage in R&D cooperation, regardless of the type of partners. Furthermore, it is found that independent firms are less likely to cooperate in R&D with academic institutes than subsidiaries and affiliated firms.

Keywords: Start-up; R&D cooperation; Founder; Human capital; University; Business partner.

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1. Introduction

This paper explores the determinants of research and development (R&D) cooperation in Japanese start-ups, using a sample from an original survey conducted in 2008. We examine the effects of founder-, firm-, and industry-specific characteristics on R&D cooperation according to the type of partners. In particular, we focus on the role of founders' human capital, which has been ignored in the literature on R&D cooperation. Understanding the determinants of R&D cooperation in start-ups will provide clues on how to create and improve opportunities for research matching, which would contribute to building national innovation systems through start-ups.

Many existing studies argue that small businesses play an important role in a large fraction of innovations (e.g., Acs and Audretsch, 1990). More recently, special attention has been paid to start-ups as the sources of regional innovation and productivity (e.g., Acs and Armington, 2006; Audretsch et al., 2006). However, it is not easy for small start-ups to successfully innovate because of their limited business experience and resources. To compensate for these deficiencies, alliances with external organizations—particularly for R&D cooperation—are considered to be an effective strategy for start-ups. R&D cooperation would allow start-ups to not only obtain complementary assets but also share costs and risks, thereby improving R&D productivity.

The role of founders' human capital in start-ups has also been discussed in the literature. Colombo and Grilli (2005) argued that, according to the competence-based view, new technology-based firms (NTBFs) established by individuals with greater human capital should outperform other NTBFs because of their unique capabilities. They emphasized that the capability effect of founders' human capital has a positive impact on the performance of NTBFs. That is, founders' human capital is a valuable resource of the start-up and plays a critical role in its performance. While the firm's performance reflects corporate strategy, including the decision to form an alliance, the founder's human capital may exert significant influence on the types of alliances, including R&D cooperation. Previous studies on R&D cooperation, however, have ignored the role of founders' human capital. We thus attempt to provide new evidence for the significant role played by founders' human capital in the R&D cooperation of start-ups.

Our empirical results suggest that founders' human capital is important in the determination of R&D cooperation, although its effects vary according to the type of partners. More specifically, the results show that founders' educational background, prior innovation output, and affiliation to academic associations significantly affect R&D cooperation with academic institutes (universities and public research institutes), while their prior innovation output and work experience have positive and significant effects on R&D cooperation with business partners. Furthermore, it is found that independent firms are less likely to cooperate in R&D with academic institutes than subsidiaries and affiliated firms.

The remainder of this paper is organized as follows. In Section 2, we review previous studies on the determinants of R&D cooperation and discuss some differences between these studies and the present paper. In Section 3, we discuss the theoretical background and develop our hypotheses on the determinants of R&D cooperation. Section 4 describes the data used in the analysis. Section 5 presents the empirical results. The final section provides some concluding remarks.

2. Literature review

R&D cooperation has stimulated a rich stream of literature.[1] As is often argued, R&D cooperation is a useful means of exploiting external technologies and knowledge. R&D cooperation can allow firms to obtain complementary assets and to share costs and risks. For start-ups whose resources tend to be limited, R&D cooperation appears more effective.

In the fields of economics and management, many studies have investigated the determinants

[1] For theoretical discussions on R&D cooperation, see, for example, Katz (1986), d'Aspremont and Jacquemin (1988), and Suzumura (1992).

of R&D cooperation from various perspectives. Table 1 summarizes the findings of major empirical studies in recent years on the determinants of R&D cooperation. Among them, some studies have examined R&D cooperation between firms, focusing on large established firms (e.g., Bayona et al., 2001; Fritsch and Lukas, 2001). Other studies have examined the determinants of R&D cooperation between firms and universities (e.g., Veugelers and Cassiman, 2005). Bayona et al. (2001), for example, explored the motives of industrial firms to cooperate in R&D, using a sample of Spanish firms. They found that firms with sufficient capacity to carry out R&D tend to cooperate in R&D, and the reasons for cooperative R&D differ overall between large and small firms. Moreover, Cassiman and Veugelers (2002) and Lòpez (2008) emphasized the roles of incoming spillovers and appropriability as well as the costs and risks of innovative activities in determining R&D cooperation, considering the endogeneity of important variables.

While most studies tend to focus on R&D cooperation involving large firms, only a few studies, including Bayona et al. (2001), have addressed the R&D cooperation of small and medium-sized enterprises (SMEs). With respect to the alliance of SMEs, Fontana et al. (2006) examined the determinants of R&D cooperation between firms and public research organizations including universities, using a sample of innovative SMEs in European countries. Muscio (2007) also examined the impact of absorptive capacity on SMEs' collaboration with firms, universities, and technology transfer centers. To date, however, little is known about R&D cooperation in start-ups, except for the findings of Colombo et al. (2006), who examined the determinants of commercial and technological alliances by Italian high-tech start-ups.

On the other hand, it has often been argued that the success of start-ups is dependent on their founders' human capital. Bates (1990), for example, argued that the entrepreneurs' human capital inputs affect small business longevity, and Cressy (1996) emphasized that human capital is the true determinant of firm survival. In addition, some empirical studies have provided evidence on the relationship between firm growth and the human capital of founders or entrepreneurs (e.g., Honjo, 2004; Colombo and Grilli, 2005). These studies have indicated that founders' human capital is a valuable resource for start-ups and plays a critical role in the firm's performance, partly because it can compensate for lack of business experience and resources. However, as repeatedly mentioned, the role of founders' human capital in R&D cooperation tends to be ignored in the literature. Colombo et al. (2006) examined the determinants of the alliances of Italian high-tech start-ups; however, surprisingly, they do not confirm any effects of founders' human capital, such as education and professional experience.[2] In this respect, it is unclear whether or not R&D cooperation is affected by founders' human capital, and further investigation is required to reach a conclusive answer.

Moreover, some studies have focused on R&D cooperation between firms and academic institutes (universities and/or public research institutes). For example, Mohnen and Hoareau (2003) investigated the determinants of R&D cooperation between firms and universities or government laboratories, using a sample of French, German, Irish, and Spanish firms.[3] They provided evidence that firm-specific characteristics, such as patent holding, group affiliation, and subsidies, affect R&D cooperation. Fontana et al. (2006) also examined the determinants of R&D cooperation between firms and academic institutes with a sample of innovative SMEs in Europe, and argued that the openness of firms to the external environments significantly affects the probability of R&D cooperation with academic institutes.

Furthermore, other studies, such as Fritsch and Lukas (2001) and Miotti and Sachwald (2003), provided evidence of some differences in the determinants of R&D cooperation among different

[2] On the other hand, Colombo and Grilli (2005) found that the nature of the education and prior work experience of founders exerts a key influence on firm growth.
[3] Mohnen and Hoareau (2003) used data from the Community Innovation Surveys (CIS) in European countries. As shown in Table 1, some studies have used data from each country's version of the CIS to capture R&D cooperation: Tether (2002) for the UK, Miotti and Sachwald (2003) for France, Belderbos et al. (2004) for the Netherlands, Veugelers and Cassiman (2005) for Belgium, and Lòpez (2008) for Spain.

types of partners. These results suggested that R&D cooperation varies according to the type of partners and that the determinants of R&D cooperation with academic institutes may differ from those with other types of external organizations, such as customers and suppliers.

