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R&D, innovation, and business performance of Japanese start-ups: A comparison with established firms

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ABSTRACT

Despite the importance of innovation activities in business start-ups, few studies have comprehensively compared these undertakings to equivalent ones in established firms. Therefore, we compare the determinants of R&D intensity, innovation, and firm performance in start-ups and established firms with a three-stage model, using comparable datasets in Japan. Estimation results suggest that 1) the effects of public financial support on R&D intensity are positive but smaller for start-ups; 2) the effects of research cooperation with business partners and universities on innovation are positive and larger for start-up; and 3) the effects of product and process innovation on labor productivity (level and growth) are positive both for start-ups and established firms.

Keywords: R&D; innovation; productivity; start-up; established firms

1. Introduction

Since J. A. Schumpeter, entrepreneurship and innovation have been regarded as major sources of economic growth. Several empirical studies confirm the contribution of innovation to productivity growth (e.g., Crépon et al. 1998; Griffith et al. 2006; OECD 2009) and to employment growth (Hall et al. 2008; Lachenmaier and Rottmann 2011) at the firm level. Moreover, Acs and Armington (2004) and Audretsch and Keilbach

(2005) demonstrate that entrepreneurial activities measured as the start-up ratio are a key factor for regional economic growth and productivity.

Despite the importance of innovation activities in business start-ups, few studies have comprehensively compared these undertakings to equivalent ones in established firms. Several empirical studies estimate the determinants of R&D input and outcomes by focusing on start-ups (Kato et al. 2013) or SMEs (Hall et al. 2009). Okamuro et al. (2011) analyze the determinants of R&D cooperation of business start-ups with business partners or universities. Okamuro (2009) compares the determinants of the propensity to conduct R&D and the R&D intensity of start-ups and all SMEs in the manufacturing sector. Huergo and Jaumandreu (2004a) find a nonlinear relationship between firm age and the probability of introducing an innovation. However, to the best of our knowledge, few studies comprehensively compare the determinants of R&D intensity, innovation, and firm performance of start-ups and established firms. In order to understand the characteristics and impact of innovation activities in start-ups, we should focus not only on R&D input but also on innovation and its impact on firm performance in both start-ups and established firms.

Moreover, especially in Japan, despite the growing policy interests in innovation[1], there is little empirical research that employs the national innovation surveys, except for a few studies, such as Kwon et al. (2008) and Isogawa et al. (2012). Thus, this paper bridges these gaps by using comparable datasets from different surveys.

In sum, our empirical results suggest that 1) the effects of public financial support on R&D intensity are smaller for start-ups; 2) the effects of research cooperation with business partners or universities on innovation are larger for start-ups; and 3) the effects of product and process innovation on labor productivity (level and growth) are positive both for start-ups and established firms. These results imply that, in order to promote the innovation and growth of start-ups, we should provide them with more or better support to engage in research cooperation.

The remainder of this paper is organized as follows: We explain our data and estimation models in Sections 2 and 3. Subsequently, we present our empirical results in Section 4. We conclude the paper in Section 5.

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[1] Since the mid-1990s, the Japanese government has intensively promoted R&D and innovation with the "Science and Technology Basic Plans." Implementation of the science-based science and technology policy is a new and important agenda in the fourth plan starting in 2011.

2. Data

Based on the data sources, we distinguish start-ups from established firms as follows: The former are firms within two years of operation and the latter those with more than two years of operation.

We obtained data on start-ups from our original questionnaire survey series for Japanese start-ups that were carried out annually from 2008 to 2011. The first wave of this survey targeted 14,401 start-ups in the manufacturing and the software industry in Japan incorporated between January 2007 and August 2008; it was compiled by Tokyo Shoko Research (TSR), a major credit investigation company in Japan and based on the Corporation Register. Since our sample may also include the firms that were established earlier but incorporated after January 2007, we extracted the "real" start-ups, that is, those that were established during 2007 and 2008, using the survey response. We conducted the first postal survey in 2008 and received 1,514 responses, of which 1,060 were "real" start-ups[2].

We then carried out follow-up surveys in the successive years for the respondents of the previous year's survey until 2011. For the empirical analysis of this paper, we extracted the respondent firms of the third survey in 2010 and excluded incomplete responses and some outliers. Thus, our final dataset of start-ups comprises 894 firms less than 2 years of age at time of the initial survey in 2008. We use the data from the third survey wave (and not the first one) to obtain sufficient information on innovation and firm performance and to secure comparability with the dataset of established firms.

Comparable data of established firms (that comprises approximately 2,000 firms) were obtained from the Japanese National Innovation Survey 2009 (J-NIS 2009) conducted in 2009 by the National Institute of Science and Technology Policy (NISTEP), as official statistics carried out according to the Oslo Manual and the Community Innovation Survey 2010 (CIS2010) in the EU. The sample of the survey comprises the firms with more than ten employees and covers the entire manufacturing sector and most non-manufacturing sectors, including the software industry. In all, 15,871 firms were selected as our sample from the 331,037 firms in the list of the Establishment and Enterprise Census conducted in 2006 by the Statistics Bureau of the

[2] For further information on this survey, see Okamuro et al. (2011).

Ministry of Internal Affairs and Communications. Of 4,579 respondents, 1,993 firms could be classified as belonging to the manufacturing or the software industry. Excluding incomplete responses and some outliers in addition to young firms less than 2 years of age, our final dataset of established firms comprises 1,517 firms that had at least 2 years of operation at time of the initial survey year, 2006.

Table 1 shows the simple comparison between start-ups and established firms in our datasets: The former are 1) less likely to conduct R&D, but more R&D intensive on average; 2) less likely to cooperate with business partners, universities, or public research institutes, but more dependent on the information from competitors; 3) less likely to innovate; and 4) more likely to grow faster, but less productive and profitable.

(Insert Table 1)

Table 2 shows the correlation matrix of the variables. It reveals that, while labor productivity is positively associated with product and process innovation, the correlation of the growth rate of labor productivity with product and process innovation is negligible. Productivity and profitability are positively correlated each other. Profitability is positively correlated with product innovation but negatively correlated with process innovation. R&D input is positively associated with productivity, profitability and product, and process innovation. Geographic factors, such as the expert ratio (the ratio of professionals in the workforce) and the density of industry and university, are also positively correlated with R&D intensity.

(Insert Table 2)

3. Model

We simultaneously examine the differences between start-up firms and established firms in the determinants of innovation input (R&D intensity) and output (introduction of new products and processes) and firm performance (productivity and profitability). For this purpose, we employ a three-stage model proposed by Crepon et al. 1998 (see also OECD 2009) in order to consider the selectivity and endogeneity issues. In the first stage, R&D intensity measured as the ratio of R&D expenditures per person (in natural logarithm) is determined. In the second stage, we investigate the relationship between innovation input (R&D intensity) and output, distinguishing between product and process innovation and considering the effect of R&D cooperation. In the third and final stage, we examine the effects of innovation output on firm performance, measured as the level and growth rate of labor productivity and the positive profit dummy.

3.1. First stage: R&D intensity model

We assume that the R&D intensity of firms, defined as R&D expenditures per employee, is determined by two equations: the generalized Tobit model (Heckman, 1976, 1979). Firms decide at first whether or not they engage in R&D activity (the first equation) and then determine the relative level of R&D expenditures (the second equation). We use the same set of factors as explanatory variables for both equations, but estimate different sets of coefficients for each equation. We focus on the differences between start-up and established firms with respect to the effects of public financial support and local accessibility to research personnel. In addition, we control for the effects of firm size and age, the differences between affiliated and independent firms, industry-specific effects, and the density of businesses and universities in the municipality and prefecture where the firms' headquarters are located.

3.2. Second stage: Innovation model

Firms generate new products and processes as innovation outputs. In this regard, we distinguish between product innovation (the generation of new or significantly improved products) and process innovation (the implementation of new or significantly improved production method)[3]. As the determinants of innovations, the predicted values of R&D intensity in the first stage are a main variable. In addition, Robin and Schubert (2013) have recently found a positive effect of cooperation with public research institutes on the probability of introducing product innovation but no effect on process innovation. As shown in Belderbos et al. (2004), supplier and customer firms and

[3] According to Oslo Manual (OECD 2005), process innovation covers not only the implementation of a new or significantly improved production methods but also that of new or significantly improved delivery methods and techniques, equipment, and software in ancillary support activities. Since the survey for start-ups did not consider the latter two types of process innovation, we regard only the implementation of a new production method as process innovation.

competitors might be also important as collaboration partners and external knowledge sources. Therefore, we first distinguish the cooperation with universities and firms with supplier/customer relationships. Second, we examine the effects of external knowledge from competitors by utilizing a survey question on the importance of competitors as information sources in R&D (innovation) activity. We then examine the difference in the magnitude of effects of those cooperation and external knowledge from competitors on innovation between start-ups and established firms.

