# Center for Economic Institutions

# Working Paper Series

**No. 2009-7**


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November 2009


Center for Economic Institutions

Working Paper Series



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# Determinants of R&D cooperation in Japanese high-tech start-ups*

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**Abstract**

This paper explores the determinants of R&D cooperation in Japanese high-tech 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 the type of partners. Our findings indicate that founder-specific characteristics, such as educational background, academic affiliation, and prior innovation output, are fairly important in determining R&D cooperation with universities and public research institutes. We also provide evidence that founders' work experience and prior innovation output 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 on R&D with universities and public research institutes, than subsidiaries and affiliated firms.

*JEL classification:* L14; M13; O32.

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

*This study is supported by a Grant-in-Aid for Scientific Research (A) (No. 20243018) of the Japan Society for the Promotion of Science. We thank the members of the scientific research project team, Roberto Fontana, Sadao Nagaoka, and Hiroyuki Odagiri for their comments and suggestions on an earlier version of the paper. We also thank the participants at the Comparative Analysis of Enterprise Data Conference in Tokyo and the Business and Economics Workshop in Shizuoka, Japan, both in October 2009, for their useful comments. Needless to say, any remaining errors are our own.

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## 1. Introduction

To date, much literature has argued 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; van Stel, 2006). However, it is not easy for small start-ups to be successful in innovation because of their limited business experiences and resources. To compensate for the lack of business experiences and resources, alliance with external organizations — especially for research and development (R&D) cooperation — is considered to be an effective strategy for start-ups. R&D cooperation will be able to allow start-ups not only to obtain complementary assets but also to share costs and risks, which improve R&D productivity.

This paper explores the determinants of R&D cooperation in Japanese high-tech 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 the type of partners. We provide evidence on the factors determining R&D cooperation of start-ups with particular emphasis on the roles of founders' human capital. Understanding the determinants of R&D cooperation will promote understanding on how we should create and improve the opportunities for business and research matching, which would contribute to building national innovation systems through high-tech start-ups.

The resource-based view (RBV) emphasizes firm's idiosyncratic resources that affect its competitive advantages (e.g., Wernerfelt, 1984; Barney, 1991). The RBV suggests that start-ups pursue entrepreneurial strategies based on their own capabilities. In addition, Colombo and Grilli (2005) argue 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 emphasize the capability effect of founders' human capital that explains its positive impact on the performance of NTBFs. That is, founders' human capital plays a critical role in the firm's performance as the valuable resources of start-ups, partly because it can alleviate the lack of business experiences and resources. While the firm's performance reflects corporate strategy, such as alliance, the founder's human capital may exert large influence on the alliance strategy, including R&D cooperation with external organizations. As Lee et al. (2001) argue, external contacts perform a very important role in the procurement of complementary assets. More specifically, R&D cooperation can be an effective strategy for start-ups to obtain complementary assets and to share costs and risks because of their limited business experiences and resources. Further, the founder characteristics of start-ups have a greater impact on R&D cooperation than those of established firms.

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

## 2. Literature review

R&D cooperation has been examined in a rich stream of literature.[1] As is often argued, R&D cooperation is a useful way to exploit external technologies and knowledge. R&D cooperation can allow firms to obtain complementary assets and to share costs and risks. For start-ups, R&D cooperation appears more effective, since most start-ups' resources tend to be few and limited.

In the fields of economics and management, much literature has investigated the determinants of R&D cooperation from various perspectives. Table 1 summarizes empirical studies on the determinants of R&D cooperation. Among them, some studies

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

examine R&D cooperation between firms, focusing on large established firms (e.g., Bayona et al., 2001; Fritsch and Lukas, 2001). Other studies examine the determinants of R&D cooperation between firms and universities (e.g., Veugelers and Cassiman, 2005). Bayona et al. (2001), for example, explore the motives of industrial firms to cooperate in R&D, using a sample of Spanish firms. They found that firms with large and sufficient capacity to carry out R&D tend to cooperate on R&D, and the reasons for cooperative R&D are overall different between large and small firms. More recently, Lopez (2008) emphasizes the roles of incoming spillovers and the costs and risks of innovative activities in determining R&D cooperation among firms, using data on Spanish manufacturing firms.

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) examine the determinants of R&D cooperation between firms and public research organizations including universities, using a sample of innovative SMEs in the European countries. Muscio (2007) also examines 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 of start-ups, except for Colombo et al. (2006) that examine the determinants of commercial and technological alliances of Italian high-tech start-ups.