Regarding R&D cooperation in Japan, for example, Branstetter and Sakakibara (1998, 2002) highlighted government-sponsored research consortia among large firms, and Motohashi (2005) examined the determinants of university-industry collaborations.[4] Okamuro (2007) investigated the determinants of successful R&D cooperation in Japanese SMEs. However, these studies have analyzed the R&D cooperation of established firms, whereas R&D cooperation of start-ups in Japan has not yet been investigated. While, as is often argued, Japan has achieved technological catch-up and is now striving for technological leadership, the country is characterized by almost the lowest ratio of business start-ups among OECD countries. Hence, policy makers are concerned about the lack of entrepreneurs to propel future economic growth. This study on R&D cooperation in start-ups would provide a new perspective on the opportunities for research matching in support of national innovation systems in countries with low start-up ratios, such as Japan.

3. Hypotheses

The founders of start-ups have more influence on the firms' strategies, including R&D cooperation, than the top managers of established firms, but the effects of founder-specific characteristics on R&D cooperation have been ignored in the literature. According to the competence-based view, founders' human capital is reflected in the way their capabilities affect the strategies of start-ups. Moreover, high human capital is likely to contribute to the development of valuable networks. Founders with high human capital attract external research partners, which may

[4] In addition, Miyata (1995) examined the determinants of R&D cooperation in Japanese firms, focusing on industry effects.

promote R&D cooperation.

In addition to these direct effects, founders' human capital signals their firms' capabilities to potential partners under uncertainty and information asymmetry. As Spence (1973, 1974) argued, workers' education levels can provide a positive signal of their capability to employers even if it does not change their productivity. A similar argument can be applied to the relationship between founders and potential research partners. Moreover, as pointed out by Fontana et al. (2006), technical and scientific capabilities of firms attract potential partners and open new opportunities for collaboration. These arguments lead us to assume that R&D cooperation of start-ups depends on founder-specific characteristics. Here, we use educational background, prior innovation output, and work experience as the measures of founder-specific characteristics affecting R&D cooperation.

As already mentioned, R&D cooperation may vary according to the type of partners. Specifically, the determinants of R&D cooperation with academic institutes (universities or public research institutes) may differ from those with business partners, including customers and suppliers. Therefore, we examine the determinants of R&D cooperation with academic institutes and with business partners separately. In the following hypotheses, however, we consider how founders' human capital affect R&D cooperation for either of the two types. In Section 5, we will further discuss our findings on the differences between the types of partners.

First, let us consider founders' educational background. Colombo and Grilli (2005) argued that, according to the competence-based view, the distinctive capabilities of NTBFs are closely related to the knowledge and skills of their founders. As pointed out by Colombo and Grill, generic human capital is related to the general knowledge acquired by entrepreneurs both through formal education and professional experience. In practice, most studies have used educational background as a measure of founders' human capital (e.g., Bates, 1990; Åstebro and Bernhardt, 2003). Colombo and Grilli (2005) also measured founders' human capital by years of education. As discussed before, the signaling received by research partners in regard to founders' capabilities may influence opportunities for start-ups in R&D cooperation. Moreover, founders' educational background may act as the source of their networks for R&D. It is likely that the longer the academic education, the wider the network with researchers in external organizations that, in this paper, indicate academic institutes or business partners. Therefore, we formulate the following hypothesis.

Hypothesis 1. Firms with highly educated founders are more likely to engage in R&D cooperation with external organizations.

In addition to educational background, founders' experiences in innovation prior to start-up are considered to be a measure of human capital affecting R&D cooperation. Colombo et al. (2006) argued that the synergistic gains from technological alliances depend on the technological competencies of NTBFs.[5] As discussed earlier, founders of start-ups are expected to exert greater influence on the decision to engage in R&D cooperation than the top managers of established firms. Since start-ups lack business experience and a track record, founders' human capital plays a crucial role as a valuable resource for start-ups. Therefore, the prior innovation output of the founders themselves, rather than that of the firms, may signal the technological competencies of start-ups. From these reasons, we obtain the following hypothesis.

Hypothesis 2. Firms whose founders had innovation output prior to start-up are more likely to engage in R&D cooperation with external organizations.

Moreover, founders' affiliation to academic associations may affect the probability of R&D cooperation. Through participation in academic associations, especially those in the natural sciences,

[5] Narin et al. (1987) argued that firms' prior innovation output as measured in patents signals the competencies of the firms to third parties.

including engineering, founders can build their networks with researchers in external organizations, especially research organizations in the natural sciences[6]. Further, the affiliation to academic associations tends to reflect the founders' innovation potential and willingness to collect the most recent research available, which may provide a signal to research partners. Therefore, R&D cooperation with external organizations, especially with academic institutes, may be associated with whether or not the firm's founder belongs to an academic association in the natural sciences including engineering. Hence, we propose the following hypothesis.

Hypothesis 3. Firms whose founders are affiliated to academic associations in the natural sciences are more likely to engage in R&D cooperation with external organizations.

Founders' professional experience may also be associated with R&D cooperation. If the founders have prior work experience in a related field, they can take more advantage of their network at start-up. In addition, if they have managerial experience in other firms at start-up, they are expected to have more managerial skills as well as a wider business network with external organizations, than those without any managerial experience. In particular, prior work experience in a related field may play an important role in R&D cooperation with business partners, including customers and suppliers. Therefore, we formulate the following hypothesis.

Hypothesis 4. Firms whose founders have prior work experience in a related field or managerial experience in other firms are more likely to engage in R&D cooperation with external organizations.

In the following sections, we examine the determinants of R&D cooperation on the basis of

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[6] In this paper, we focus on academic associations in the natural sciences, which do not include those in human or social sciences. Membership of associations in the human or social sciences hardly provides the founders with useful contacts with professional researchers in natural sciences. Therefore, in the questionnaire survey that provides the dataset used in this paper, which will be explained in the following section, we intentionally restricted academic associations to those in the natural sciences, including engineering.

the preceding hypotheses, using original data on Japanese start-ups. Moreover, by examining the determinants of R&D cooperation separately by type of partners, we will show how the determinants of R&D cooperation differ between academic institutes and business partners.