3.3. Third stage: Performance model

Finally, to validate the measurement of our indicators for innovations and to access the differences in an economic impact of innovations between start-ups and established firms, we estimate the effects of product and process innovation on firm economic performance, such as the levels or growth rates of labor productivity and profitability. As the proxy for productivity, we employ labor productivity. Since our dataset of startups does not consist of physical capital accumulation and the input of materials, we cannot measure the total factor productivity and also not control for capital intensity or intermediate inputs. Instead, we include several control variables: initial employment size, age, affiliated firm dummy, and initial labor productivity level. Our choice of the proxy for profitability is also limited because of a lack of detailed financial information. We use a dummy variable that takes the value of one, if the firm’s (operating) profit is positive[4].

Product and process innovation may be complimentary. However, a marginally strong correlation between these two types of innovations (0.306 as shown in Table 2) might make it difficult to identify the effects of these two types of innovations. To explore the relevant specification, we examine several approaches: First, we inspect the predicted probability that the firm introduces either the product or process innovation as an explanatory variable. Second, we include the predicted probabilities of product innovation and process innovation, alternately or independently, as explanatory variables. Third, we include the predicted probability of product innovation only, process innovation only, and product and process innovations together as explanatory

[4] For the startups, we cannot identify the firms’ answers to the profitability question based on which kind of profit.

variables.

4. Results

Table 3 shows the estimation results of the generalized Tobit model for R&D intensity. For each specification, the first column shows the coefficients of the probit model in which the dependent variable is a dummy variable for R&D conducting firms, and the second column reports the coefficients of linear model of the level of R&D intensity. In addition, in the last row, the correlation coefficients of the residuals of two equations are reported for each specification. The results show the positive effects of initial labor productivity on both the selection equation and R&D intensity and the positive effects of employment size and firm age on only R&D intensity. Affiliated firms conduct R&D investment at a higher probability, but their R&D intensity is lower than that of independent firms. Public financial support and the expert ratio in local labor market increase the probability of R&D investment and the R&D intensity of firms (see Figure 1 and 2). The geographic agglomeration of industry and university have no effects on either the selection or the intensity of R&D. Interestingly, the effects of public support on both the selection and intensity of R&D are significantly smaller for start-ups than established firms, while we do not find significant difference of the effects of the expert ratio between these groups.

(Insert Table 3)

(Insert Figure 1 and 2)

Table 4 shows the second stage results of the bivariate probit model for product and process innovation. For each specification, we report the coefficients of the product innovation equation and those of the process innovation equation in the first column and the second column, respectively. The effects of predicted R&D intensity are significantly positive on product innovation (see Figure 3) but not on process innovation (see Figure 4). We find the positive effects of collaboration with business partners (see Figure 5 and 6) and universities (see Figure 7 and 8) both on product and process innovation while the information from competitors affect only product innovation (Figure 9 and 10). Firm size has positive effects, but firm age has no effect. Affiliated firms have a lower probability of product innovation but there is no significant difference in the probability of process innovation between affiliated and independent firms. We find several significant differences in the effects of collaboration with partner firms and universities and in information from competitors on innovation between start-ups and established firms: the positive effects of collaboration with business partners (supplier and client) and universities on product innovation are greater in start-ups than in established firms, while the effect of information from competitors on product innovation is lower in start-ups than in established firms. Collaborations with universities also increase the probability of process innovation more in start-ups than in established firms. As the same as in the first stage of the R&D intensity model, we do not find any significant effects of geographic agglomeration factors on innovations.

(Insert Table 4)

(Insert Figure 3-10)

Table 5-7 reports the third stage results of the firm performance model with three different dependent variables: the level of labor productivity in Table 5, the growth rate of labor productivity in Table 6, and profitability in Table 7. While the models shown in first five columns of Table 5 and Table 6 estimate the common coefficients for start-ups and established firms, the models in the successive five columns (6-10), include the interaction terms of these innovation indicators with start-up firm dummy. In those tables, the last two columns examine the direct effects of R&D intensity on productivity.

The results in column [1] to [3] in Table 5 show that positive effects of product and process innovation on the level of labor productivity, controlling for effects of scale economy and affiliated firms. When we jointly include product and process innovation in the specification [4] and [5] of Table 5, however, the coefficient of process innovation turn negative. The effects of process innovation on productivity are also controversial in the literature. On the one hand, OECD (2009) consistently reports the significantly negative coefficients of process innovation on productivity of 18 countries, while the coefficients of product innovation are jointly estimated as positive. On the other hand, Griffith et al. (2006) report the significantly positive effects of process innovation and product innovation, using capital investment intensity only as an instrumental variable for process innovation[5].

(Insert Table 5)

We also find the negative coefficients of the interaction terms between the start-up firm dummy and product and process innovations. These imply that the effects of product or process innovation are smaller in start-ups than in established firms. In column [11] and [12], we also see the significant effects of predicted R&D intensity on productivity. These imply that our innovation indicators might not capture the whole effects of R&D.

Table 6 shows the estimation results for the growth rate of labor productivity rather than the level of labor productivity, as in Table 5. In general, there are not large differences in the results on the effects of process innovation and interaction terms between start-ups and product and/or process innovations. The results in column [1] to [3] in Table 6 show the positive effects of product and process innovation on the labor productivity growth. We also find no significant coefficients of the interaction terms between the start-up firm dummy and product and process innovations in column [6] to [8] in Table 6. These imply that the effects of product or process innovation are positive and not significantly different in start-ups and in established firms (Figure 11 illustrates these relationships).

(Insert Table 6)

(Insert Figure 11)

But in column [4] we find no significant coefficient when we jointly include product and process innovation, and in column [5] we find a significant positive coefficient only on joint introduction of product and process innovations. These results indicate the strong complementarity of product and process innovation. Moreover, the results in column [10] indicate that this complementarity works more in start-ups than in

[5] Hall et al. (2009) confirms that the effect of process innovation on productivity is estimated as significantly positive only when they instrument it by capital investment intensity and do not include capital investment intensity in the productivity equation; otherwise, it is estimated as negative or positive but not as significant.

established firms. In particular, the result indicates that, for start-ups, labor productivity growth rate falls when they introduce process innovation but not product innovation.

The first six columns in Table 7 show the estimation results of profitability equation without control variables, and the last four columns of this table display the results with control variables. The results without control variables have almost the same implications as the results for labor productivity growth: the positive and significant effects of product and process innovation, when they are not distinguished (column [1]) or included independently (column [2] and [3]); but no significant coefficients when they are jointly included (column [4]) and when they complement each other (column [5]). We find no significant difference between start-ups and established firms in the effects of innovation on profitability (column [6]). However, these significant results disappear when we add one of the control variables (column [7] to [10]): firm age, size, or initial labor productivity. Since we use a dummy and not a continuous variable for profitability, the data may not have sufficient variation to identify these effects.

(Insert Table 7)

5. Conclusion

In this paper, we empirically examined the differences between start-ups and established firms with respect to determinants of R&D and innovation and the relationship between innovation and firm performance using a comprehensive datasets derived from two surveys on innovation activities in Japanese private firms in the last years of the first decade of the new century; one is the survey of start-ups and another is the Japanese national innovation survey. Our empirical results suggest that 1) the effects of public financial support on R&D intensity are generally positive but smaller for start-ups, 2) the effects of research cooperation with business partners or universities on innovation are generally positive but larger for start-ups, and 3) the effects of product and process innovation on labor productivity (level and growth) are positive both for start-ups and established firms.

However, our research has several limitations: First, an appropriate correction for the reported standard errors is needed. Second, we should examine the correction for endogeneity in public subsidies and R&D cooperation. Third, we ignore differences in the intensity, magnitude, or quality of innovations between firms.

Despite these limitations, our empirical results imply that in order to promote innovation and growth of start-ups, we should provide more or better support for start-ups to engage in research cooperation with both business partners and universities, rather than the financial support. In general, start-up firms have scarce internal knowledge and R&D stock compared to established or mature firms, despite their greater incentives for innovation; and they rely heavily on external knowledge and research collaboration with others. Our findings indicate that governments can accelerate innovation and productivity growth more efficiently by promoting research collaborations between start-up firms and universities and between start-ups and their business partners, rather than by increasing public financial supports for start-ups.

