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Hiroyuki Okamuro
Junichi Nishimura

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Institute of Economic Research
Hitotsubashi University
2-1 Naka, Kunitatchi Tokyo, 186-8601 Japan
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Impact of University Intellectual Property Policy on the Performance of University-Industry Research Collaboration

Hiroyuki Okamuro[a]* and Junichi Nishimura[b]

Abstract

Despite various expected advantages, university-industry research collaboration (UIC), a relationship between two different worlds, often faces serious difficulties. Thus, the performance of UIC depends on the research partners' strategies to bridge the gaps between them according to the institutional environment. In Japan, UIC has developed rapidly since the late 1990s based on drastic institutional changes regarding universities. We pay special attention to the role of the university intellectual property (IP) policy introduced after 2003 and empirically examine its impact on the performance of UIC projects. A clear and equitable IP policy that can be applied flexibly to the needs of partners would be optimal for a UIC to be efficiently managed. Otherwise, the project might face serious conflicts of interests and low incentive for cooperation. Using a sample of Japanese firms from our original survey, we find that the IP policy of partner universities indeed has a positive and significant impact on various performances of UIC projects, controlling for firm and project characteristics and considering potential selection bias from UIC participation.

Keywords: university; intellectual property policy; research collaboration; project performance; Japan

JEL Classification Code: D23, L24, O32, O34

* Corresponding author

[a] Hitotsubashi University, Graduate School of Economics, Kunitachi, Tokyo 186-8601 Japan; e-mail: okamuro@econ.hit-u.ac.jp; phone: +81-42-5808792; fax: +81-42-5808882.

[b] Hitotsubashi University, Institute of Innovation Research, Kunitachi, Tokyo 186-8603 Japan

1. Introduction

The open innovation system, especially university-industry research collaboration (hereafter UIC), has been attracting considerable attention worldwide. Through UIC, researchers at universities can access research funds and benefit from the ideas and expertise of private firms, while the latter can absorb and utilize the advanced scientific knowledge created at universities.

However, participation in a UIC as such does not necessarily guarantee its success. UIC is a complex relationship between extremely different worlds. Researchers in academia and private business often have considerably different interests, objectives, constraints, and incentives. Such disparities may cause serious conflicts, misunderstanding, and distrust between the partners of UIC, and thus lower the satisfaction of the participants and decrease the effectiveness of UIC (Das and Teng 1998; Grilli and Milano 2009). Therefore, how to manage a UIC project by bridging different cultures should be a key consideration for the success of UIC (Mora-Valentin et al. 2004), even as the strategies for managing UIC are constrained by the institutional environment.

In Japan, UIC has increased and intensified rapidly since the late 1990s. The recent development of UIC in Japan follows some major changes in the national innovation system, especially in the university system (Hemmert et al. 2008; Woolgar 2007). Under the Science and Technology Basic Plan launched in 1996, the Ministry of Education, Culture, Sport, Science and Technology (MEXT) has promoted the establishment of Technology Licensing Organizations (TLO) since 1998 and Intellectual Property (IP) Centers since 2003 in Japanese universities. In addition to some other legal and institutional changes, Japanese universities have been activating their IP policy as one of their most important strategies. According to MEXT (2009), 58% of all universities (92% of national universities) drew up an IP policy by 2008, the year of our survey. Therefore, in this paper, we pay special attention to the university IP policy as an advantage of using recent Japanese data.

The IP policy of the partner university may affect the UIC performance by determining the basic rules of UIC with regard to the management of existing and generated IP. A clear and equitable IP policy that can be flexibly applied to the needs of partners would be optimal for a UIC to be efficiently managed. Otherwise, the project might face serious conflicts of interests and low incentive for cooperation.

Thus, by focusing on the IP policy of partner universities, we empirically investigate the determinants of UIC performance in Japan using original survey data. In this paper, UIC is defined as project-based collaboration in research and development (R&D) between universities and private companies aiming at the generation or transfer of new technologies, products, or processes. Unlike most previous studies, we integrate the analyses of both UIC participation and performance by using Heckman's two-step procedure to check and control for possible sample selection bias from UIC participation. We examine the effects of firm and top manager's characteristics in the first step, and then those of firm and project characteristics (focusing on the partner university's IP policy) in the second step.