4. Data

4. 1. Data sources

To the best of our knowledge, there exists no data source for R&D activities by start-ups in Japan. In order to construct a sample of start-ups for our research project, we conducted a postal questionnaire survey in 2008. We sent questionnaires to 13,582 firms in the Japanese manufacturing and software industries, which were incorporated between January 2007 and August 2008.[7] The list of firms for the survey was obtained from a database compiled by Tokyo Shoko Research (TSR), a major credit investigation company in Japan. In the questionnaire survey, we asked the founders about firm-specific characteristics, including R&D activities, as well as their personal attributes.[8]

The number of effective responses was 1,514 (approximately 11% of the target). With regard to industry structure and location, the respondents were not considerably different from the target firms as a whole, though software firms are more strongly represented among the respondents than manufacturing start-ups. From among the responses, we selected 1,060 "real" start-ups that had started their businesses during 2007 and 2008.[9] Then, we identified 672 R&D-oriented firms whose founders conducted R&D or that employed R&D personnel when starting their businesses or afterward.[10] As a result, we obtained 499 firms in the final sample because of missing values for some variables.

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[7] Among 14,401 firms to which we sent the questionnaires, 819 firms could not be reached.

[8] Since many firms start businesses with multiple founders, we asked the respondents about the number of co-founders. In practice, our sample includes firms with multiple founders. In the case of multiple founders, we asked the firm about the president.

[9] Thus, we excluded the firms that were established before December 2006 as sole proprietors and incorporated after January 2007.

[10] The ratio of R&D-oriented firms to all the respondents appears to be fairly high. This is in part attributable to our broad definition of R&D-oriented firms and to the fact that we target relatively R&D-intensive industries for the purpose of our research project, but we cannot exclude response bias.

While we compiled data on founder- and firm-specific characteristics, including R&D cooperation, from the survey, we used another data source to collect data on industry-specific characteristics. Data on the appropriability of innovation output and technological opportunities were obtained from the *Report on the Japanese National Innovation Survey 2003*, compiled by the National Institute of Science and Technology Policy (NISTEP) of the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

4. 2. R&D cooperation

In the questionnaire survey, we asked the founders whether or not they engaged in R&D cooperation with academic institutes (universities or public research institutes), or with business partners, including customers and suppliers.[11] Table 2 provides summary statistics for R&D cooperation by type of partners. As shown here, 61 of 499 firms (approximately 12%) engaged in R&D cooperation with academic institutes, while 141 firms (approximately 28%) cooperated in R&D with business partners.

With respect to the sub-samples by industry in Table 2, the propensity for R&D cooperation is the highest in the chemical and precision machinery industries, regardless of the type of partners. On the whole, start-ups in the manufacturing sector are more likely to cooperate in R&D than those in the software sector. Further, the propensity for R&D cooperation tends to vary across industries and according to the type of partners, even in the same industry.

4.3. Determinants of R&D cooperation

In this paper, we investigate the determinants of R&D cooperation using regression models and test the hypotheses developed in Section 3. On the basis of the questionnaire survey, the dependent variables for R&D cooperation are defined as two dummies that take the value of one if

[11] In our questionnaire survey, we could not clearly identify if a founder was really new to R&D cooperation with academic institutes or business partners. Therefore, the possibility remains that the founders in our sample had already engaged in R&D cooperation before starting their businesses.

the firm engages in R&D cooperation with academic institutes (universities or public research institutes) (*C_UNIV*) and with business partners (*C_FIRM*), respectively, and zero otherwise.[12]

Table 3 presents the definitions of both dependent and independent variables; the latter will be discussed below in detail. In addition, Table 4 shows the summary statistics of the dependent and independent variables. Table 5 provides the mean values of the independent variables for the sub-samples by type of partners and the statistical significance of the differences of mean values between the sub-samples. The correlation matrix of the variables is shown in Table A1 of Appendix.

4.3.1. Founder-specific characteristics

With respect to founder-specific characteristics, the variables for education level, work experience, and prior innovation output are included in the model. First, we use dummy variables to examine the effects of founders' education level: undergraduate university education (*UEDU*), graduate school education (*GEDU*), or others (reference variable). Table 4 indicates that 48% of the founders had achieved a bachelor's degree and 10% a master's or doctorate degree. As shown in Table 5, the means of *GEDU* are significantly different between the sub-samples of the firms that engaged in R&D cooperation and the others for *C_UNIV*, suggesting that the firms whose founders had graduate school education tend to conduct R&D cooperation with academic institutes.

Second, the variables for founders' prior innovation output are also included in the model. Prior innovation output is defined as two dummies, each taking the value of one if the founders achieved product/process innovations (*INNOV*) and patent applications (*PAT*) before start-up, and zero otherwise. As shown in Table 4, founders had prior experience of product/process

12 In the questionnaire survey, we asked the founders whether they conducted R&D cooperation with (1) universities, (2) public research institutes, and (3) business partners. Then, we combined the responses to (1) and (2) as R&D cooperation with academic institutes, because only 2% of the firms engaged in R&D cooperation with public research institutes.

innovations and patent applications, before start-up, in 33% and 19% of firms respectively. The means of *INNOV* and *PAT* shown in Table 5 highlight considerable differences between the firms that engaged in R&D cooperation and the others, regardless of the type of partners. Table 5 indicates that 57% and 43% of the sample firms that take the value of one for *INNOV*, respectively, engaged in R&D cooperation with academic institutes, while 50% and 30% of the firms that take the value of one for these variables, respectively, cooperate on R&D with business partners. With a *PAT* of 1*,* the corresponding figures are 43% and 30% respectively These differences are statistically significant for both variables and the types of partners.

Third, the model includes a dummy variable for firms whose founders are affiliated to academic associations in the natural sciences (*ACAD*). As shown in Table 4, 13% of the founders in our sample are affiliated to academic associations in the natural sciences. Table 5 indicates that 40% of the firms whose founders are affiliated to academic associations cooperate in R&D with academic institutes, while only 10% of the firms whose founders have no membership in academic associations cooperate in R&D with these institutes, and that this difference is statistically significant. Regarding R&D cooperation with business partners, however, the propensity for R&D cooperation does not significantly vary according to the affiliation of the founders with academic associations.

Fourth, we include two dummy variables for founders' professional experiences in the model. One is a dummy taking the value of one for firms whose founders had prior work experience in a related field before start-up, and zero otherwise (*WEXP*); the other is a dummy that takes on the value of one if the firms' whose founders had prior managerial experience before start-up, and zero otherwise (*MEXP*). Table 4 shows that, before start-up, 87% of the founders in our sample worked in the a related field and 37% as managers of other firms. Table 5 suggests that as regards the means of these variables there are no significant differences between the firms that engaged in

R&D cooperation with academic institutes and the others. , there are no significant differences in the means of these variables. The same applies to the propensity of for R&D cooperation with business partners.

Finally, we include as a control variable in the model the founders' age at start-up (*AGE*). In the sample, the minimum and maximum ages of founders at start-up are 20 and 80 years respectively. The natural logarithm of founders' age at start-up is used in the regressions. As shown in Table 5, the founders of start-ups engaged in R&D cooperation with academic institutes are significantly younger than the others, while there are no significant differences between the mean start-up ages with regard to R&D cooperation with business partners.