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Table 1. Descriptive statistics

Variables	Established firms (firm age ≥ 2)					Start-up firms (firm age < 2)				
	n	Mean	S.D.	Min	Max	n	Mean	S.D.	Min	Max
Positive R&D (dummy)	1,283	0.461	0.499	0.000	1.000	880	0.308	0.462	0.000	1.000
R&D intensity (expenditure per person: 1mil. yen)	1,283	0.422	1.679	0.000	28.654	880	0.550	2.246	0.000	50.000
Log. of R&D intensity	591	-1.512	1.778	-7.378	3.355	271	-0.557	1.688	-6.765	3.912
Product innovation (dummy)	872	0.669	0.471	0.000	1.000	510	0.412	0.493	0.000	1.000
Process innovation (dummy)	872	0.429	0.495	0.000	1.000	510	0.161	0.368	0.000	1.000
Labor productivity (sales per person: 1 mil. yen)	674	36.228	45.841	0.000	458.652	223	17.030	32.669	0.000	360.000
Log. of labor productivity	674	3.211	0.879	0.000	6.130	223	2.288	1.020	0.000	5.889
Labor productivity growth rate	674	0.004	0.351	-2.244	3.714	223	0.120	0.880	-2.877	3.586
Positive profit (dummy)	743	0.709	0.454	0.000	1.000	247	0.543	0.499	0.000	1.000
Collaboration with business partners (dummy)	872	0.541	0.499	0.000	1.000	510	0.408	0.492	0.000	1.000
Collaboration with universities (dummy)	872	0.271	0.445	0.000	1.000	510	0.125	0.332	0.000	1.000
Information from competitor (dummy)	872	0.382	0.486	0.000	1.000	510	0.500	0.500	0.000	1.000
Employment size	1,517	321.937	1162.589	1.000	31595.000	894	11.892	42.296	1.000	620.000
Log. of employment size	1,517	4.342	1.927	0.000	10.361	894	1.404	1.134	0.000	6.430
Initial labor productivity (sales per person: 1 mil. yen)	1,517	31.585	44.660	0.000	671.597	894	15.407	30.763	0.000	600.000
Log. of initial labor productivity	1,517	3.007	0.966	0.000	6.511	894	2.186	1.056	0.000	6.399
Firm age	1,517	32.879	22.049	2.000	230.000	894	0.557	0.497	0.000	1.000
Affiliated firm dummy	1,517	0.405	0.491	0.000	1.000	894	0.219	0.414	0.000	1.000
Public financial support (dummy)	1,517	0.213	0.410	0.000	1.000	894	0.318	0.466	0.000	1.000
Expert ratio – city	1,517	0.141	0.033	0.059	0.247	894	0.153	0.037	0.064	0.247
Expert ratio – prefecture	1,517	0.140	0.019	0.111	0.171	894	0.146	0.020	0.111	0.171
Industry density – city	1,517	6.181	21.550	0.000	141.182	894	10.300	26.006	0.000	141.182
Industry density – prefecture	1,517	0.714	1.364	0.000	5.566	894	1.262	1.778	0.000	5.566
University density – city	1,517	0.029	0.083	0.000	0.707	894	0.040	0.097	0.000	0.707
University density – prefecture	1,517	0.008	0.010	0.000	0.028	894	0.011	0.011	0.000	0.028

Table 2. Correlation matrix of variables

		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]
[1]	Positive R&D (dummy)	1.000																				
[2]	Log of R&D intensity	-	1.000																			
[3]	Product innovation (dummy)	.334	.120	1.000																		
[4]	Process innovation (dummy)	.237	-.008	.306	1.000																	
[5]	Log of labor productivity	.294	.145	.193	.155	1.000																
[6]	Labor productivity growth rate	.044	.100	-.023	.016	.239	1.000															
[9]	Positive profit (dummy)	.062	-.070	.075	-.050	.245	.072	1.000														
[10]	Collaboration with business partners (dummy)	.199	.075	.289	.227	.124	.034	-.025	1.000													
[11]	Collaboration with universities (dummy)	.260	.154	.244	.176	.147	.032	.041	.247	1.000												
[12]	Information from competitor (dummy)	-.032	.055	.028	-.034	-.052	-.018	.014	.017	-.038	1.000											
[13]	Log of employment size	.272	-.166	.346	.303	.506	-.109	.165	.229	.286	-.103	1.000										
[14]	Log of initial labor productivity	.201	.040	.258	.214	.859	-.293	.220	.167	.149	-.064	.453	1.000									
[15]	Log. of firm age	.217	-.221	.306	.307	.416	-.118	.129	.163	.235	-.146	.736	.415	1.000								
[16]	Affiliated firm dummy	.089	.081	.128	.105	.370	-.034	.074	.127	.110	-.068	.445	.277	.218	1.000							
[17]	Public financial support (dummy)	.033	.083	.037	.020	-.060	.107	-.064	.001	.186	.032	-.127	-.052	-.144	-.135	1.000						
[18]	Expert ratio – city	.082	.203	.005	-.084	-.024	-.013	.069	-.043	.054	.074	-.101	-.034	-.164	-.055	.037	1.000					
[19]	Expert ratio – prefecture	.075	.210	-.014	-.081	-.001	.014	.069	-.037	.014	.085	-.105	.000	-.143	-.054	.028	.640	1.000				
[20]	Industry density – city	-.009	.074	-.032	-.108	-.043	-.008	.100	-.097	-.048	.068	-.015	-.059	-.094	-.008	-.045	.355	.328	1.000			
[21]	Industry density – prefecture	-.026	.147	-.028	-.106	-.023	.007	.089	-.073	-.033	.116	-.123	-.070	-.172	-.060	-.028	.405	.536	.631	1.000		
[22]	University density – city	.079	.155	-.003	-.024	-.001	-.036	.056	.015	.061	.044	.016	.000	-.070	.035	.014	.581	.450	.444	.446	1.000	
[23]	University density – prefecture	.052	.222	.021	-.064	.042	-.015	.063	-.027	.046	.094	-.056	.022	-.122	-.030	.002	.586	.856	.436	.706	.545	1.000

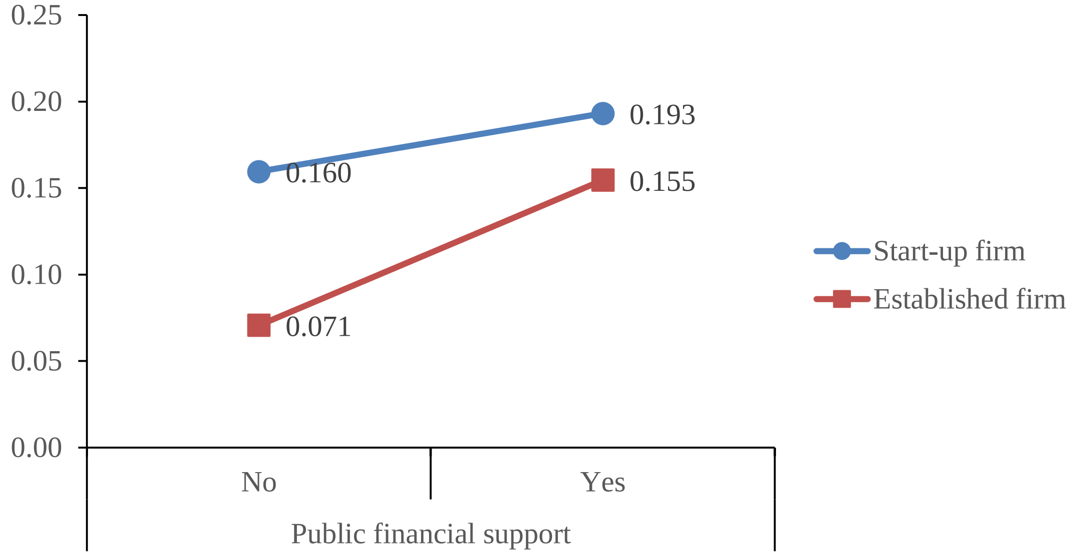
Table 3. First stage results for R&D intensity (Generalized tobit model - ML estimation)