The remainder of this paper is organized as follows: We provide a brief review of previous literature in Section 2 and the development of UIC in Japan in Section 3. The conceptual framework and the hypotheses are presented in Section 4. In Section 5, we explain the empirical methodology and present the data, and discuss the empirical results in Section 6. Finally, Section 7 concludes this paper.

2. Literature review

Several studies have thus far investigated the effectiveness of technology transfer by universities or technology transfer offices (TTOs) (Anderson et al. 2007; Caldera and Debande 2010; Chapple et al. 2005; Debackere and Veugelers 2005; Friedmand and Silberman 2003; Macho-Stadler et al. 2007; Siegel et al. 2003; Siegel et al. 2007; Thursby et al. 2001; Thursby and Kemp 2002; Thursby and Thursby 2002).

Siegel et al. (2007) summarize recent empirical studies on university TTOs and the key factors for their performance, reporting that the performance of technology transfer is affected by university characteristics, including ownership (public or private), academic quality, local conditions of high-tech demand, and the design of licensing contract as well as TTO characteristics such as size and age. More recently, Caldera and Debande (2010) examined how TTO characteristics affect university's performance of technology transfer, controlling for the nature and type of technology transfer and academic quality. Using the survey data on technology transfer activities of 52 universities in Spain over 2001–2005, they find that university's rules on the conflicts of interests between academic teaching responsibilities and external activities have a positive effect on R&D contracts, licenses, or spin-off creation. In sum, previous empirical studies suggest the importance of university IP policy for the performance of technology transfer from universities. However, the effects of university IP policy on the performance of collaborative R&D between university and industry have never been explicitly addressed.

Most studies of UIC performance examine the effect of engaging in UIC as such and find that UIC participation directly or indirectly increases R&D productivity of participating firms, measured by the number of patent applications (e.g., George et al. 2002; Zucker and Darby 2001). A recent study by Eom and Lee (2010) demonstrates that UIC participation in Korea improves both firm and innovation performance. However, few studies empirically investigate how project and partner characteristics affect UIC performance. Okamuro (2007) analyzes how project characteristics affect technological and commercial success of inter-firm R&D cooperation, but not of UIC. Hemmert et al. (2009) examine the effect of project characteristics on trust formation in UIC, but not on project performance.

Characteristics of UIC projects may change and develop as they proceed. However, existing studies do not explicitly consider the development of UIC projects, except for Mora-Valentin et al. (2004), who examine the effects of project characteristics on the performance of cooperative R&D, distinguishing between contextual factors (initial conditions) and organizational factors (how the project is organized and managed). They provide an empirical model that integrates various factors from several previous studies in management science and find that both contextual and organizational factors affect UIC performance. However, their model comprises only these factors and does not include other basic project or partner characteristics.

Most previous studies investigate the determinants of either participation or performance of UIC, thus addressing these research issues separately. However, empirical results of UIC performance can be subject to latent sample selection bias, unless the probability of UIC participation is randomly given (Eom and Lee 2010). Therefore, we should check and control for possible influence of the determinants of UIC participation on UIC performance. Eom and Lee (2010) employ Heckman’s two-step procedure to cope with sample selection bias, but in the second step (performance function), they focus only on firm characteristics.

Thus, we propose and employ a two-step procedure to integrate the estimations of the determinants of UIC participation and UIC performance, including the characteristics of the top manager and the firm in the first step, and project and partner characteristics (including the partner university’s IP policy) in the second step. Most previous studies use firm-side data for empirical analysis and neglect university-side data. With rapid changes in the university system, the strategy of the partner university with regard to intellectual property (IP) policy is particularly important, especially in the Japanese context.