On the other hand, it has often been argued that the success of start-ups is dependent on founders' human capital. Bates (1990), for example, argues that entrepreneurs' human capital inputs affect small business longevity, and Cressy (1996) emphasizes 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 indicate that founders' human capital plays a critical role in the firm's performance as the valuable resources of start-ups, partly because it can alleviate the lack of business experiences and resources. However, the roles of founders' human capital in R&D cooperation tend to be ignored in the literature. Colombo et al. (2006) examine the determinants of the alliances of Italian high-tech start-ups, but, surprisingly, the significant effects of founder-specific variables, such as education and professional experience, were not confirmed.[2] In this respect, it is unclear whether R&D cooperation is affected by founders' human capital, and further investigation is required for a conclusive answer.

Moreover, some studies have focused on R&D cooperation between firms and universities and/or public research institutes. For example, Mohnen and Hoareau (2003) investigate the determinants of R&D cooperation between firms and universities or government labs, using a sample of French, German, Irish, and Spanish firms.[3] They provide evidence that firm-specific characteristics, such as patent holding, group affiliation, and subsidies, affect R&D cooperation. Fontana et al. (2006) also examine the determinants of R&D cooperation between firms and public research organizations with a sample of innovative SMEs in Europe, and argue that the openness of firms to the external environments significantly affects the probability of R&D cooperation with academic institutions. Furthermore, other studies, such as Fritsch and Lukas (2001) and Miotti and Sachwald (2003), provide evidence on some differences in the determinants of R&D cooperation among different types of partners. These results suggest that R&D cooperation varies according to the types of partners, and the determinants of R&D cooperation with universities and public research institutes may be different from those with the other types of external organizations, such as customers and suppliers.

[2]On the other hand, Colombo and Grilli (2005) find that the nature of the education and of the prior work experience of founders exerts a key influence on firm growth.

[3]Mohnen and Hoareau (2003) use data from the Community Innovation Surveys (CIS) in the European countries. As shown in Table 1, several studies use 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 Lopez (2008) for Spain.

Regarding R&D cooperation in Japan, for example, Branstetter and Sakakibara (1998, 2002) highlight government-sponsored research consortia among large firms, and Motohashi (2005) examines the determinants of university-industry collaborations.[4] Okamuro (2007) investigates the determinants of successful R&D cooperation in Japanese SMEs. However, these studies analyze the R&D cooperation of established firms, and that of start-ups in Japan has not been investigated yet. Whereas, as is often argued, Japan has finished the technological catch-up and strives for technological leadership, Japan is characterized by almost the lowest ratio of business start-ups among the OECD countries. Because of this, policy makers are concerned about the lack of entrepreneurs for future economic growth. This paper highlighting the R&D cooperation of high-tech start-ups would provide a new perspective on the opportunities for business and research matching, in supporting national innovation systems in the country with a low start-up rate like Japan.

## 3. Hypotheses

The founders of start-ups have more influence on 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. In the context of R&D cooperation, founders' human capital is considered to directly reflect their capabilities affecting 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 promote R&D cooperation. In addition to these direct effects, founders' human capital signals the capabilities of their firms to potential partners. Spence (1973, 1974) argue that workers' education level can provide a positive signal of their capability to the employers even if it does not change their productivity. Similar argument can be applied to the relationship between founders

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

and potential research partners. Uncertainty and information asymmetries between them make the signaling of capabilities effective to promote R&D cooperation between them. As pointed out by Fontana et al. (2006), technical and scientific capabilities of firms attract potential partners, and open new opportunities for collaboration. Based on this argument, we use educational background, prior innovation output, and work experience as the measures of founder-specific characteristics affecting R&D cooperation.

First, let us consider founders' educational background. Colombo and Grilli (2005) argue 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 use educational background as a measure of founders' human capital (e.g, Bates, 1990; Åstebro and Bernhardt, 2003). Colombo and Grilli (2005) also measure founders' human capital by the years of education. As discussed before, signaling of founders' capabilities to research partners may exert influence on the R&D cooperation of start-ups. Moreover, founders' educational background may act as the source of their networks for R&D. It is likely that the longer the years of academic education, the wider the network with researchers in academic institutions. Therefore, the effects of founders' educational background may be observed more distinctly in R&D cooperation with universities and/or public research institutes. From these respects, we formulate the following hypotheses.

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

**Hypothesis 1b.** Firms with highly educated founders are more likely to engage in R&D cooperation with universities and public research institutes than with non-academic organizations.

In addition to educational background, founders' experiences of innovation prior to start-up are considered to be a measure of human capital affecting R&D cooperation. Colombo et al. (2006) argue 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 have greater influence on the decision of R&D cooperation than the top managers of established firms. Since start-ups have few business experiences and track records, founders' human capital plays a crucial role as the valuable resources of 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' academic affiliation may affect the probability of R&D cooperation. Through the participation in academic associations, founders can build their networks with researchers in external organizations, especially research organizations in natural sciences. Further, academic affiliation tends to reflect founders' innovation potential and willingness by collecting the most recent research on the area, which may provide a signal to research partners. Therefore, whether or not the founder is the member of an academic association in natural sciences may be associated with R&D cooperation with external, especially academic, organizations. From these respects, we propose the following hypotheses.