Dependent variable: positive R&D dummy and log of R&D per employee

	[1]		[2]		[3]		[4]		[5]	
Dependent variable	R&D>0	R&D int.	R&D>0	R&D int.	R&D>0	R&D int.	R&D>0	R&D int.	R&D>0	R&D int.
Initial labor productivity	0.405***	0.121***	0.428***	0.125***	0.429***	0.127***	0.435***	0.128***	0.439***	0.128***
	[0.081]	[0.034]	[0.080]	[0.034]	[0.079]	[0.034]	[0.080]	[0.034]	[0.080]	[0.034]
Initial employment size	-0.072	0.188***	-0.077	0.190***	-0.073	0.197***	-0.078	0.196***	-0.073	0.196***
	[0.053]	[0.024]	[0.053]	[0.024]	[0.053]	[0.024]	[0.053]	[0.024]	[0.053]	[0.024]
Age	-0.137**	0.010	0.143	0.108***	0.143	0.114***	0.149*	0.117***	0.154*	0.113***
	[0.058]	[0.026]	[0.088]	[0.041]	[0.088]	[0.041]	[0.088]	[0.041]	[0.089]	[0.042]
Affiliated (dummy)	0.523***	-0.152**	0.548***	-0.154**	0.542***	-0.160**	0.535***	-0.161**	0.526***	-0.163**
	[0.150]	[0.071]	[0.147]	[0.071]	[0.147]	[0.071]	[0.148]	[0.071]	[0.148]	[0.071]
Public financial support (dummy)	0.504***	0.203***	0.498***	0.208***	0.695***	0.404***	0.685***	0.404***	0.694***	0.407***
	[0.136]	[0.067]	[0.135]	[0.067]	[0.161]	[0.092]	[0.160]	[0.093]	[0.161]	[0.093]
Expert ratio – city	5.414**	3.429***	5.235**	3.390***	4.987**	3.226***	7.009**	3.860**	7.575***	3.882**
	[2.441]	[1.201]	[2.427]	[1.208]	[2.407]	[1.210]	[2.823]	[1.541]	[2.883]	[1.600]
Expert ratio – prefecture	1.477	7.886**	1.641	7.947***	1.901	8.007***	-0.455	8.028**	0.537	3.637
	[5.963]	[3.069]	[5.916]	[3.083]	[5.919]	[3.090]	[6.597]	[3.497]	[7.248]	[3.998]
Industry density – city	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002	-0.001
	[0.004]	[0.002]	[0.004]	[0.002]	[0.004]	[0.002]	[0.004]	[0.002]	[0.005]	[0.002]
Industry density – prefecture	-0.080	-0.038	-0.088	-0.039	-0.084	-0.037	-0.089	-0.036	-0.135	-0.059
	[0.077]	[0.037]	[0.076]	[0.037]	[0.076]	[0.037]	[0.076]	[0.038]	[0.091]	[0.051]
Univ. density – city	0.126	0.559	0.281	0.594	0.269	0.609	0.340	0.629	0.119	0.579
	[0.929]	[0.433]	[0.941]	[0.437]	[0.933]	[0.440]	[0.919]	[0.441]	[1.028]	[0.619]
Univ. density – prefecture	26.206*	-7.254	23.433*	-8.149	22.781	-8.113	22.114	-8.223	22.364	5.084
	[14.033]	[6.940]	[13.923]	[6.984]	[13.891]	[6.996]	[13.828]	[7.010]	[16.087]	[8.937]
Start-up (dummy)			1.219***	0.402***	1.388***	0.549***	1.291	0.796*	1.819	-0.642
			[0.271]	[0.125]	[0.286]	[0.137]	[0.965]	[0.456]	[1.585]	[0.774]
Start-up x Public financial support					-0.505*	-0.401***	-0.510*	-0.402***	-0.512*	-0.404***
					[0.291]	[0.136]	[0.293]	[0.136]	[0.294]	[0.136]
Start-up x Expert ratio – city							-5.823	-1.519	-6.541	-1.604
							[4.542]	[2.159]	[4.976]	[2.408]
Start-up x Expert ratio – prefecture							6.816	-0.106	3.418	11.498*
							[7.860]	[3.849]	[12.400]	[6.269]
Start-up x Industry density – city									-0.004	0.002
									[0.007]	[0.003]
Start-up x Industry density – prefecture									0.093	0.072
									[0.141]	[0.068]
Start-up x Univ. density – city									0.544	0.053
									[2.039]	[0.880]
Start-up x Univ. density – prefecture									1.272	-34.268**
									[27.853]	[13.965]
Constant	-4.999***	-2.773***	-5.958***	-3.105***	-6.002***	-3.194***	-5.961***	-3.293***	-6.236***	-2.736***
	[0.933]	[0.408]	[0.977]	[0.421]	[0.983]	[0.424]	[1.020]	[0.458]	[1.093]	[0.517]
Industry dummies (2 digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of observations	2,163		2,163		2,163		2,163		2,163	
# of firms no R&D	1301		1301		1301		1301		1301	
Chi-squared (statistics)	328.2231		347.5391		356.9189		355.8323		357.3385	
Chi-squared (p-value)	0.000		0.000		0.000		0.000		0.000	
Correlation between errors	0.543		0.533		0.528		0.526		0.551	

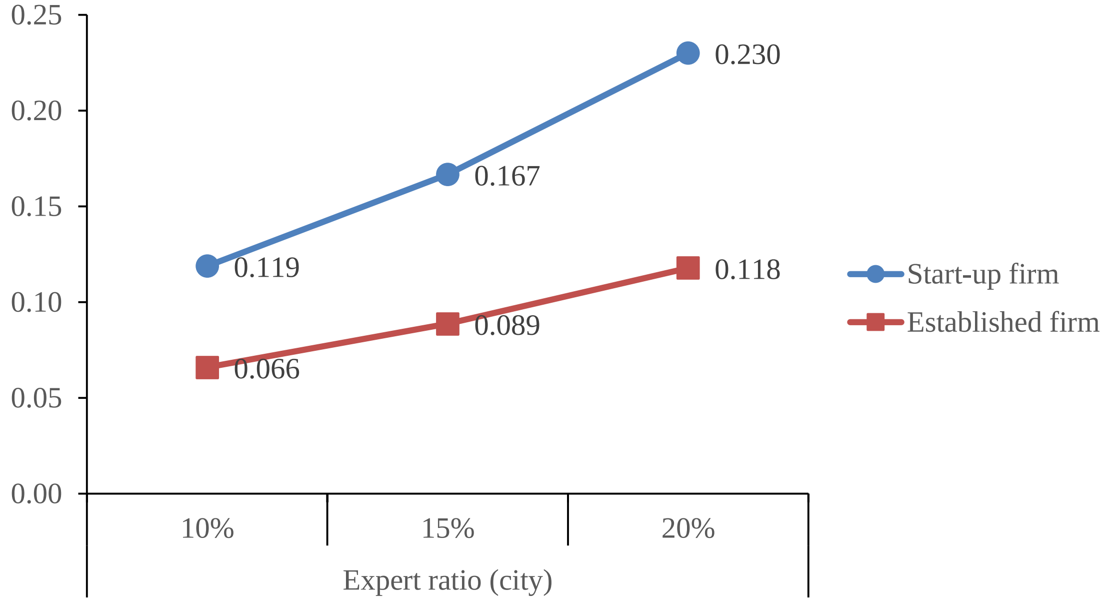
Notes: Robust standard errors are in brackets. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Figure 1: Marginal effects of public financial support on R&D intensity



Notes: The vertical axis is the predicted value of R&D expenditure (in 1 million yen) per person. The predicted values are calculated from the estimation results of column [4] in Table 3 at the mean values of the remaining covariates.

Figure 2: Marginal effects of expert ratio in city on R&D intensity



Notes: The vertical axis is the predicted value of R&D expenditure (in 1 million yen) per person. The predicted values are calculated from the estimation result of column [4] in Table 3 at the mean values of the remaining covariates.