Finally, previous empirical studies on UIC, including the studies on the determinants of UIC participation, concentrate on Western countries, especially in Europe, and few studies on UIC have been carried out in Japan and in East Asia (Eom and Lee 2010; Hemmert et al. 2008; Motohashi 2005; Okamuro et al. 2011), despite rapid development of UIC in recent years.

Thus, our study has the following major contributions to the literature: First, we focus on project and partner characteristics as the determinants of UIC performance rather than examining the effect of UIC participation itself. More specifically, we shed light on the role of the university IP policy, which is important in the context of rapid changes in the university system. Second, by using Heckman's two-step procedure, we check and control for potential sample selection bias of participating in UIC. Finally, this is a pioneering empirical research on the determinants of both the participation in and performance of the UIC in Japan.

3. Development of UIC in Japan

In this section, we will sketch the development and institutional background of UIC in Japan. Formal and informal UIC has been active for more than 100 years[1], encompassing a large part of the history of Japanese universities. Therefore, it would be too simplistic to assume that UIC is underdeveloped in Japan or lags far behind the United States and Europe. However, UIC was legally constrained after World War II as a public reaction against the cooperation with the defense industry during the wartime and became even more inactive after the 1960s[2].

Although MEXT changed its university policy to permit UIC during the 1980s, the crucial moment in the establishment of a science and technology policy came in 1995 with the Science and Technology Basic Law. Two important initiatives aimed at promoting UIC were taken under the first Science and Technology Basic Plan (1996–2000): "The act to promote technology transfer from universities" in 1998—the so-called TLO Act—which financially supports the Technology Licensing Organizations (TLOs) at universities, and "the special act to regenerate industrial vitality" in 1999, which enabled national universities to retain IP rights based on government research funds (the Japanese version of the U.S. Bayh-Dole). According to the Japan Science and Technology Agency (JST) (2011), there were 46 officially acknowledged TLOs in September 2010, of which 38 were affiliated to national or public universities.

Under the second Science and Technology Basic Plan (2001–2005), the university

[1] Baba and Goto (eds.) (2007) provide several important examples of UIC in Japan from the 1880s to the 1950s.

[2] Even during the period when formal UIC was inactive, close informal relationships were in place. These informal relationships were formed and maintained through the placement of students (Branscomb et al., 1999).

system in Japan experienced further drastic changes. In 2003, MEXT started to set up IP Centers at universities to manage and improve the use of intellectual property. By March 2009, 22% of all universities (81% of national universities) established IP Centers, and the number of patents applied by Japanese universities increased four times from 2,462 in 2003 to 9,869 in 2007 (MEXT 2009). In 2004, national universities were transformed into more independent university corporations. In 2005, the Ministry of Economy, Trade, and Industry (METI) achieved its goal to create 1,000 academic spin-offs within five years. It is also noteworthy that the constraints on the faculty of national universities to work for private firms have been relaxed systematically since 2000. In order to promote UIC at the regional level, METI launched the Industrial Cluster Project in 2001, followed by MEXT's Intellectual Cluster Project in 2002[3].

Supported by these policies, the number of R&D collaborations between national universities and private firms etc. increased remarkably from 56 in 1983 to 2,568 in 1998 and to 14,303 in 2008 (MEXT 2009; National Institute of Science and Technology Policy 2003)[4]. The number of joint R&D projects involving private and public universities (prefectural and municipal) amounted to 3,335 in 2008, so that national universities accounted for the majority of UIC projects (81%).

It is noteworthy that small firms play an important and increasing role in R&D collaboration with national universities[5]: their share in the joint R&D projects with national universities has consistently increased, from 13% in the mid-1980s (1983–1986) to 40% at the beginning of the 21st century (2001–2004)[6].

4. Conceptual framework and hypotheses

Previous empirical studies concentrate on the effect of UIC participation as such and not on the determinants of UIC performance. Focusing on inter-firm R&D cooperation, Okamuro (2007) argues and demonstrates that contractual and organizational characteristics

[3]See Nishimura and Okamuro (2011a, 2011b) for more details of these cluster projects.