**Hypothesis 3a.** Firms whose founders are affiliated with academic associations in natural sciences are more likely to engage in R&D cooperation with external organiza-

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

tions.

**Hypothesis 3b.** Firms whose founders are affiliated with academic associations in natural sciences are more likely to engage in R&D cooperation with universities and public research institutes than with non-academic organizations.

On the other hand, founders' work experience may also be associated with R&D cooperation. If the founder has prior work experience as an employee in the same industry, he or she can take more advantage of his or her network at start-up. In addition, if the founder has managerial experience in another firm prior to start-up, he or she is expected to have more managerial skills as well as a wider business network with external organizations, than the founder without any managerial experience. In particular, prior work experience in the same industry may play a more important role in R&D cooperation with business partners including customers and suppliers, than with universities and public research institutes. Therefore, we formulate the following hypotheses.

**Hypothesis 4a.** Firms whose founders have work experience in the same industry or in management are more likely to engage in R&D cooperation with external organizations.

**Hypothesis 4b.** Firms whose founders have work experience in the same industry are more likely to engage in R&D cooperation with business partners than with academic organizations.

In addition to the effects of founder-specific characteristics, we discuss those of firm-specific characteristics on R&D cooperation. Since start-ups have different characteristics, alliance strategies also vary among start-ups. According to Cohen and Levinthal (1989), the benefits from R&D cooperation depend on the absorptive capacity of firms, which suggests the importance of sufficient size and R&D capacity for R&D cooperation. In fact, this view has been supported by some empirical studies, including

Fontana et al. (2006) and López (2008).[6] As Fontana et al. (2006) argue, larger firms have more resources to help them to establish relationships with public research organizations. Considering the difference in firm size and R&D capacity among start-ups, we test the following hypotheses.

**Hypothesis 5.** Larger firms are more likely to engage in R&D cooperation with external organizations.

**Hypothesis 6.** Firms investing more in R&D are more likely to engage in R&D cooperation with external organizations.

Furthermore, there may be some differences in the probability to cooperate on R&D between independent firms and subsidiaries or affiliated firms. For example, Mohnen and Hoareau (2003) indeed find that members of a corporate group tend to cooperate in R&D. As pointed out by Mohnen and Hoareau (2003), firms that belong to large corporate groups might be able to tap information from universities/government labs or establish contacts with them more easily through this network. In this respect, whether the firm is an independent or affiliated firm may be a key determinant of R&D cooperation, especially with universities and public research institutes. From these respects, we formulate the following hypotheses.

**Hypothesis 7a.** Independent firms are less likely to cooperate on R&D than subsidiaries and affiliated firms.

**Hypothesis 7b.** Independent firms are less likely to cooperate on R&D with universities and public research institutes, than subsidiaries and affiliated firms.

Based on these hypotheses, we examine the determinants of R&D cooperation using original data on Japanese high-tech start-ups in the following sections.

[6] For the previous empirical evidence on the effects of firm size and R&D capacity, see also Table 1.

# 4. Data

## 4.1. Data sources

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

The number of effective responses was 1,514 (approximately 11% of the target). Among them, we selected 1,060 "real" start-ups that had started their businesses during 2007 and 2008. Then, we identified 672 R&D-oriented firms whose founders conducted R&D or that employed R&D personnel when starting their businesses or afterwards.[8] As a result, we obtain 499 firms in the final sample because of missing values for some variables.

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

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

[8]The ratio of R&D-oriented firms to all the respondents appears to be fairly high. This is in part attributed to the fact that we target relatively R&D-intensive industries for the purpose of our research project.

and Technology (MEXT).

### 4.2. R&D cooperation

In the questionnaires survey, we asked founders whether or not they engage in R&D cooperation with universities or public research institutes, and business partners including both customers and suppliers, respectively.[9] Table 2 provides the summary statistics for R&D cooperation by the type of partners. As shown here, 61 of 499 firms (approximately 12%) engage in R&D cooperation with universities or public research institutes, while 141 firms (approximately 28%) cooperate on R&D with business partners.

With respect to the sub-samples by industries 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. As a whole, start-ups in the manufacturing sector are more likely to cooperate on R&D than those in the software sector. Further, the propensity for R&D cooperation tends to vary according to the types of partners even in the same industry. These statistics suggest that the propensity for R&D cooperation differs across industries and according to the types of partners.

### 4.3. Determinants of R&D cooperation

In this paper, we investigate the determinants of R&D cooperation using a regression model, and test the hypotheses developed in Section 3. Based on the questionnaire survey, the dependent variables for R&D cooperation are defined as two dummies that take the value one if the firm engages in R&D cooperation with universities or public research institutes ($C\_UNIV$), and with business partners ($C\_FIRM$), respectively, and zero otherwise.