4.3.2. Firm-specific characteristics

The variable for firm size (*SIZE*), measured as the natural logarithm of the number of employees at start-up, is included in the model as a firm-specific characteristic affecting R&D cooperation. The median of the number of employees in the sample is 2, indicating that the sample consists of very small firms. As shown in Table 5, the propensity for R&D cooperation significantly varies according to firm size only with regard to cooperation with business partners. The variable for R&D expenditures (*RD*), measured as their natural logarithm, is also used as an independent variable.[13] As shown in Table 5, there are significant differences between the means of this variable for the firms that engage in R&D cooperation and others, with regard to both types of partners.

Moreover, a dummy variable for independent firms (*IND*), as compared to subsidiaries or affiliated firms, is used as an independent variable in the model. As shown in Table 4, 83% of the sample firms are independent firms. As pointed out by Mohnen and Hoareau (2003), firms that belong to large corporate groups might be able to tap information from universities/government

[13] Instead of R&D expenditure, we also used R&D intensity, defined as the number of R&D personnel divided by the total number of employers and employees. Because of missing values for R&D personnel, the sample size was reduced considerably in the model with R&D intensity. In fact, the effect of R&D intensity was not significant, and, hence, we do not use R&D intensity in the model.

laboratories or establish contact with them more easily through this network. Indeed, according to Table 5, independent firms are significantly less likely to cooperate with academic institutes, while this is not the case for R&D cooperation with business partners.

As discussed by Colombo et al. (2006), the presence of co-founders may also influence R&D cooperation. Therefore, we include a dummy variable for multiple founders (*MFOUND*) as a control variable. In fact, as shown in Table 4, 47% of the sample firms have multiple founders. However, Table 5 shows no significant differences between the firms with and without co-founders as regards their propensity for R&D cooperation, regardless of the type of partners[14].

In addition, we include two control variables for the reasons behind the choice of business field and location. In the questionnaire, we asked the founders the most important reason they chose the current business and start-up location. We constructed a dummy variable for business choice (*DBUSI*), which takes the value of one if the most important reason for the choice of the current business is to make the best use of unique capabilities and technologies, and zero otherwise. We use another dummy variable for location choice (*DLOC*), which takes the value of one if the most important reason for the location choice is easy access to necessary information and technologies, and zero otherwise. Table 5 shows that the differences in these variables are significant only for R&D cooperation with business partners.

4.3.3. Industry-specific characteristics

Furthermore, we include variables for industry-specific characteristics as control variables in the model.[15] Following Okamuro (2009), variables for appropriability (*APPROP*) and technological opportunities (*TECHOPP*) are used to control for differences in the technological environments

[14] From the questionnaire survey, we obtained some information on co-founders such as the number of co-founders and their roles in the management. Later, we briefly report the estimation results using these additional variables on co-founders.

[15] Instead of these variables, we estimated the model with industry dummies at the two-digit level to control for industry-specific characteristics. Because the estimation results using industry dummies are consistent with those using *APPROP* and *TECHOPP*, we report only the results with these variables.

among industries. *APPROP* is defined as the extent to which the innovative outcomes can be appropriated by the innovators themselves. *TECHOPP* denotes the availability of useful information for innovation.[16] Table 5 suggests that start-up firms in the industries with higher appropriability are significantly more likely to cooperate with academic institutes than those in other industries, while firms in industries with higher technological opportunities are significantly less likely to cooperate with business partners than those in other industries.

5. Estimation methods and results

5.1 Estimation methods

We examine the determinants of R&D cooperation in Japanese start-ups by estimating regression models. We comparably estimate the determinants of R&D cooperation with academic institutes and with business partners. Our empirical model is described as follows:

$$\text{Prob}\ (\mathit{Cooperation} = 1) = f\,(\mathit{Founder}, \mathit{Firm}, \mathit{Industry}) + \varepsilon, \qquad (1)$$

where *Cooperation* represents *C_UNIV* or *C_FIRM*. *Founder*, *Firm*, and *Industry* indicate founder-specific, firm-specific, and industry-specific characteristics, respectively. ε is the error term.

Since R&D cooperation is measured by binary variables, we adopt a binary choice model. Because the decisions on R&D cooperation with academic institutes and with business partners may be simultaneous or correlated to each other, we considered a bivariate probit model assuming a correlation between the error terms of the two models, with *C_UNIV* and *C_FIRM* as dependent variables. However, because this assumption was rejected, we will report the results of the univariate probit models instead of the bivariate probit model.[17]

5.2 Estimation results

[16] For more details on the construction and measurement of these variables, see Okamuro (2009).
[17] In fact, the estimation results of the bivariate probit model are quite similar to those of the univariate probit model.

In Table 6, we show the estimation results of the probit models for the determinants of R&D cooperation with academic institutes (*C_UNIV*) in columns (i) and (ii) and those with business partners (*C_FIRM*) in columns (iii) and (iv).

With respect to the founder-specific characteristics, Table 6 demonstrates that the variable for graduate school education (*GEDU*) has a positive and significant effect on R&D cooperation with academic institutes (*C_UNIV*), but no significant effect on R&D cooperation with business partners (*C_FIRM*). However, the variable for undergraduate education (*UEDU*) has no significant effect on R&D cooperation, regardless of the type of partners. These results indicate that firms with highly educated founders are more likely to cooperate in R&D with academic institutes, which supports Hypothesis 1.

In Table 6, the variables for founders' prior innovation output, *INNOV* and *PAT*, have both positive and significant effects on the probability of R&D cooperation, regardless of whether *C_UNIV* or *C_FIRM* are used as dependent variables. These results suggest that start-ups whose founders possess sufficient research capabilities are more likely to cooperate in R&D with external organizations, regardless of the type of partners, partly because research capabilities of founders act as a signal of the firms' capabilities to potential partners. These results support Hypothesis 2.

It is noteworthy that we can exclude a reverse causality for these variables in the sense that R&D cooperation might positively affect founders' prior innovation output, because founder-specific characteristics are fixed before start-up, while R&D cooperation refers to the strategy after start-up. However, some unobserved factors such as inherently high productivity of the founder may influence both pre-start-up innovation experience and post-start-up R&D cooperation. In this regard, we should stress that in our empirical estimation, we control for those variables that may reflect the potential productivity of founders, such as their educational background and work experiences.[18]

Moreover, as shown in columns (i) and (ii) of Table 6, the dummy variable for founders' affiliation to academic associations (*ACAD*) has a significantly positive effect on *C_UNIV*. In columns (iii) and (iv), however, *ACAD* does not have any significant effect on *C_FIRM*. While the effects of founders' professional experiences (*WEXP* and *MEXP*) are not significant in columns (i) and (ii), the coefficients of *WEXP* on *C_FIRM* indicate significantly positive signs in columns (iii) and (iv). These results support Hypotheses 3 and 4. Thus, these findings suggest that founders' own academic and business networks are important in determining R&D cooperation with academic and business partners respectively. As for the variable for founders' age (*AGE*), we do not find any significant association with *C_UNIV* and *C_FIRM*.