[4]These numbers do not include commissioned (contracted) research projects. National universities include national graduate institutes and junior colleges. Public organizations and local authorities count among private firms etc. This statistic counts only the formal projects reported to MEXT from each national university since 1983.

[5]According to the Small and Medium Enterprise Basic Law revised in 1999, small businesses in the manufacturing sector are defined as those with less than 300 employees or a capital of 300 million yen.

[6]In calculating the share of small businesses, the number of joint R&D projects with private firms (excluding public organizations and local authorities) is used as the denominator.

of cooperative projects significantly affect technological and commercial success of joint R&D. With regard to UIC, the organization and management of the project may be even more crucial for project performance compared to inter-firm cooperation, because UIC is a partnership between completely different types of organizations with different objectives, interests, administration, and incentive systems. To bridge the gap between such different worlds and to achieve high performance in UIC, project and partner characteristics that promote sufficient information sharing, efficient coordination, and mutual trust are essential (Barnes et al. 2002; Hemmert et al. 2009; Mora-Valentin et al. 2004).

Specifically, the IP policy of the partner university may significantly affect UIC performance. This is a particularly important and interesting issue for Japan, where universities rapidly establish TLOs and IP Centers to make efficient use of their patents and to smooth or promote UICs, as mentioned before. The university IP policy determines the basic rules of UIC with regard to the management of existing and generated IP[7]. A clear and equitable IP policy that can be applied flexibly to the needs of partners would be optimal for a UIC to be efficiently managed. Otherwise, the project might face serious conflicts of interests and low incentive for cooperation. Hence, we present the first hypothesis as follows:

H1: Clear, equitable, and flexible IP policy of the partner university positively affects UIC performance.

Moreover, if the IP policy of the partner university affects UIC performance by promoting effective coordination among project members, as explained above, the effect of the university IP policy on UIC performance is expected to be mediated by the effectiveness of coordination in the project or the efforts for effective coordination. By measuring the effectiveness of coordination in UIC based on the levels of communication quality and firm's commitment, we postulate the second hypothesis as follows:

H2: The effect of the partner university's IP policy on UIC performance is mediated by the level of communication quality in and firm's commitment to the project.

We may regard the IP policy of the university as exogenous. The IP policy of a university is administratively determined at the head office or the IP Center, conditioned by government

[7] In Japan, IP policy may differ across universities according to their conditions. Each university can quite flexibly determine its IP policy in accordance with certain legal and administrative rules.

policies, and managed by IP managers who are dispatched by MEXT or directly hired by university administration. Even professors cannot determine or influence the IP policy of their own universities, especially at national universities, where even the most distinguished researchers are treated equally with less productive and refutable colleagues. With regard to the decision by firm's managers, we assume that they select university partners according to their research capability and research matching, but not according to the university IP policy. Therefore, the university IP policy can be regarded as exogenous and independent of any strategies of the UIC partners[8].

5. Empirical strategy

5.1. Empirical models and variables

We estimate the determinants of UIC participation and UIC performance in an integrated way, using Heckman's two-step procedure (cf. Eom and Lee 2010). In this way, we can also control for potential sample selection bias with regard to UIC participation (Heckman 1979). A firm with higher R&D capability is more likely to be involved in UIC (Cohen and Levinthal 1989; Fontana et al. 2006; Lopez 2008). Therefore, in the first step, we estimate the probability of UIC engagement using a probit model with the whole sample to examine what type of firm is willing to collaborate with universities. In the second step, we investigate the effect of the university IP policy on UIC performance by OLS with a sub-sample of UIC participants, controlling for sample selection bias. We also control for several project characteristics following Mora-Valentin et al. (2004).

5.1.1. First step: Determinants of UIC participation

We estimate a probit model to analyze the determinants of UIC participation. The empirical specification is as follows:

$$\text{Prob(UIC)} = f(\text{top managers' education, firm characteristics}).$$

The dependent variable is a UIC dummy (*uic*), which takes on the value of one if a firm engaged in and finished a UIC project during the preceding three years, and zero otherwise.