The definitions of the variables are presented in Table 3 that includes the independent variables, which will be discussed below in details. In addition, Table 4 shows

[9] In our questionnaire survey, we did not clearly identify if the R&D cooperation with external organizations is really new to the founder. Therefore, the possibility remains that the founder in our sample had already engaged in R&D cooperation before starting the business.

the summary statistics of the dependent and independent variables. Table 5 provides the mean values of independent variables for the sub-samples by the type of partners.

*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% (10%) of the founders achieved bachelor degree (master or doctor degrees). As shown in Table 5, the means of $GEDU$ are clearly 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 universities or public research institutes.

Second, the variables for founders' prior innovation output are also included in the model. In this paper, prior innovation output is defined as two dummies, taking the value one for firms whose founders achieved product/process innovations ($INNOV$) and patent applications ($PAT$) before start-up, respectively, and zero otherwise. As shown in Table 4, founders have prior experience of product/process innovations and patent applications before start-up in 33% and 19% of firms, respectively. A clear finding in Table 5 is that there are considerable differences in the means of $INNOV$ and $PAT$ between the firms that engaged in R&D cooperation and the others, regardless of the types of partners. Table 5 indicates that 57% and 43% of the sample firms that take the value one for $INNOV$ and $PAT$ engage in R&D cooperation with universities or public research institutes, and that 50% and 30% of the firms that take the value one for these variables cooperate on R&D with business partners, respectively.

Third, the dummy variable for the firms whose founders are affiliated with academic associations in natural sciences ($ACAD$) is included in the model. As shown in Table 4, 13% of the founders in our sample are affiliated with academic associations in natural sciences. Table 5 indicates that 40% of the firms whose founders are affiliated with academic associations cooperate on R&D with universities or public research institutes, while only 10% of the firms whose founders have no membership in academic associations cooperate on R&D with these organizations. Regarding the R&D cooperation with business partners, however, the propensity for R&D cooperation does not vary according to the affiliation of the founders with academic associations.

Fourth, we include two dummy variables for founders' work experiences in the model. One is a dummy taking the value one for firms whose founders have worked in the same industry before start-up, and zero otherwise ($JEXP$); the other is a dummy taking the value one for firms whose founders have prior managerial experience before start-up, and zero otherwise ($MEXP$). Table 4 shows that 87% (37%) of the founders in our sample worked in the same industry (as managers of other firms) before start-up. Table 5 suggests that there are no significant differences in the means of these variables between the firms that engaged in R&D cooperation with universities or public research institutes and the others, while the firms whose founders have prior work experiences tend to engage in R&D cooperation with business partners compared to the others.

Finally, we include the variable for founders' age at start-up ($AGE$) as a control variable in the model. In the sample, the minimum and maximum ages of founders are 20 and 80 at start-up, respectively. The natural logarithm of founders' age at start-up is used in the regressions. As shown in Table 5, there are no significant differences in the means of start-up ages between the firms that engaged in R&D cooperation and the others, regardless of the types of partners.

*Firm-specific characteristics*

As firm-specific characteristics affecting R&D cooperation, the variable for firm size ($SIZE$), measured as the natural logarithm of the number of employees at start-up, is included in the model. The median of the number of employees in the sample is 2, indicating that the sample consists of small firms. As shown in Table 5, it appears that the propensity for R&D cooperation does not vary according to firm size. The variable for R&D expenditures ($RD$), measured as the natural logarithm of the R&D expenditures, is also used as an independent variable.[10] As shown in Table 5, the means of this variable exhibit considerable differences between the firms that engage in R&D cooperation and the others, regardless of the 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. According to the means of this variable in Table 5, independent firms are less likely to cooperate with universities or public research institutes, but there are no significant differences in the propensity for R&D cooperation with business partners between independent firms and subsidiaries or affiliated firms.

As discussed by Colombo et al. (2006), the presence of co-founders may also have influence on R&D cooperation. Therefore, we include a dummy variable for whether or not the firm has 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 that there are no distinct differences in the propensity for R&D cooperation between the firms with sole and multiple founders, regardless of the types of partners.

In addition, we include two control variables regarding the reasons of choosing its business field and location. In the questionnaire, we asked the founders about the most important reason to choose the current business and the location of start-up. In this paper, we construct a dummy variable for business choice ($DBUSI$), taking the value one if the most important reason to choose 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 ($DLOC$), taking the value one if the most important reason

[10] 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 report the results with R&D intensity.

to choose the location is to obtain easy access to necessary information and technologies, and zero otherwise.