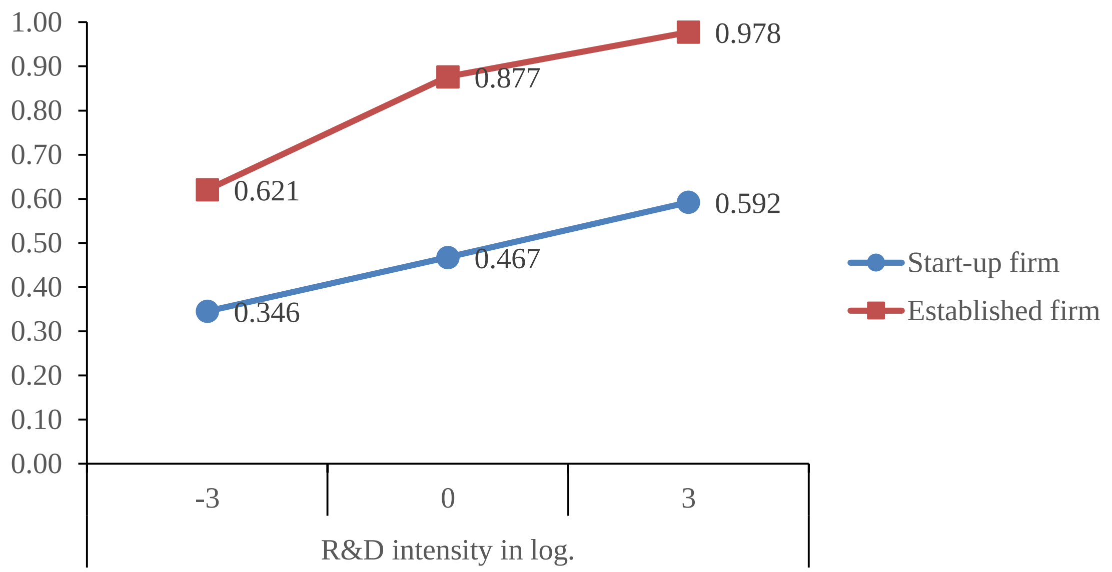
Table 4. Second stage results for product and process innovation (bivariate probit model - ML estimation)

Dependent variables: Dummy variables indicating the introduction of product innovation and process innovation

	[1]		[2]		[3]	
Dependent variable	Product	Process	Product	Process	Product	Process
Predicted R&D intensity	0.169***	-0.057	0.186**	-0.001	0.283***	0.039
	[0.065]	[0.067]	[0.082]	[0.086]	[0.091]	[0.089]
Collaboration with business partners (dummy)	0.565***	0.443***	0.567***	0.433***	0.355***	0.375***
	[0.076]	[0.079]	[0.076]	[0.079]	[0.098]	[0.095]
Collaboration with universities (dummy)	0.467***	0.236**	0.467***	0.231**	0.336***	0.109
	[0.105]	[0.095]	[0.105]	[0.095]	[0.124]	[0.111]
Information from competitors (dummy)	0.213***	0.024	0.207***	0.023	0.344***	0.086
	[0.077]	[0.078]	[0.077]	[0.078]	[0.101]	[0.093]
Initial employment size	0.150***	0.081***	0.153***	0.089***	0.167***	0.097***
	[0.029]	[0.028]	[0.029]	[0.029]	[0.030]	[0.030]
Age	0.074	0.062	0.066	0.052	0.065	0.054
	[0.050]	[0.048]	[0.051]	[0.050]	[0.051]	[0.052]
Affiliated (dummy)	-0.198**	-0.104	-0.206**	-0.141	-0.235**	-0.164
	[0.098]	[0.098]	[0.102]	[0.103]	[0.106]	[0.106]
Start-up (dummy)	-0.069	-0.200	-0.104	-0.253	-0.635**	-0.460
	[0.163]	[0.174]	[0.172]	[0.184]	[0.289]	[0.308]
Start-up x Predicted R&D intensity					-0.178*	-0.050
					[0.094]	[0.101]
Start-up x Collaboration with business partners					0.568***	0.192
					[0.157]	[0.175]
Start-up x Collaboration with universities					0.412*	0.473**
					[0.229]	[0.224]
Start-up x Information from competitors					-0.277*	-0.137
					[0.160]	[0.177]
Industry density – city			-0.001	-0.004*	-0.001	-0.004
			[0.002]	[0.002]	[0.002]	[0.003]
Industry density – prefecture			0.016	0.075	0.020	0.074
			[0.044]	[0.048]	[0.045]	[0.048]
Univ. density – city			-0.754	0.315	-0.795	0.320
			[0.486]	[0.461]	[0.506]	[0.540]
Univ. density – prefecture			2.538	-9.868	2.825	-9.821
			[6.380]	[6.329]	[6.571]	[6.581]
Constant	-0.342	-1.287***	-0.271	-1.074***	0.039	-0.940**
	[0.324]	[0.335]	[0.391]	[0.406]	[0.400]	[0.407]
Industry dummies (2 digit)	Yes	Yes	Yes	Yes	Yes	Yes
# of observations	1,382		1,382		1,382	
Chi-squared (statistics)	446.021		456.576		470.224	
Chi-squared (p-value)	0.000		0.000		0.000	
Correlation between errors	0.367		0.366		0.360	

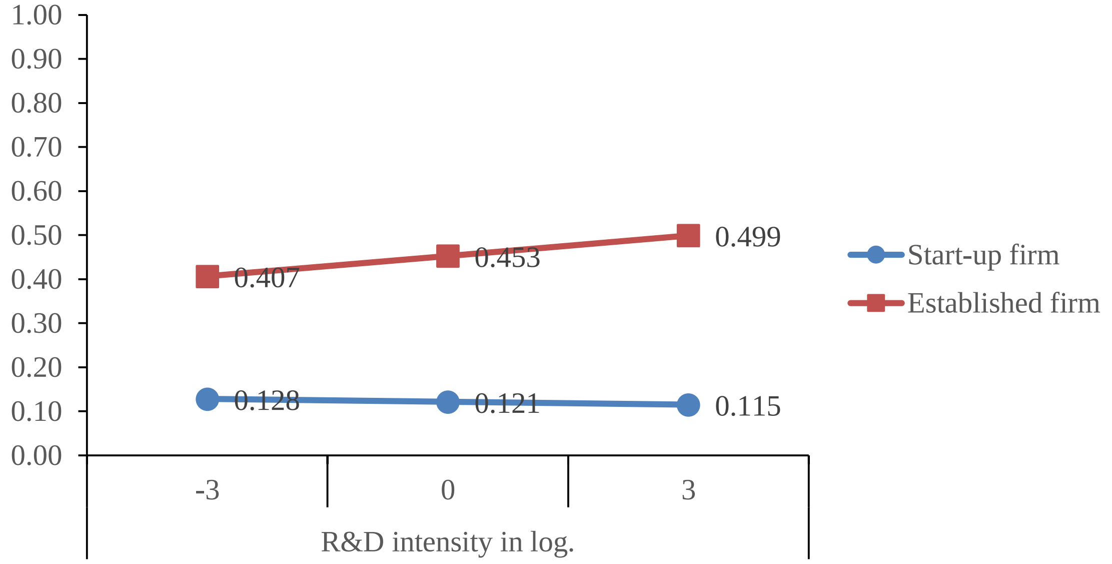
Notes: Robust standard errors are in brackets. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Figure 3: Marginal effects of R&D intensity on product innovation



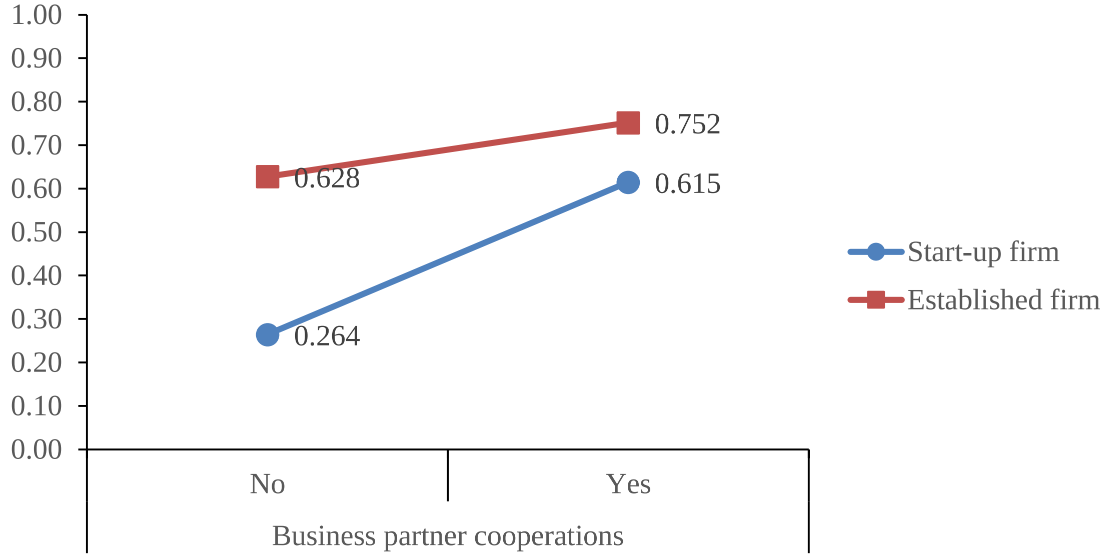
Notes: The vertical axis is the predicted probability to have a product innovation. The predicted values are calculated from the estimation result of column [3] in Table 4 at the mean values of the remaining covariates.