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[8] Hall et al. (2001) point out that IP issues are major barriers for firms to cooperate with universities. Therefore, we cannot completely exclude the possibility of sample selection bias in the sense that failed attempts of UIC due to poor or unfavorable IP policy are not observable and thus not included in the sample. Unfortunately, we cannot control for such selection bias due to data constraints.

We use top managers' education and firm characteristics as independent variables.

Top managers' education

Focusing on start-up firms, Okamuro et al. (2011) show that top managers' human capital, including their graduate education, significantly affects firms' propensity to cooperate with universities and public research institutes. They argue that especially for small start-ups, top managers' human capital proxies extensive network and high capability of the firms, and signals their capability to potential partners, thereby allowing the firms to find university partners more easily. Therefore, we assume that firms that have top managers with higher education level are more likely to participate in UIC.

We distinguish between different educational levels and backgrounds using five dummy variables: (1) graduates of junior high schools or high schools (who do not have university degrees), (2) bachelors in the human or social sciences (*univ_soc*), (3) bachelors in the natural sciences (*univ_nat*), (4) those with graduate degrees in the human or social sciences (*grad_soc*), and (5) those with graduate degrees in the natural sciences (*grad_nat*). We use the first group as the baseline reference in our model. If top managers' educational level is important for UIC participation, we can expect positive signs for the coefficients of *univ_soc*, *univ_nat*, *grad_soc*, and *grad_nat*. We may also expect an education in the natural sciences to have a stronger effect on UIC participation than that in the human or social sciences, because top managers with a natural science background may have lower barriers to UIC.

Firm characteristics

We use dummies for firm age (*age*), number of employees (*emp*), R&D ratio to sales (*rd_ratio*), and firms' technology dummies as the variables of firm characteristics variables. Firm age (*age*) may be a proxy for accumulated experience and network formation. The number of employees (*emp*) is a measure of firm size. R&D ratio to sales is regarded as R&D intensity. Dummy variables of technology fields, that is, biotechnology (*d_bio*), microelectronics (*d_micro*), and software (*d_soft*, reference group), are included in the model to control for technological opportunities. According to the previous literature (Fritsch and Lukas 2001; Mohnen and Hoareau 2003), we postulate that *age*, *emp*, and *rd_ratio* have positive effects on UIC participation.

5.1.2. Second step: Determinants of UIC performance

We employ OLS to examine the success factors of UIC. In order to control for sample selection bias, we incorporate in the model the inverse Mills ratio, which is calculated in the probit model. Our empirical model is described as follows:

UIC performance = f (partner characteristics, project characteristics, firm characteristics, inverse Mills ratio).

We use four dependent variables on UIC performance obtained from the survey data. We asked the respondent firms for their subjective evaluation of UIC performance using a 7-point Likert scale (where 1 = do not agree at all and 7 = strongly agree) with regard to the extent to which they agree with the following statements: (1) the results and benefits of this UIC met our expectations (*expected_results*), and (2) the UIC was a technical success (*tech_success*). We also asked them to categorize the concrete technological outcomes they could achieve as a direct result of UIC, using a 7-point Likert scale (where 1 = none and 7 = lot) regarding (1) new patent applications (*patents*) and (2) new products developed (*products*).

The independent variables comprise partner, project, and firm characteristics.

Partner characteristics

We pay special attention to the IP policy of the partner university, considering the recent emergence and development of IP policies at Japanese universities. We measure the firm's evaluation of the partner university's IP policy with regard to clearness, equitability (in sharing revenue and royalty), and flexibility to meet the needs of partners, using 7-point Likert scales (Appendix 1) and construct the variable *univ_ip* as the average value of these three items (later we use these items separately). According to Hypothesis 1, we expect the coefficient of this variable to be positive. We also include the national university dummy (*national_univ*) to control for the differences among UICs with national, other public, and private universities. Further, we use the firm's evaluation of the research capability of its partner university regarding the level of scientific research and specific knowledge (*research_capability*) to control for the partner's competence. This variable is measured by a single questionnaire item using a 7-point Likert scale (Appendix 1). Finally, the distance to the university partner (*distance*) is included in the model, which is a categorical variable that takes one of the following six values: 1 = less than 10 km, 2 = 10–20 km, 3= 21–50 km, 4 = 51–100 km, 5 = 101–500 km, and 6 = more than 500 km.