With respect to the variables for firm-specific characteristics, the coefficients of firm size (*SIZE*) are not significant in any of the models in Table 6. As already discussed, some previous studies found positive and significant effects of firm size on R&D cooperation. While most studies have used data on relatively large firms, as repeatedly explained earlier, we employ data on small start-ups. Therefore, our findings, which are not consistent with those of previous studies, may imply that the size effect on R&D cooperation is negligible with small firms, including start-ups; however, this effect appears to be significant among relatively large firms.

In contrast, the coefficients of R&D expenditures (*RD*) are positive and significant after controlling for firm size in all models of Table 6. These results suggest that firms investing more in R&D relative to their size tend to cooperate in R&D with external organizations, regardless of the type of partners. Our findings are consistent with Cohen and Levinthal (1990), who indicate that firms investing more in R&D are more likely to engage in R&D cooperation than others because of their sufficient absorptive capacity.

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[18] The authors thank an anonymous reviewer for suggesting this point.

The variable for independent firms (*IND*) has a negative and significant effect in columns (i) and (ii) of Table 6, but no significant effect in columns (iii) and (iv). This suggests that independent firms are less likely to cooperate in R&D with academic institutes, as compared to subsidiaries or affiliated firms. Our findings imply that subsidiaries and affiliated firms have wider networks than independent firms through parent or group companies, and therefore have more opportunities to engage in R&D cooperation. Moreover, overall, the coefficients of the variables for business and location choices (*DBUSI* and *DLOC*) are not significant in Table 6, although these variables were expected to have significant effects on R&D cooperation.

The dummy variable for multiple founders (*MFOUND*) has no significant effect. This finding suggests that, at least for our sample firms, the propensity to cooperate in R&D does not significantly depend on whether or not co-founders exist.[19]

As for the industry-specific characteristics, columns (i) and (ii) of Table 6 indicate that higher appropriability (*APPROP*) leads to R&D cooperation with academic institutes, while columns (iii) and (iv) indicate that this variable does not have any significant effect on R&D cooperation with business partners. Moreover, Table 6 shows that the variable for technological opportunities (*TECHOPP*) does not have any significant effects on R&D cooperation, regardless of the type of partners.

Overall, our hypotheses are supported in the empirical analyses. With respect to the founder-specific characteristics, founders' educational background, prior innovation output, affiliation to academic associations, and work experience are found to have positive effects on the propensity to cooperate in R&D. As for the differences between the types of partners, we find that founders' education background and membership in academic associations solely affect R&D

[19] To supplement this finding, we estimated the effects of additional variables of co-founders with a sub-sample of firms with multiple founders: The first one is the number of co-founders, and the second their role in the top management, which is measured as a subjective evaluation of the complementarity of their competence with that of the core founder by using a 5-point Likert scale. However, we could not obtain any significant results for these additional variables. The results of these additional estimations can be obtained from the authors upon request.

cooperation with academic institutes, while their work experiences solely affect R&D cooperation with business partners. In sum, the estimation results suggest that the founders' research capabilities and networks are fairly important factors in determining R&D cooperation, regardless of the type of partners.

5.3 Alternative estimations

In addition to the probit models, we consider alternative empirical models and discuss the estimation results of these models. As a robustness check, we conduct a multinomial probit estimation with four possible choices, an instrumental variable (IV) probit estimation considering the endogeneity of R&D expenditures, and a negative binomial estimation on the determinants of the number of cooperative R&D projects. The estimation results are shown in Table A2 of Appendix.

First, we estimate the determinants of R&D cooperation with a multinomial probit model with four choices (no R&D cooperation, cooperation with academic institutes only, cooperation with business partners only, and cooperation with both types), taking the first choice as the basic outcome. Among the respondents, 322 firms (65%) did not engage in R&D cooperation, 36 firms (7%) cooperated only with academic institutes, 116 firms (23%) cooperated only with business partners, and 25 firms (5%) cooperated with both types. As for the choices of R&D cooperation with either academic institutes only or business partners only, respectively, the estimation results of the multinomial probit model are not considerably different from those of the probit models[20].

We then adopt an instrumental variable (IV) probit model considering the endogeneity of R&D cooperation or intensity, following Cassiman and Veugelers (2002). Among the independent

[20] It is noteworthy that the observations for the choices "cooperation with academic institutes only" and "cooperation with both types" are very few and the probability of these choices is very low.

variables, R&D expenditures may be endogenous if we assume that they increase as a result of R&D cooperation. As the instrumental variable, we use industry's R&D intensity (the ratio of R&D expenditures to sales) at the two-digit level, which is expected to be significantly correlated with R&D expenditures of start-ups, but not with the propensity for R&D cooperation.[21] The estimation results show that the coefficients of R&D expenditures are still positive, though not significant with regard to the cooperation with academic institutes.[22] The effects of the other variables on the propensity of R&D cooperation do not change considerably. Therefore, we can conclude that the estimation results are robust even when the endogeneity of R&D expenditures is considered.

Finally, we examine the determinants of the number of cooperative R&D projects engaged in by start-ups. In the questionnaire survey, we also asked for the number of cooperative R&D projects, classified according to the type of partners. As discussed by Fontana et al. (2006), a decision to cooperate in R&D with other organizations may be different from a decision on the number of cooperative R&D projects. Therefore, we estimate the determinants of the number of cooperative R&D projects with academic institutes and business partners, using negative binomial models. However, the estimation results are quite similar to those of Table 6, except for the positive and significant effect of firm size (*SIZE*) on R&D cooperation with business partners.[23]

6. Conclusions

This paper has explored the determinants of R&D cooperation in Japanese start-ups. Using a

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[21] Data on industry's R&D intensity are obtained from the *Results of Basic Survey of Japanese Business Structure and Activities*, by the Ministry of Economy, Trade and Industry (METI).

[22] We estimate two-step IV probit model. In the first-step, we regress *RD* on all the assumed exogenous variables (all the independent variables in Table 3, except for *RD*) and the industry's average R&D intensity as an instrument.

[23] As Table 4 suggests, only 12% and 28% of our sample firms cooperate with academic institutes and business partners respectively. Most firms engaged in R&D cooperation, either with academic institutes or business partners, conduct just one project. Hence, the distributions of the observations of the dependent variables are in fact not considerably different from that of *C_UNIV* and *C_FIRM*. This may be the major reason that we do not find significant differences between the results of probit and negative binomial estimations.

sample from an original survey conducted in 2008, we examined the effects of founder-, firm-, and industry-specific characteristics on R&D cooperation according to the type of partners. Our findings indicate that founder-specific characteristics such as educational background, prior innovation output, and affiliation to academic associations are fairly important in determining R&D cooperation with academic institutes (universities and public research institutes). We also provide evidence that the effects of founders' work experience and prior innovation output are significant in determining R&D cooperation with business partners. With respect to firm-specific characteristics, it was found that the firms making larger investments in R&D tend to engage in R&D cooperation, regardless of the type of partners. Furthermore, it was found that independent firms are less likely to cooperate in R&D with universities and public research institutes than subsidiaries or affiliated firms.