*Industry-specific characteristics*

Furthermore, the variables for industry-specific characteristics are included as control variables in the model.[11] Following Okamuro (2009), the variables for the appropriability ($APPROP$) and technological opportunities ($TECHOPP$) are used to control for differences in the technological environments 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.[12]

## 5. Estimation results

We examine the determinants of R&D cooperation in Japanese high-tech start-ups, by estimating the regression model. Since, as already mentioned, R&D cooperation is measured by binary variables, we adopt probit models to estimate the determinants of R&D cooperation. In Table 6, we show the estimation results for the determinants of R&D cooperation with universities or public research institutes ($C\_UNIV$) in Columns (i) and (ii) and those with business partners ($C\_FIRM$) in Columns (iii) and (iv).

With respect to founder-specific characteristics, Tables 6 demonstrates that the variable for graduate school education ($GEDU$) has a positive and significant effect on R&D cooperation with universities or public research institutes ($C\_UNIV$), but no significant effect on R&D cooperation with business partners ($C\_FIRM$). However, the variable for undergraduate university education ($UEDU$) has no significant effect on R&D cooperation, regardless of the types of partners. These results indicate that firms with highly educated founders are more likely to cooperate on R&D with universities

[11] 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.

[12] For more details on the construction and measurement of these variables, see Okamuro (2009).

or public research institutes, which supports Hypothesis 1b.

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 on R&D with external organizations, partly because research capabilities of founders act as a signal of the firms' capabilities to potential partners.

Moreover, as shown in Columns (i) and (ii) of Table 6, the dummy variable for founders' academic affiliation ($ACAD$) has a significantly positive effect on $C\_UNIV$. In Columns (iii) and (iv) of Table 6, however, $ACAD$ does not have any significant effect on $C\_FIRM$. While the effects of founders' work experiences ($JEXP$ and $MEXP$) are not significant in Columns (i) and (ii) of Table 6, the coefficients of $JEXP$ on $C\_FIRM$ indicate significantly positive signs in Columns (iii) and (iv) of Table 6. 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 $C\_FIRM$ in Table 6.

With respect to the variables for firm-specific characteristics, the coefficients of firm size ($SIZE$) are not significant in any models of Table 6. As already discussed, some previous studies found positive and significant effects of firm size on R&D cooperation. While most of the studies have used data on relatively large firms, as repeatedly explained, 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 within small firms, including start-ups, while it appears 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 on R&D with external organizations, regardless of the types of partners. Our findings are consistent with Cohen and Levinthal (1989), which indicate that the firms investing more in R&D are more likely to engage in R&D cooperation than the others because of their sufficient absorptive capacity.

The variable for the 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 on R&D with universities or public research institutes, compared to subsidiaries or affiliated firms, which supports Hypothesis 7b. Our findings imply that subsidiaries and affiliated firms have wider networks than independent firms through parent or group companies, and therefore, they have more opportunities to engage in R&D cooperation. Moreover, the coefficients of the variables for business and location choices ($DBUSI$ and $DLOC$) are overall not significant in Table 6, although these variables were expected to have significant effects on R&D cooperation.

As for industry-specific characteristics, Columns (i) and (ii) of Table 6 indicate that higher appropriability ($APPROP$) leads to R&D cooperation with universities or public research institutes, while Columns (iii) and (iv) indicate that this variable does not have any significant effect regarding 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 types of partners.

In addition to the determinants of R&D cooperation, we examine the determinants of the number of cooperative R&D projects engaged by Japanese high-tech start-ups. In the questionnaire survey, we asked for the number of cooperative R&D projects by the types of partners. As discussed by Fontana et al. (2006), a decision to cooperate on R&D with external 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 universities or public research institutes ($NC\_UNIV$), and business partners ($NC\_FIRM$), using negative binomial models.

The summary statistics of $NC\_UNIV$ and $NC\_FIRM$ are shown in Table 4, and the maximum values of these variables are 13 and 10, respectively. The estimation results with the negative binomial models are shown in Table 7. The effects of founder-specific characteristics are generally consistent with those in Table 6, both for $NC\_UNIV$ and $NC\_FIRM$. With respect to firm-specific characteristics, however, the variable for firm size ($SIZE$) has positive and significant effects on $NC\_FIRM$, whereas it has no significant effects on $NC\_UNIV$. From the estimation results of Tables 6 and 7, we can confirm that firm size does not affect the decision to cooperate on R&D with business partners, but the decision to increase the number of cooperative R&D projects with them, which is partly consistent with the argument of absorptive capacity by Cohen and Levinthal (1989) and some previous studies, including Fontana et al. (2006).

Finally, we summarize the results on our hypotheses in Table 8. Our hypotheses are generally supported in the empirical analysis. With respect to founder-specific characteristics, founders' education level, work experience, and prior innovation output are found to have positive effects on R&D cooperation. In particular, the estimation results show that the founders' research capabilities and networks are fairly important factors in determining R&D cooperation, regardless of the types of partners. Our findings suggest that the start-ups whose founders possess sufficient research capabilities and network are more likely to engage in R&D cooperation with external organizations, suggesting that founders' personal attributes act as a signal of the research capabilities of their firms to potential partners.