Project characteristics

With regard to project characteristics, we use two types of ex ante relationship factors that are determined prior to the UIC and two kinds of ex post relationship factors that are determined after the beginning of UIC, following Mora-Valentin et al. (2004).

The former variables of ex ante factors comprise (1) the closeness of the relationship with the university partners before the UIC (*close_relationship*) and (2) the extent of contractual safeguards on performance obligation, project schedules and budget, data protection, profit sharing, etc., regarding UIC (*contract*). Both of them are measured using 7-point Likert scales. We created this variable by calculating the mean of evaluation scores of eight related questionnaire items, while the variable *close_relationship* is derived from a single item in the survey (Appendix 1). We expect these variables to have positive effects on UIC performance.

The latter variables of ex post factors include (1) communication quality with regard to timeliness, reliability, and completeness of information exchange in UIC (*commuquality*) and (2) strength of commitment by the participating firm (*commitment*). These variables are constructed by a subjective evaluation based on 7-point Likert scales (Appendix 1). According to Hypothesis 2, the effect of university IP policy (*univ_ip*) is mediated by these variables; we expect that, when they are included in the model, the coefficients of *univ_ip* become much smaller and less significant. We also expect them to have positive effects on UIC performance.

The survey collected further information on project membership, project duration, technological orientation, public subsidy for UIC, and uncertainty surrounding the UIC project. As a variable of membership structure, we include in the model the number of participants (firms, universities, and public research institutes) (*number_participants*)[9]. In addition to project duration (*proyr*), the technological orientation of the UIC may also be related with the technological success of UIC. Thus, from the survey data, we create dummy variables of technological orientation in three categories (*basic research*, *applied research*, and *development*), among which the first one is regarded as the baseline reference. In order to control for the effect of public subsidy, we use the dummy variable *subsidy*, which takes on the value of one if the UIC received public funds. Finally, we control for market and technology unpredictability surrounding the UIC project using the variables *unpre_mkt* and *unpre_tech*. These variables are measured by 7-point Likert scales (Appendix 1).

[9] UIC projects may include more than one university and/or other firms and research institutes (research consortia). The other variables about the partner university refer to the most important partner if there is more than one university in the UIC project.

Firm characteristics

Finally, we use the same variables of firm characteristics (*age*, *emp*, *rd_ratio*, *d_bio*, and *d_micro*) as in the probit model in the second-step OLS. Firm age (*age*) may be regarded as business experience and network formation. Firm size (*emp)* is a proxy for organizational capability, and R&D ratio (*rd_ratio*) is a measure of R&D capability or absorptive capability. We predict that these firm characteristics positively contribute to UIC performance. UIC performance may differ across technology fields, which we consider with dummy variables of technological fields (*d_bio* and *d_micro*).

5.2. Data source and sample

Our empirical analyses are based on original survey data. We conducted a postal survey in summer 2008 among 9,882 firms in Japan with 20 or more employees in the fields of biotechnology, microelectronics, and software, and obtained 1,732 responses (17.5%). We selected these three technology fields as representing major science-based industries in which UIC is especially important (Meyer-Krahmer and Schmoch 1998). Our sample firms were extracted from the company database of Tokyo Shoko Research (TSR) and the directory of the Japan Bioindustry Association (JBA).

Among the respondents, 1,560 firms could in fact be classified into the above three technological fields, and of them, 264 (17%) completed UIC during the preceding three years (the sub-sample for the second-step analysis). The basic statistics of the dependent and independent variables are summarized in Table 1.