However, this paper does have some limitations, which should be addressed in future research. While we found significant effects of founder-specific characteristics on the R&D cooperation of start-ups, we could not clearly identify the mechanism of how these characteristics affect R&D cooperation. For example, we cannot conclude whether R&D cooperation with academic institutes results from the signaling of superior capabilities arising from the founders' educational background or from the exploitation of networks by founders. In addition, we did not address the dynamic aspect of R&D cooperation, since we used cross-sectional data from our recent survey. Specifically, we cannot exclude the possibility that the founders started R&D cooperation before establishing their businesses, although our main motivation is to clarify the relationship, rather than to confirm the causality, between founders' human capital and R&D cooperation of start-ups. Further investigation with a panel data set obtained through repeated surveys is needed to better understand the process of R&D cooperation. Moreover, we have insufficient information on the characteristics of co-founders, although a half of our sample firms were started by multiple founders.[24]

Despite these limitations, this paper provides new evidence and yields new implications, thus contributing to the literature. While most previous studies have focused on the R&D cooperation of large established firms, we addressed the R&D cooperation of start-ups. In addition, we shed light on the roles of founders' human capital in R&D cooperation, which has been largely ignored in the literature. Our findings suggest that founders' human capital plays a critical role in determining the R&D cooperation of start-ups. In other words, we may be able to conclude that firms with greater human capital have better opportunities for R&D cooperation than those with less human capital.

From the viewpoint of public policy, this paper suggests that policy makers should pay more attention to founders' attributes in providing start-ups with opportunities for research matching with potential partners, especially academic institutes. Specifically, the support policy for R&D cooperation should more explicitly address the needs of founders with a "low" level of human capital who are willing to cooperate in R&D, because they face difficulties in finding optimal partners by themselves.

The Japanese government has provided various supports, including industrial cluster policies, for R&D cooperation between small firms and academic institutes (e.g., Nishimura and Okamuro, forthcoming). According to the OECD (2008), nevertheless, the ratio of Japanese small firms collaborating on innovation with academic institutes is the lowest among OECD countries. In this respect, if the government can provide R&D-oriented start-ups with more opportunities for research matching by taking into account founders' attributes, even firms without sufficient experience and reputation at start-up would enjoy the benefits of collaborative networks and thus achieve superior performance. The involvement of start-ups will strengthen national innovation

[24] Although we considered the effect of co-founders by using the dummy for multiple founders (*MFOUND*) and checked the effects of the number of co-founders and their role in management with additional variables available from the questionnaire survey, we cannot take the human capital of co-founders into consideration explicitly.

systems and stimulate future innovations in stagnating countries with low business start-up ratios, such as Japan.

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Table 1

Review of previous studies on the determinants of R&D cooperation.

Paper	Partner type	Major significant determinants	Sample	Econometric model
Bayona et al., 2001	All types of firms	Firm (size[+], rd[+]), Industry	1,652 Spanish firms (SMEs, large firms)	Logit
Belderbos et al., 2004	Comp, cust, sup, uni/ins	Firm (size[+], rdint[+], spill[+]), Industry	2,194 Dutch firms*	Multivariate probit
Cassiman and Veugelers, 2002	Cust/sup, uni	Firm (size[+], spill[+]), Industry	411 Belgian firms*	IV probit
Colombo et al., 2006	All types of firms	Firm (size[+], patent[+], vc[+]), Industry	522 Italian firms (Start-ups)	Hazard, panel probit
Fritsch and Lukas, 2001	Comp, cust, sup, ins	Firm (size[+], rdint[+]), Industry, Region	1,800 German firms	Count data hurdle-model
Fontana et al., 2006	Uni/ins	Firm (size[+], rdint[+], patent[+], subsidy[+]), Industry, Country	558 EU firms (SMEs)	Negative binomial
Lòpez, 2008	All types of firms	Firm (size[+], rdint[+], spill[+], risk[+]), Industry	6,026 Spanish firms*	Simultaneous equations
Miotti and Sachwald, 2003	Sup/cust, comp, uni/ins	Firm (size[+], rd[+], subsidy[+]), Industry	2,378 French firms*	Logit
Mohnen and Hoareau, 2003	Uni/ins	Firm (size[+], rd[+], patent[+], group[+], subsidy[+]), Industry, Country	9,191 French, German, Irish, and Spanish firms	Trivariate probit
Motohashi, 2005	Uni	Firm (size[+], rd[+], patent[+]), Industry	724 Japanese firms	Binary choice
Tether, 2002	Comp, cust, sup, uni, consul	Firm (size[+], rd[+]), Industry	1,275 UK firms*	Logit
Veugelers and Cassiman, 2005	Uni	Firm (size[+]), Industry	325 Belgian firms*	IV probit

Notes:

1. The choice of R&D cooperation with other organizations or the number of cooperative R&D projects is used as the dependent variables in the above papers.
2. Partner types comprise competitor (comp), customer (cust), supplier (sup), university (uni), public research institute (ins), and consultant (consul).
3. Firm, Industry, Region, and Country denote that the variables are at the firm, industry, region, and country levels, respectively.
4. Determinants are abbreviated as follows: firm size, size; R&D [intensity], rd [int]; incoming spillover, spill; patent holding or application, patent; venture capital financing, vc; public subsidy or support, subsidy; the importance of cost and risk, risk; group affiliation, group.
5. * indicates that the dataset is derived from a national version of the Community Innovation Survey of the EU.

Table 2
Summary statistics on R&D cooperation by industry.

Industry	*N* (A)	Academic institutes		Business partners	
		Coop (B)	B/A (%)	Coop (C)	C/A (%)
Food and beverage	40	3	7.5	9	22.5
Textile and clothing	19	2	10.5	7	36.8
Publishing and printing	11	1	9.1	1	9.1
Chemicals	26	10	38.5	13	50.0
Plastics	11	2	18.2	6	54.5
Fabricated metals	19	4	21.1	6	31.6
General machinery	41	4	9.8	13	31.7
Electrical machinery	23	4	17.4	10	43.5
Electronics machinery	22	3	13.6	10	45.5
Transportation equipments	10	0	0.0	3	30.0
Precision instruments	12	5	41.7	6	50.0
Software	184	16	8.7	37	20.1
All industries	499	61	12.2	141	28.3

Notes:
1. *N* indicates the number of observations.
2. Industries with 10 or more firms in our sample are listed in this table. Therefore, the sum of the numbers of observations (*N*) in the listed industries does not correspond to the number of observations in "All industries" (499).
3. Academic institutes comprise universities and public research institutes.
4. "Coop" denotes the number of firms engaged in R&D cooperation.

Table 3
Definitions of variables.