## 6. Conclusions

This paper has explored the determinants of R&D cooperation in Japanese high-tech start-ups. Using a sample from an original survey conducted in 2008, we examined the effects of the founder-, firm-, and industry-specific characteristics on R&D cooperation by the type of partners. Our findings indicate that founder-specific characteristics, such as educational background, academic affiliation, and prior innovation output, are fairly important in determining R&D cooperation with universities and public research institutions. 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 firms investing more 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 on R&D with universities and public research institutes, than subsidiaries or affiliated firms.

However, this paper includes some limitations, which should be addressed in future research. We found the significant effects of founder-specific characteristics on the R&D cooperation of start-ups, but did not identify how these characteristics affect R&D cooperation. That is, we cannot determine whether, for example, founders' educational background affects R&D cooperation as the variable reflecting their potential capabilities or the signal of the capabilities to research partners. In addition, we did not show the dynamic aspect of R&D cooperation, since we used cross-section data from our recent survey. Further investigation with a panel data set through repeated surveys is needed to better understand the dynamic process of R&D cooperation.

Despite these limitations, this paper provides new evidence and implications. While most of the previous studies have focused on R&D cooperation of large established firms, we addressed R&D cooperation of start-ups. In addition, we shed light on the roles of founders 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 high-tech start-ups, while it serves as the capabilities of the start-ups. From the viewpoint of public policy, this paper indicates that policy makers should pay more attention to founders' attributes in providing opportunities for business and research matching between high-tech start-ups and academic organizations. As shown in this paper, the education and work experience of founders help promote R&D cooperation with external organizations, and greater human capital could strengthen a national innovation system including high-tech start-ups, which is expected to provide better opportunities to stimulate future innovations in stagnating countries with low business start-ups like Japan.

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Table 1: Review of the 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 | 1652 Spanish firms (SMEs, large firms) | Logit |
| Belderbos et al., 2004 | Comp, cust, sup, uni/ins | Firm (size[+], rdint[+], spill[+]), Industry | 2194 Dutch firms* | Multivariate probit |
| Colombo et al., 2006 | All types of firms | Firm (size[+], patent[+], vc[+]), Founder, Industry | 522 Italian firms (Startups) | Hazard, panel probit |
| Fritsch and Lukas, 2001 | Comp, cust, sup, ins | Firm (size[+], rdint[+]), Industry, Region | 1800 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 |
| López, 2008 | All types of firms | Firm (size[+], rdint[+], spill[+], risk[+]), Industry | 6026 Spanish firms* | Simultaneous equations |
| Miotti and Sachwald, 2003 | Vertical, comp, uni/ins | Firm (size[+], rd[+], subsidy[+]), Industry | 2378 French firms* | Logit |
| Mohnen and Hoareau, 2003 | Uni/ins | Firm (size[+], rd[+], patent[+], group[+], subsidy[+]), Industry, Country | 9191 French, German, Irish and Spanish firms | Trivariate probit |
| Motohashi, 2005 | Uni | Firm (size[+], rd[+], patent[+]), Industry | 724 Japanese firms | Binary choice (not specified) |
| Tether, 2002 | Comp, cust, sup, uni, consul | Firm (size[+], rd[+]), Industry | 1275 UK firms* | Logit |
| Veugelers and Cassiman, 2005 | Uni | Firm (size[+]), Industry | 325 Belgian firms* | IV probit |

Note:

1. Whether the firm engaged in R&D cooperation with other organizations is (partly) used as dependent variables in the above papers.
2. Firm, Founder, Industry, Region and Country represent that the variables are at the firm, industry, region and country levels, respectively.
3. Partner (comp: competitor, cust: customer, sup: supplier, uni: university, ins: public research institute, consul: consultant).
4. Determinants (size: firm size, rd[int]: R&D [intensity], spill: incoming spillover, patent: patent holding or application, vc: venture capital financing, subsidy: public subsidy or support, risk: the importance of cost and risk, group: group affiliation).
5. $*$ indicates that the data set is from each country's version of the European Community Innovation Survey.