Figure 4: Marginal effects of R&D intensity on process innovation



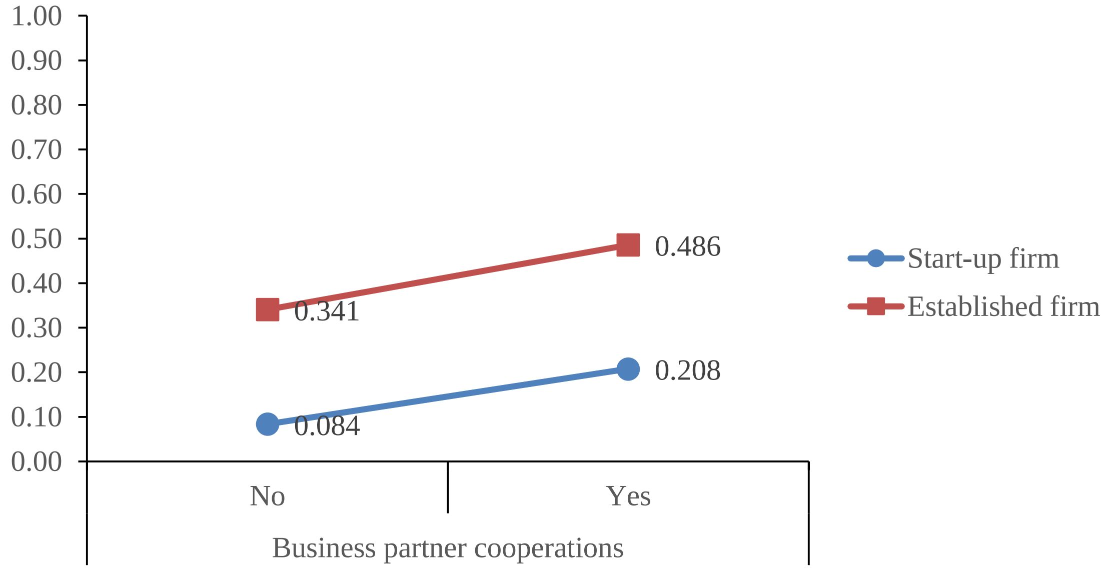
Notes: Vertical axis is the predicted probability to have a process innovation. Predicted values are calculated from the estimation result of column [3] in Table 4 at the mean values of the remaining covariates.

Figure 5: Marginal effects of business partner cooperation on product innovation



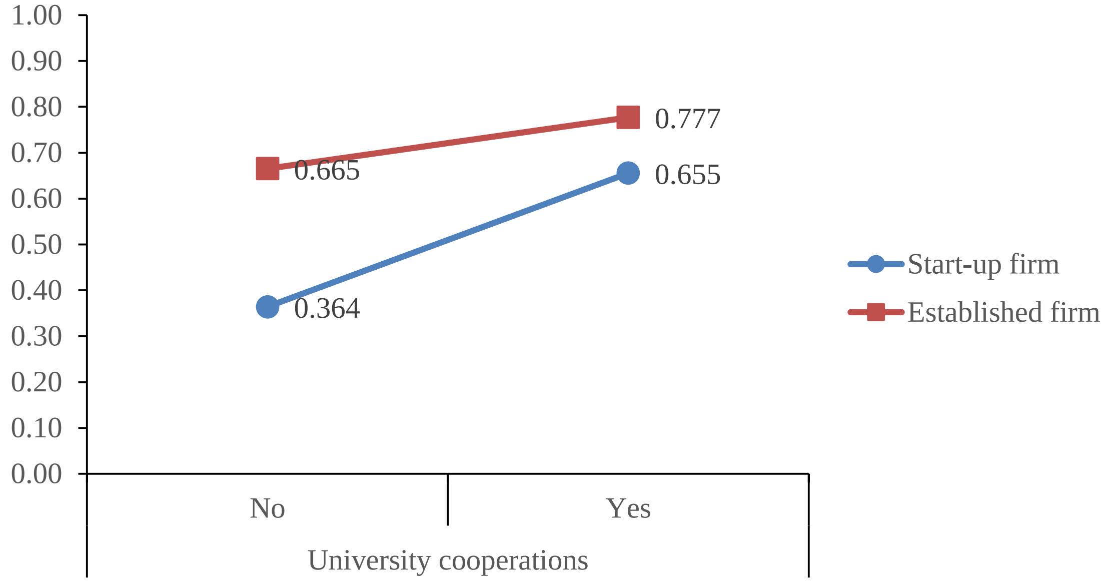
Notes: The vertical axis is the predicted probability to have a product innovation. The predicted values are calculated from the estimation result of column [3] in Table 4 at the mean values of the remaining covariates.

Figure 6: Marginal effects of business partner cooperation on process innovation



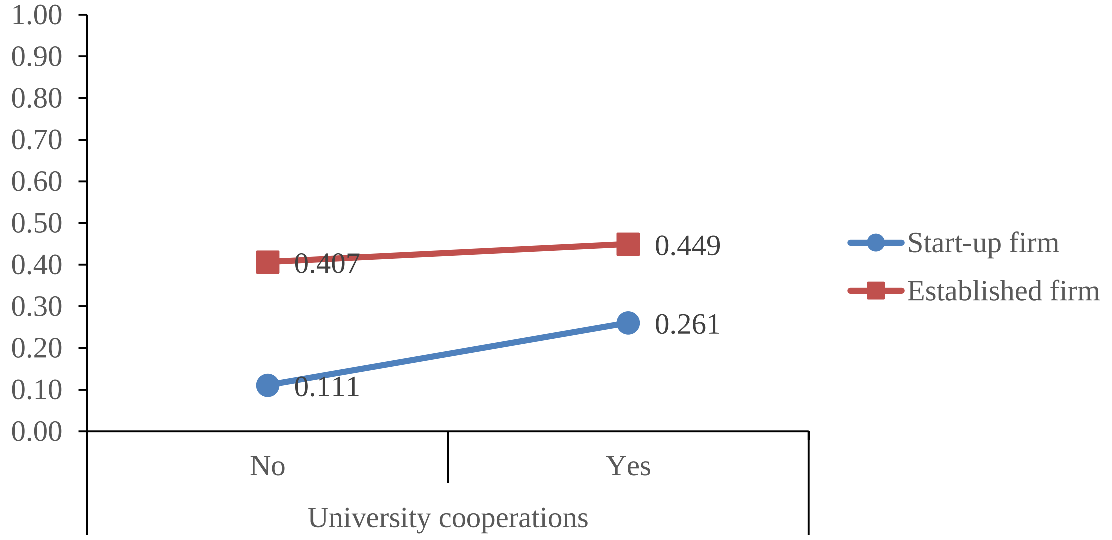
Notes: The vertical axis is the predicted probability to have a process innovation. The predicted values are calculated from the estimation result of column [3] in Table 4 at the mean values of the remaining covariates.

Figure 7: Marginal effects of university cooperation on product innovation



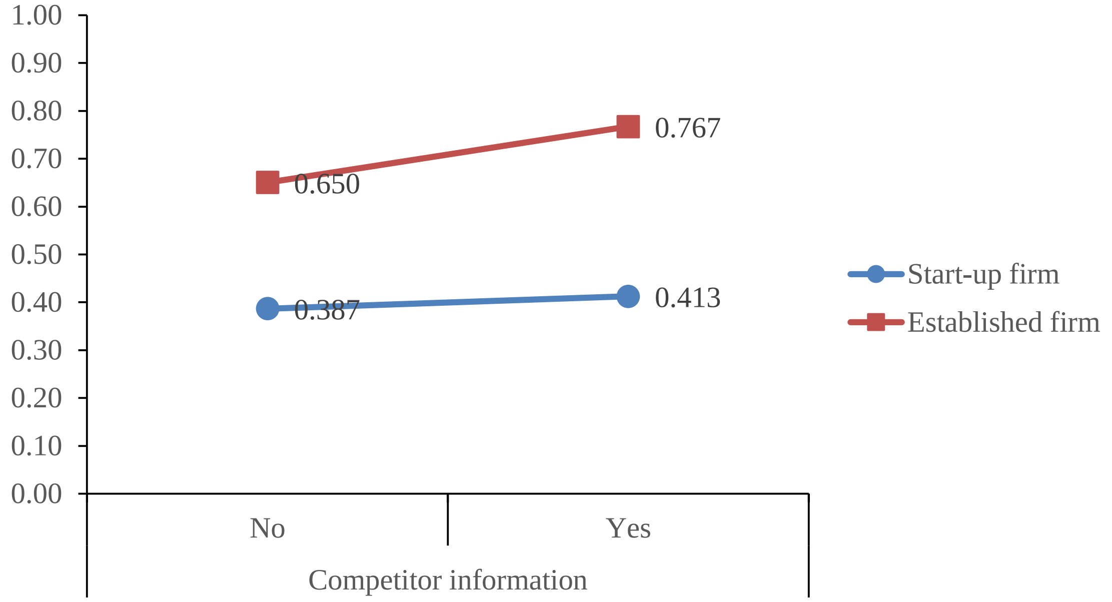
Notes: the vertical axis is the predicted probability to have a product innovation. The predicted values are calculated from the estimation result of column [3] in Table 4 at the mean values of the remaining covariates.