Variables	Definition
(Dependent variables)	
C_UNIV	Dummy variable: 1 if the firm engages in R&D cooperation with universities or public research institutes, 0 otherwise.
C_FIRM	Dummy variable: 1 if the firm engages in R&D cooperation with business partners, 0 otherwise.
(Independent variables)	
Founder-specific characteristics	
UEDU	Dummy variable: 1 if the founder has undergraduate education, 0 otherwise.
GEDU	Dummy variable: 1 if the founder has graduate school education, 0 otherwise.
INNOV	Dummy variable: 1 if the founder has prior experience of product/process innovations at start-up, 0 otherwise.
PAT	Dummy variable: 1 if the founder has prior experience of patent applications at start-up, 0 otherwise.
ACAD	Dummy variable: 1 if the founder is a member of an academic association in the natural sciences, 0 otherwise.
WEXP	Dummy variable: 1 if the founder had prior work experience in the related field at start-up, 0 otherwise.
MEXP	Dummy variable: 1 if the founder had prior managerial experience in other firms at start-up, 0 otherwise.
AGE	Natural logarithm of the founder's age at start-up
Firm-specific characteristics	
SIZE	Natural logarithm of the number of employees at start-up
RD	Natural logarithm of R&D expenditures at start-up
IND	Dummy variable: 1 if the firm is founded as an independent firm, 0 otherwise (as a subsidiary or an affiliated firm).
MFOUND	Dummy variable: 1 if the firm has multiple founders, 0 otherwise.
DBUSI	Dummy variable: 1 if the most important reason to choose the current business is to make the best use of unique capabilities and technologies, 0 otherwise.
DLOC	Dummy variable: 1 if the most important reason to choose the location is to obtain easy access to necessary information and technologies, 0 otherwise.
Industry-specific characteristics	
APPROP	Degree of appropriability
TECHOPP	Degree of technological opportunities

Table 4
Summary statistics of the variables.

Variables	*N*	Mean	Std. dev.	Minimum	Maximum
(Dependent variables)					
C_UNIV	499	0.122	0.328	0	1
C_FIRM	499	0.283	0.451	0	1
(Independent variables)					
Founder-specific characteristics					
UEDU	499	0.481	0.500	0	1
GEDU	499	0.104	0.306	0	1
INNOV	499	0.327	0.469	0	1
PAT	499	0.192	0.395	0	1
ACAD	499	0.134	0.341	0	1
WEXP	499	0.868	0.339	0	1
MEXP	499	0.367	0.482	0	1
AGE	499	3.813	0.256	2.996	4.477
Firm-specific characteristics					
SIZE	499	1.026	0.989	0	5.557
RD	499	2.636	2.931	0	10.463
IND	499	0.826	0.380	0	1
MFOUND	499	0.465	0.499	0	1
DBUSI	499	0.385	0.487	0	1
DLOC	499	0.204	0.404	0	1
Industry-specific characteristics					
APPROP	499	1.200	0.211	0.869	1.834
TECHOPP	499	0.890	0.168	0.559	1.120

Note: *N* indicates the number of observations.

Table 5
Mean values of the independent variables in sub-samples by the type of partners.

	C_UNIV			*C_FIRM*		
Variables	0 (*N*: 438)	1 (*N*: 61)	*p*-value	0 (*N*: 358)	1 (*N*: 141)	*p*-value
Founder-specific characteristics						
UEDU	0.477	0.508	0.650	0.469	0.511	0.406
GEDU	0.080	0.279	0.000	0.109	0.092	0.582
INNOV	0.292	0.574	0.000	0.260	0.496	0.000
PAT	0.160	0.426	0.000	0.151	0.298	0.000
ACAD	0.098	0.393	0.000	0.128	0.149	0.547
WEXP	0.874	0.820	0.237	0.852	0.908	0.098
MEXP	0.361	0.410	0.456	0.352	0.404	0.276
AGE	3.801	3.901	0.004	3.802	3.842	0.112
Firm-specific characteristics						
SIZE	1.006	1.174	0.212	0.962	1.190	0.021
RD	2.369	4.548	0.000	2.181	3.790	0.000
IND	0.842	0.705	0.008	0.835	0.801	0.371
MFOUND	0.450	0.574	0.069	0.444	0.518	0.138
DBUSI	0.370	0.492	0.067	0.349	0.475	0.009
DLOC	0.194	0.279	0.125	0.179	0.270	0.024
Industry-specific characteristics						
APPROP	1.191	1.268	0.007	1.194	1.216	0.279
TECHOPP	0.889	0.896	0.746	0.900	0.864	0.029

Notes:

1. *N* indicates the number of observations in the sub-samples.
2. We show the *p*-values of significance tests (*t* test for continuous variables and Wilcoxon rank-sum (Mann-Whitney) test for discrete variables) for the differences of the mean values between the sub-samples.

Table 6
Estimation results using probit model.

	C_UNIV		*C_FIRM*	
Variables	(i)	(ii)	(iii)	(iv)
Founder-specific characteristics				
UEDU	0.261	0.246	0.024	0.007
	(0.183)	(0.184)	(0.134)	(0.133)
GEDU	0.716***	0.682***	-0.264	-0.336
	(0.142)	(0.240)	(0.241)	(0.234)
INNOV	0.352**		0.454***	
	(0.169)		(0.136)	
PAT		0.497***		0.464***
		(0.182)		(0.158)
ACAD	0.574***	0.552***	-0.161	-0.170
	(0.198)	(0.197)	(0.194)	(0.191)
WEXP	-0.303	-0.275	0.483**	0.532**
	(0.225)	(0.228)	(0.217)	(0.216)
MEXP	0.021	0.021	0.029	0.033
	(0.170)	(0.172)	(0.139)	(0.138)
AGE	0.478	0.368	0.051	-0.000
	(0.378)	(0.367)	(0.258)	(0.261)
Firm-specific characteristics				
SIZE	-0.062	-0.045	0.069	0.088
	(0.079)	(0.082)	(0.070)	(0.071)
RD	0.081***	0.086***	0.101***	0.107***
	(0.029)	(0.029)	(0.023)	(0.022)
IND	-0.510**	-0.535**	0.016	-0.001
	(0.207)	(0.207)	(0.181)	(0.179)
MFOUND	0.070	0.095	0.047	0.075
	(0.170)	(0.171)	(0.132)	(0.130)
DBUSI	0.081	0.052	0.204	0.207
	(0.159)	(0.159)	(0.131)	(0.131)
DLOC	0.104	0.127	0.173	0.195
	(0.185)	(0.186)	(0.152)	(0.152)
Industry-specific characteristics				
APPROP	0.655*	0.716**	0.187	0.231
	(0.351)	(0.358)	(0.294)	(0.295)
TECHOPP	0.413	0.464	-0.574	-0.566
	(0.505)	(0.511)	(0.402)	(0.393)
Constant term	-4.308***	-4.018**	-1.576	-1.440
	(1.634)	(1.609)	(1.171)	(0.170)
Number of observations	499	499	499	499
Log pseudolikelihood	-147.678	-146.456	-265.626	-267.322

Notes:
1. Robust standard errors are in parentheses.
2. Levels of significance: *** 1%; ** 5%; and * 10%.