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

| | | Universities/research institutes | | Business partners | |
|---|---|---|---|---|---|
| Industry | $N$ (A) | Yes (B) | B/A (%) | Yes (C) | C/A (%) |
| Food and beverage | 40 | 3 | 7.5 | 9 | 22.5 |
| Textiles | 19 | 2 | 10.5 | 7 | 36.8 |
| Wood | 5 | 1 | 20.0 | 1 | 20.0 |
| Furniture | 2 | 0 | 0.0 | 0 | 0.0 |
| Paper and pulp | 5 | 0 | 0.0 | 2 | 40.0 |
| Publishing and printing | 11 | 1 | 9.1 | 1 | 9.1 |
| Chemicals | 26 | 10 | 38.5 | 13 | 50.0 |
| Petroleum and coal | 2 | 1 | 50.0 | 0 | 0.0 |
| Plastics | 11 | 2 | 18.2 | 6 | 54.5 |
| Rubber | 2 | 0 | 0.0 | 0 | 0.0 |
| Leather | 4 | 0 | 0.0 | 1 | 25.0 |
| Stone, clay and glass | 8 | 1 | 12.5 | 1 | 12.5 |
| Iron and steel | 4 | 1 | 25.0 | 1 | 25.0 |
| Nonferrous metals | 5 | 1 | 20.0 | 1 | 20.0 |
| Fablicated 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 |
| Communications machinery | 3 | 1 | 33.3 | 1 | 33.3 |
| Electronic machinery | 22 | 3 | 13.6 | 10 | 45.5 |
| Transportation machinery | 10 | 0 | 0.0 | 3 | 30.0 |
| Precision machinery | 12 | 5 | 41.7 | 6 | 50.0 |
| Miscellaneous manufacturing | 41 | 1 | 2.4 | 12 | 29.3 |
| Software | 184 | 16 | 8.7 | 37 | 20.1 |
| Full sample | 499 | 61 | 12.2 | 141 | 28.3 |

Note:

1. $N$ indicates the number of observations.
2. 'Yes' represents the number of firms engaged in R&D cooperation.

Table 3: Definitions of variables.

| Variable | Definition |
|---|---|
| (Dependent variable) | |
| $C\_UNIV$ | 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. |
| $NC\_UNIV$ | Number of R&D cooperation engaged by the firm with universities or public research institutes, 0 otherwise. |
| $NC\_FIRM$ | Number of R&D cooperation engaged by the firm with business partners, 0 otherwise. |
| (Independent variable) | |
| *Founder-specific characteristics* | |
| $UEDU$ | Dummy variable: 1 if the founder had undergraduate university education, 0 otherwise. |
| $GEDU$ | Dummy variable: 1 if the founder had 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 members of academic associations in natural science, 0 otherwise. |
| $JEXP$ | Dummy variable: 1 if the founder had prior experience as an employee in the same industry at start-up, 0 otherwise. |
| $MEXP$ | Dummy variable: 1 if the founder had prior experience as a manager 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 if 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 for variables.

| | Number of obs. | Mean | Std. dev. | Minimum | Maximum |
|---|---|---|---|---|---|
| (Dependent variable) | | | | | |
| $C\_UNIV$ | 499 | 0.122 | 0.328 | 0 | 1 |
| $C\_FIRM$ | 499 | 0.283 | 0.451 | 0 | 1 |
| $NC\_UNIV$ | 495 | 0.240 | 1.004 | 0 | 13 |
| $NC\_FIRM$ | 480 | 0.467 | 1.069 | 0 | 10 |
| (Independent variable) | | | | | |
| *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 |
| $JEXP$ | 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 |

Table 5: Mean values of independent variables for sub-samples, by the type of partners.

| | $C\_UNIV$ | | $C\_FIRM$ | |
|---|---|---|---|---|
| Variable | 1 ($N:61$) | 0 ($N:438$) | 1 ($N:141$) | 0 ($N:358$) |
| *Founder-specific characteristics* | | | | |
| $UEDU$ | 0.508 | 0.477 | 0.511 | 0.469 |
| $GEDU$ | 0.279 | 0.080 | 0.092 | 0.109 |
| $INNOV$ | 0.574 | 0.292 | 0.496 | 0.260 |
| $PAT$ | 0.426 | 0.160 | 0.298 | 0.151 |
| $ACAD$ | 0.393 | 0.098 | 0.149 | 0.128 |
| $JEXP$ | 0.820 | 0.874 | 0.908 | 0.852 |
| $MEXP$ | 0.410 | 0.361 | 0.404 | 0.352 |
| $AGE$ | 3.901 | 3.801 | 3.842 | 3.802 |
| *Firm-specific characteristics* | | | | |
| $SIZE$ | 1.174 | 1.006 | 1.190 | 0.962 |
| $RD$ | 4.548 | 2.369 | 3.790 | 2.181 |
| $IND$ | 0.705 | 0.842 | 0.801 | 0.835 |
| $MFOUND$ | 0.574 | 0.450 | 0.518 | 0.444 |
| $DBUSI$ | 0.492 | 0.370 | 0.475 | 0.349 |
| $DLOC$ | 0.279 | 0.194 | 0.270 | 0.179 |
| *Industry-specific characteristics* | | | | |
| $APPROP$ | 1.268 | 1.191 | 1.216 | 1.194 |
| $TECHOPP$ | 0.896 | 0.889 | 0.864 | 0.900 |

Note: $N$ indicates the number of observations for subsamples.