Figure 8: Marginal effects of university cooperation on process innovation



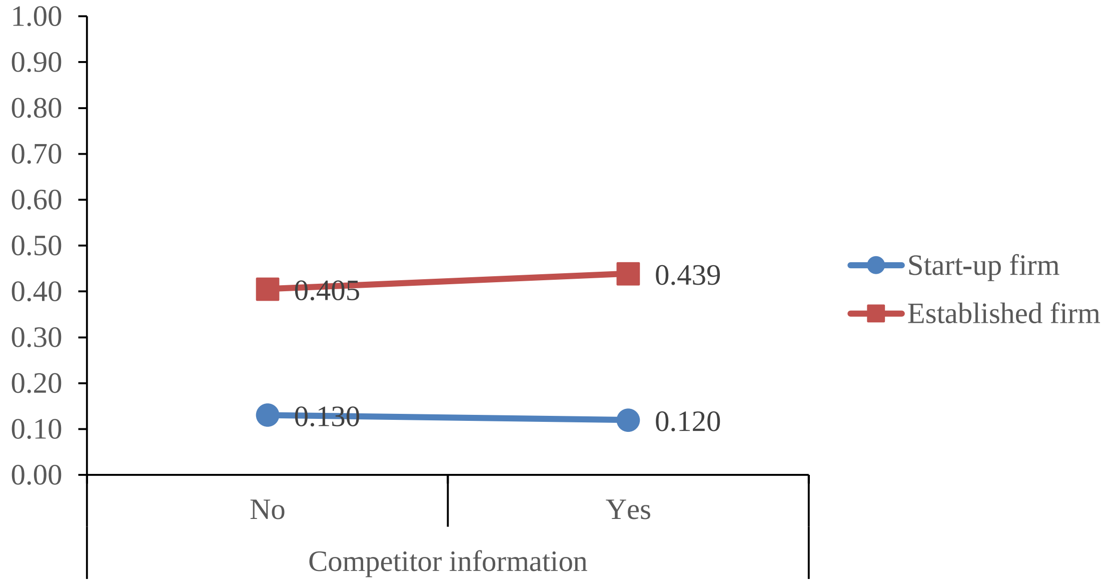
Notes: The vertical axis is the predicted probability to have a process innovation. The predicted values are calculated from the estimation result of column [3] in Table 4 at the mean values of the remaining covariates.

Figure 9: Marginal effects of competitor information on product innovation



Notes: The vertical axis is the predicted probability to have a product innovation. The predicted values are calculated from the estimation result of column [3] in Table 4 at the mean values of the remaining covariates.

Figure 10: Marginal effects of competitor information on process innovation



Notes: The vertical axis is the predicted probability to have a process innovation. The predicted values are calculated from the estimation result of column [3] in Table 4 at the mean values of the remaining covariates.

Table 5. Third stage results for performance (1) : Level of labor productivity (linear model - OLS estimation)

Dependent variable: Log. of labor produtivity

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Product or process innovation (predicted probability)	1.088***					1.670***					0.447**	0.284
	[0.221]					[0.309]					[0.201]	[0.287]
Product innovation (predicted probability)		1.119***		1.560***			1.510***		2.263***			
		[0.193]		[0.285]			[0.254]		[0.359]			
Process innovation (predicted probability)			0.865***	-0.927**				0.956***	-1.340***			
			[0.292]	[0.421]				[0.301]	[0.438]			
Product innovation only (predicted probability)					1.224***					2.077***		
					[0.354]					[0.552]		
Process innovation only (predicted probability)					-2.426***					-3.108***		
					[0.931]					[1.179]		
Product and process innovation (predicted probability)					0.560*					0.502		
					[0.294]					[0.365]		
Start-up (dummy)						0.214	-0.054	-0.096	-0.111	0.200	-1.078***	-1.248***
						[0.242]	[0.204]	[0.161]	[0.203]	[0.382]	[0.133]	[0.299]
Start-up x Product or process innovation						-0.891**						0.242
						[0.397]						[0.346]
Start-up x Product innovation							-0.606*		0.123			
							[0.360]		[0.477]			
Start-up x Process innovation								-0.430	-2.006***			
								[0.487]	[0.694]			
Start-up x Product innovation only										-0.779		
										[0.788]		
Start-up x Process innovation only										-8.436***		
										[2.448]		
Start-up x Product and process innovation										-0.409		
										[0.600]		
Predicted R&D intensity											0.707***	0.720***
											[0.051]	[0.054]
Start-up x Predicted R&D intensity												-0.021
												[0.078]
Initial employment size	0.091***	0.081***	0.120***	0.088***	0.086***	0.067**	0.058**	0.117***	0.065**	0.072***	0.114***	0.120***
	[0.028]	[0.028]	[0.028]	[0.028]	[0.028]	[0.028]	[0.028]	[0.028]	[0.028]	[0.027]	[0.024]	[0.024]
Age	0.011	0.019	0.011	0.038	0.050*	-0.063	-0.062	-0.032	-0.067*	-0.067*	-0.129***	-0.124***
	[0.029]	[0.029]	[0.029]	[0.029]	[0.030]	[0.038]	[0.038]	[0.038]	[0.038]	[0.038]	[0.035]	[0.037]
Affiliated (dummy)	0.363***	0.362***	0.363***	0.339***	0.337***	0.359***	0.357***	0.357***	0.309***	0.278***	-0.077	-0.085
	[0.067]	[0.067]	[0.068]	[0.067]	[0.067]	[0.067]	[0.067]	[0.068]	[0.066]	[0.067]	[0.066]	[0.064]
Constant	1.379***	1.462***	1.694***	1.457***	1.676***	1.302***	1.576***	1.812***	1.603***	1.912***	4.692***	4.808***
	[0.165]	[0.151]	[0.153]	[0.150]	[0.208]	[0.209]	[0.184]	[0.188]	[0.182]	[0.329]	[0.306]	[0.337]
Industry dummies (2 digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of observations	897	897	897	897	897	897	897	897	897	897	897	897
F-test (statistics)	16.5	17.3	16.1	16.8	18.4	17.3	18.0	15.6	17.6	18.1	29.9	28.2
F-test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.387	0.392	0.374	0.396	0.398	0.393	0.399	0.376	0.413	0.422	0.524	0.525