Appendix

Table A1: Correlation matrix of the variables (number of observations: 499).

Variable	*C_UNIV*	*C_FIRM*	*UEDU*	*GEDU*	*INNOV*	*PAT*	*ACAD*	*WEXP*	*MEXP*	*AGE*	*SIZE*	*RD*	*IND*	*MFOUND*	*DBUSI*	*DLOC*	*APPROP*	*TECHOPP*
C_UNIV	1.000																	
C_FIRM	0.106	1.000																
UEDU	0.020	0.037	1.000															
GEDU	0.213	-0.025	-0.328	1.000														
INNOV	0.197	0.227	0.014	0.056	1.000													
PAT	0.221	0.168	0.019	0.133	0.495	1.000												
ACAD	0.284	0.027	-0.003	0.347	0.164	0.210	1.000											
WEXP	-0.053	0.074	-0.015	-0.002	0.007	-0.050	0.015	1.000										
MEXP	0.033	0.049	0.083	-0.110	0.011	-0.023	-0.044	-0.071	1.000									
AGE	0.128	0.071	0.041	0.044	0.171	0.245	0.129	-0.066	0.216	1.000								
SIZE	0.056	0.104	-0.003	-0.026	0.089	-0.019	-0.026	-0.054	0.213	0.127	1.000							
RD	0.244	0.248	0.066	0.137	0.206	0.140	0.190	-0.086	0.074	0.086	0.113	1.000						
IND	-0.119	-0.040	-0.065	0.053	-0.052	0.010	-0.036	-0.024	-0.155	-0.095	-0.373	-0.019	1.000					
MFOUND	0.081	0.066	-0.013	-0.016	0.088	-0.007	0.010	-0.111	0.158	0.025	0.251	0.129	-0.091	1.000				
DBUSI	0.082	0.117	-0.069	0.054	0.178	0.178	0.124	0.017	0.056	0.065	0.018	0.105	0.038	0.089	1.000			
DLOC	0.069	0.101	0.019	0.022	0.071	0.017	0.077	-0.037	0.027	0.052	0.052	0.174	0.010	0.066	0.038	1.000		
APPROP	0.121	0.049	0.033	0.000	0.075	0.027	0.073	-0.046	0.039	0.064	0.044	0.045	-0.040	0.064	0.030	-0.006	1.000	
TECHOPP	0.015	-0.098	-0.032	0.066	-0.148	-0.163	0.056	0.117	-0.068	-0.267	-0.160	-0.036	0.113	0.007	-0.045	-0.072	0.030	1.000

Table A2: Estimation results using multinomial probit, IV probit (2-Step), and negative binomial models.

	Multinomial probit model			IV probit model (2-Step)		Negative binomial model	
	UNIV	*FIRM*	*BOTH*	*C_UNIV*	*C_FIRM*	*NC_UNIV*	*NC_FIRM*
Variables		(i)		(ii)	(iii)	(iv)	(v)
Founder-specific characteristics							
UEDU	0.599*	0.121	-0.028	0.276	-0.194	-0.042	-0.217
	(0.302)	(0.193)	(0.343)	(0.254)	(0.224)	(0.395)	(0.200)
GEDU	0.896*	-0.610	0.293	0.736*	-0.711*	0.858*	-0.293
	(0.429)	(0.397)	(0.473)	(0.411)	(0.410)	(0.456)	(0.336)
PAT	0.683*	0.593*	1.066**	0.524**	0.260	1.283***	0.487**
	(0.305)	(0.248)	(0.332)	(0.247)	(0.254)	(0.338)	(0.210)
ACAD	0.395	-0.510	0.657*	0.598*	-0.507	0.891***	-0.135
	(0.334)	(0.325	(0.365)	(0.337)	(0.355)	(0.312)	(0.250)
WEXP	-0.468	0.595*	0.572	-0.299	0.705*	-0.375	0.834**
	(0.323)	(0.289)	(0.490)	(0.259)	(0.272)	(0.381)	(0.334)
MEXP	0.166	0.110	-0.108	0.033	-0.058	-0.127	0.106
	(0.273)	(0.201)	(0.330)	(0.193)	(0.180)	(0.278)	(0.201)
AGE	0.341	-0.106	0.516	0.375	-0.023	0.305	0.309
	(0.535)	(0.394	(0.676)	(0.361)	(0.329)	(0.591)	(0.395)
Firm-specific characteristics							
SIZE	-0.078	0.090	0.079	-0.033	0.001	0.059	0.234**
	(0.139)	(0.104)	(0.153)	(0.111)	(0.108)	(0.152)	(0.097)
RD	0.118*	0.149*	0.220**	0.039	0.441**	0.103**	0.149***
	(0.043)	(0.033)	(0.053)	(0.266)	(0.256)	(0.050)	(0.033)
IND	-0.781*	-0.106	-0.487	-0.525**	-0.075	-0.907**	0.133
	(0.329)	(0.261)	(0.391)	(0.224)	(0.222)	(0.381)	(0.260)
MFOUND	0.179	0.144	0.096	0.117	-0.087	0.223	-0.050
	(0.268)	(0.192)	(0.316)	(0.216)	(0.202)	(0.295)	(0.186)
DBUSI	0.243	0.344*	0.159	0.069	0.085	-0.148	0.420**
	(0.264)	(0.190)	(0.306)	(0.197)	(0.183)	(0.308)	(0.192)
DLOC	0.287	0.369*	0.181	0.174	-0.149	0.236	-0.089
	(0.303)	(0.222)	(0.350)	(0.330)	(0.321)	(0.348)	(0.200)
Industry-specific characteristics							
APPROP	0.777	0.240	1.168*	0.736*	0.141	0.803	0.248
	(0.569)	(0.426)	(0.646)	(0.386)	(0.358)	(0.620)	(0.395)
TECHOPP	0.744	-0.715	-0.432	0.468	-0.571	0.286	-1.285**
	(0.834)	(0.580)	(0.930)	(0.529)	(0.480)	(1.005)	(0.580)
Constant term	-4.789*	-1.433	-6.410*	-4.011**	-1.681	-4.281*	-2.936*
	(2.342)	(1.767)	(2.892)	(1.552)	(1.480)	(2.500)	(1.765)
Number of observations		499		499	499	495	480
Log pseudolikelihood		-407.343		-	-	-221.815	-395.596

Note:
1. For IV probit model (2-Step), only the results of the second-step regressions are shown in this table.
2. The results with *INNOV* are not reported in this model, and they are generally consistent with those with *PAT*.
3. *UNIV*, *FIRM*, and *BOTH* denote cooperation with academic institutes only, cooperation with business partners only, and cooperation with both types, respectively.
4. *N_UNIV and NC_FIRM* denote the numbers of cooperative R&D projects with academic institutes and with business partners, respectively.
5. Robust standard errors are in parentheses for multinomial probit and negative binomial models, while standard errors are in parentheses for IV probit model (2-Step).
6. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.