Table 6: Estimation results using probit model.

| | *C_UNIV* | | *C_FIRM* | |
|---|---|---|---|---|
| Variable | (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) |
| *JEXP* | −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 obs. | 499 | 499 | 499 | 499 |
| Log pseudolikelihood | −147.678 | −146.456 | −265.626 | −267.322 |

Note:

1. Robust standard errors are in parentheses.
2. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 7: Estimation results using negative binomial model.

| | *NC_UNIV* | | *NC_FIRM* | |
|---|---|---|---|---|
| Variable | (i) | (ii) | (iii) | (iv) |
| *Founder-specific characteristics* | | | | |
| *UEDU* | −0.017 | −0.042 | −0.183 | −0.217 |
| | (0.389) | (0.395) | (0.199) | (0.200) |
| *GEDU* | 0.938** | 0.858* | −0.204 | −0.293 |
| | (0.470) | (0.456) | (0.338) | (0.336) |
| *INNOV* | 0.927** | | 0.587*** | |
| | (0.371) | | (0.200) | |
| *PAT* | | 1.283*** | | 0.487** |
| | | (0.338) | | (0.210) |
| *ACAD* | 0.992*** | 0.891*** | −0.140 | −0.135 |
| | (0.329) | (0.312) | (0.257) | (0.250) |
| *JEXP* | −0.440 | −0.375 | 0.759** | 0.834** |
| | (0.399) | (0.381) | (0.343) | (0.334) |
| *MEXP* | −0.111 | −0.127 | 0.077 | 0.106 |
| | (0.282) | (0.278) | (0.208) | (0.201) |
| *AGE* | 0.645 | 0.305 | 0.236 | 0.309 |
| | (0.693) | (0.591) | (0.384) | (0.395) |
| *Firm-specific characteristics* | | | | |
| *SIZE* | 0.017 | 0.059 | 0.215** | 0.234** |
| | (0.164) | (0.152) | (0.096) | (0.097) |
| *RD* | 0.098* | 0.103** | 0.143*** | 0.149*** |
| | (0.054) | (0.050) | (0.032) | (0.033) |
| *IND* | −0.916** | −0.907** | 0.119 | 0.133 |
| | (0.411) | (0.381) | (0.271) | (0.260) |
| *MFOUND* | 0.198 | 0.223 | −0.035 | −0.050 |
| | (0.299) | (0.295) | (0.187) | (0.186) |
| *DBUSI* | −0.057 | −0.148 | 0.385** | 0.420** |
| | (0.319) | (0.308) | (0.189) | (0.192) |
| *DLOC* | 0.182 | 0.236 | −0.089 | −0.089 |
| | (0.376) | (0.348) | (0.201) | (0.200) |
| *Industry-specific characteristics* | | | | |
| *APPROP* | 0.673 | 0.803 | 0.197 | 0.248 |
| | (0.657) | (0.620) | (0.387) | (0.395) |
| *TECHOPP* | 0.136 | 0.286 | −1.354** | −1.285** |
| | (0.970) | (1.005) | (0.584) | (0.580) |
| Constant term | −5.226* | −4.281* | −2.550 | −2.936* |
| | (2.763) | (2.500) | (1.707) | (1.765) |
| Number of obs. | 495 | 495 | 480 | 480 |
| Log pseudolikelihood | −224.909 | −221.815 | −393.616 | −395.596 |

Note:
1. Robust standard errors are in parentheses.
2. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 8: Summary of the estimation results.

| | Probit model | | Negative binomial model | | |
|---|---|---|---|---|---|
| Variable | $C\_UNIV$ | $C\_FIRM$ | $NC\_UNIV$ | $NC\_FIRM$ | Hypotheses supported |
| *Founder-specific characteristics* | | | | | |
| $UEDU$ | | | | | |
| $GEDU$ | + | | + | | Hypothesis.1b |
| $INNOV$ | + | + | + | + | Hypothesis.2 |
| $PAT$ | + | + | + | + | Hypothesis.2 |
| $ACAD$ | + | | + | | Hypothesis.3b |
| $JEXP$ | | + | | + | Hypothesis.4b |
| $MEXP$ | | | | | |
| $AGE$ | | | | | Control |
| *Firm-specific characteristics* | | | | | |
| $SIZE$ | | | | + | Hypothesis.5 |
| $RD$ | + | + | + | + | Hypothesis.6 |
| $IND$ | − | | − | | Hypothesis.7b |
| $MFOUND$ | | | | | Control |
| $DBUSI$ | | | | | Control |
| $DLOC$ | | | | | Control |
| *Industry-specific characteristics* | | | | | |
| $APPROP$ | | | | | Control |
| $TECHOPP$ | | | | | Control |

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