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

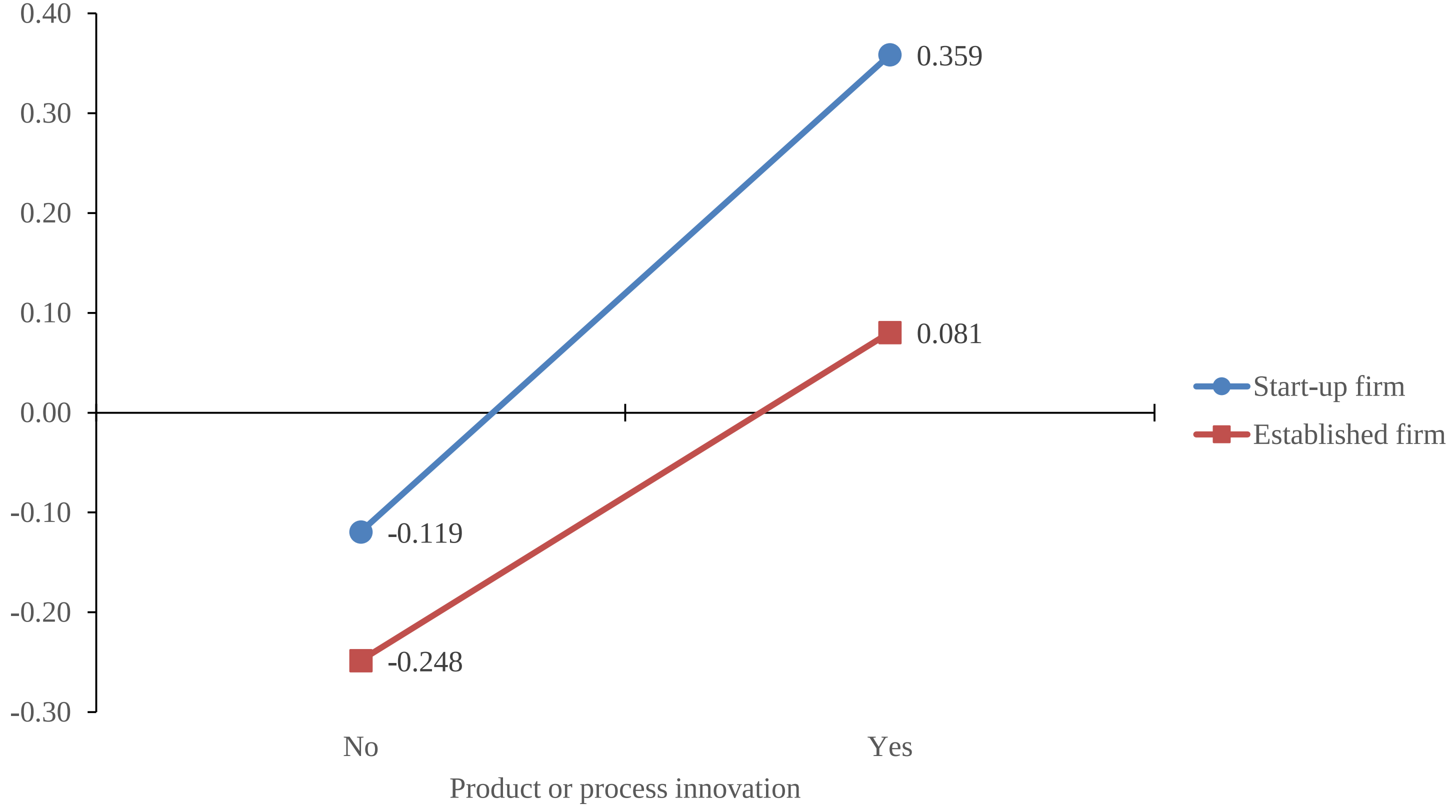
Table 6. Third stage results for performance (2): Growth rate of labor productivity (linear model - OLS estimation)

Dependent variable: Growth rate of labor produtivity

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Product or process innovation (predicted probability)	0.417**					0.329*					0.421**	0.099
	[0.172]					[0.178]					[0.174]	[0.184]
Product innovation (predicted probability)		0.369**		0.210			0.261*		0.060			
		[0.153]		[0.220]			[0.142]		[0.208]			
Process innovation (predicted probability)			0.567***	0.328				0.426**	0.335			
			[0.193]	[0.270]				[0.175]	[0.270]			
Product innovation only (predicted probability)					0.252					0.277		
					[0.270]					[0.326]		
Process innovation only (predicted probability)					0.522					0.080		
					[0.570]					[0.726]		
Product and process innovation (predicted probability)					0.547***					0.266		
					[0.191]					[0.229]		
Start-up (dummy)						-0.150	-0.204	-0.159	-0.196	0.151		-0.738***
						[0.163]	[0.141]	[0.111]	[0.142]	[0.260]		[0.234]
Start-up x Product or process innovation						0.149						0.414
						[0.276]						[0.283]
Start-up x Product innovation							0.251		0.157			
							[0.255]		[0.349]			
Start-up x Process innovation								0.556	0.328			
								[0.416]	[0.579]			
Start-up x Product innovation only										-0.670		
										[0.590]		
Start-up x Process innovation only										-3.885**		
										[1.941]		
Start-up x Product and process innovation										1.221*		
										[0.626]		
Predicted R&D intensity											-0.006	0.078**
											[0.032]	[0.035]
Start-up x Predicted R&D intensity												-0.213***
												[0.071]
Initial employment size	-0.001	-0.001	0.000	-0.003	-0.003	0.001	0.002	0.000	0.000	0.003	-0.001	0.011
	[0.018]	[0.018]	[0.017]	[0.018]	[0.018]	[0.017]	[0.017]	[0.017]	[0.017]	[0.017]	[0.018]	[0.018]
Age	-0.021	-0.017	-0.027	-0.024	-0.025	-0.032	-0.031	-0.030	-0.030	-0.033	-0.022	-0.036
	[0.022]	[0.022]	[0.023]	[0.022]	[0.022]	[0.025]	[0.025]	[0.024]	[0.025]	[0.025]	[0.022]	[0.025]
Affiliated (dummy)	0.087**	0.086**	0.094**	0.093**	0.093**	0.086**	0.084**	0.094**	0.093**	0.075*	0.090*	0.044
	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]	[0.044]	[0.044]	[0.044]	[0.046]	[0.044]
Initial labor productivity	-0.212***	-0.214***	-0.206***	-0.211***	-0.210***	-0.212***	-0.214***	-0.202***	-0.206***	-0.211***	-0.210***	-0.207***
	[0.034]	[0.034]	[0.034]	[0.034]	[0.034]	[0.034]	[0.034]	[0.034]	[0.034]	[0.034]	[0.035]	[0.035]
Constant	0.384***	0.438***	0.460***	0.436***	0.407***	0.481***	0.549***	0.525***	0.534***	0.535**	0.361**	0.816***
	[0.108]	[0.098]	[0.096]	[0.099]	[0.134]	[0.141]	[0.127]	[0.126]	[0.130]	[0.216]	[0.169]	[0.261]
Industry dummies (2 digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of observations	897	897	897	897	897	897	897	897	897	897	897	897
F-test (statistics)	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.7	2.6	2.8	2.7
F-test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.131	0.131	0.131	0.132	0.132	0.133	0.134	0.135	0.136	0.146	0.131	0.150

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

Figure 11: Marginal effects of product/process innovation on labor productivity growth



Notes: The vertical axis is the predicted growth rate of labor productivity. The predicted values are calculated from the estimation result of column [6] in Table 6 at the mean values of the remaining covariates.

Table 7. Third stage results for performance (3): Profitability (probit model - ML estimation)

Dependent variable: Positive profit dummy

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Product or process innovation (predicted probability)	0.824***					0.584*	0.398	0.248	-0.127	0.258
	[0.229]					[0.355]	[0.283]	[0.246]	[0.330]	[0.249]
Product innovation (predicted probability)		0.731***		0.461						
		[0.214]		[0.430]						
Process innovation (predicted probability)			1.004***	0.441						
			[0.304]	[0.609]						
Product innovation only (predicted probability)					0.774					
					[0.515]					
Process innovation only (predicted probability)					1.751					
					[1.298]					
Product and process innovation (predicted probability)					0.916***					
					[0.318]					
Start-up (dummy)						-0.150				
						[0.328]				
Start-up x Predicted product or process innovation						-0.433				
						[0.502]				
Affiliated (dummy)	0.143	0.143	0.168*	0.148	0.150	0.097	0.127	0.095	-0.033	-0.012
	[0.092]	[0.092]	[0.090]	[0.093]	[0.093]	[0.094]	[0.092]	[0.095]	[0.103]	[0.096]
Age							0.089**			
							[0.035]			
Initial profitability (positive profit dummy)								1.000***		
								[0.112]		
Initial employment size									0.136***	
									[0.034]	
Initial labor productivity										0.308***
										[0.054]
Constant	-0.365*	-0.252	-0.171	-0.244	-0.443*	-0.088	-0.259	-0.613***	-0.204	-0.676***
	[0.215]	[0.200]	[0.189]	[0.200]	[0.266]	[0.303]	[0.220]	[0.219]	[0.219]	[0.224]
Industry dummies (2 digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of observations	990	990	990	990	990	990	990	979	990	990
F-test (statistics)	52.2	51.0	49.8	51.3	52.7	63.6	56.8	124.5	67.3	81.3
F-test (p-value)	0.002	0.002	0.003	0.003	0.003	0.000	0.001	0.000	0.000	0.000

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