[Table 1 around here]

Among the variables of UIC performance, those of satisfaction have relatively higher mean scores (4.9 for *expected_results* and 5.1 for *tech_success*), but those of more concrete outcomes have lower scores (3.5 for *patents* and 4.1 for *products*). With regard to partner characteristics, the mean score for *univ_ip* is 5.0, suggesting that the IP policy of the partner university is quite positively evaluated by the respondents; 83% of the (most important) partner universities are national ones. On average, 4.6 member organizations are involved in a UIC project, which comes to an end within 28 months on average. 20% of the projects target basic research, and 55% of the projects obtained public subsidy for R&D.

On average, the sample firms are 22 years old and have 51 employees. They are classified into biotechnology (23%), microelectronics (20%), and software (48%)[10]. The average ratio of R&D expenditure to sales (R&D intensity) is 4.6%; 63% of top managers of the sample firms obtained undergraduate education (up to bachelor degree), while 10% have master or doctor degrees.

6. Estimation results

In this section, we first present the results of the second-step estimation of the determinants of UIC performance, focusing on the impact of the university IP policy, before reporting the results of the first-step estimation on the determinants of UIC participation.

6.1. Second step: UIC performance

Table 2 shows the estimation results of the second-step OLS regarding UIC performance with regression coefficients and robust standard errors. We have four dependent variables: *expected_results*, *tech_success*, *patents*, and *products*. Specification (1) does not include ex post project characteristics (*commuquality* and *commitment*), while Specification (2) includes both of them to check the mediation effects.

[Table 2 around here]

First, *univ_ip* has positive and significant effects on all dependent variables in Specification (1). This result confirms H1. Indeed, the IP policy of the partner university matters much for the success of a UIC project. A clear and equitable IP policy that can be flexibly applied according to the needs of participating firms contributes to UIC performance. When the variables of project coordination (*commuquality* and *commitment*) are included in the estimation, Specification (2), the coefficients of *univ_ip* are still significant, but much smaller with lower significance levels than those of Specification (1). This result supports H2 and shows that the efforts of project coordination mediate the effect of the university IP policy on UIC performance. The IP policy of the partner university loses its importance after controlling for the measures of coordination during the UIC. Therefore, the effect of IP policy on UIC performance may be largely attributed to the improvement of coordination in the project.

[10] 9% of the respondents did not provide information on their technological fields. These firms were eventually dropped in the empirical estimation.

We confirm positive and significant effects of the university IP policy on UIC performance even after controlling for improved project coordination, but we are unable to explain this remaining effect. We believe that universities with a favorable IP policy may also have a well-managed organization as well as transparent and favorable rules related to UIC (for example, regarding faculty's obligation, graduate course education, or donation), which could contribute to UIC performance.

The national university dummy (*national_univ*) has a weak but positive and significant effect on UIC performance except for patent application (*patents*) in Specification (1). The effect of national universities is no more significant after controlling for project coordination—Specification (2). The research capability of the partner university (*research capability*) has positive and significant effects on *expected_results* and *tech_success*. Distance to the partner university (*distance*) affects only *tech_success*, but positively, suggesting that research collaboration with a university in a distant region is more likely to be evaluated as a technological success than that with a nearby university.

The result that distance, and not proximity to the partner, leads to higher technological satisfaction is contrary to the findings of most previous studies (Acs et al. 2002; Anselin et al. 1997; Furman et al. 2010; Jaffe 1989; Owen-Smith and Powell 2004; Rondé and Hussler 2005)[11], but consistent with Japanese studies such as Nishimura and Okamuro (2011a)[12]. We may attribute this result to a better matching: The farther the university partners are searched for, the higher the probability that an optimal partner can be found, because an optimal research partner is not always located nearby. We may argue that this matching effect exceeds the advantage of proximity, even after controlling for the evaluation of research capability of the partner.

With regard to project characteristics, we find that the results differ across the dependent variables. The strength of ex ante ties (*close_relationship*) has no significant effect on all measures of UIC performance except for *tech_success* in Specification (1). The strength of contractual safeguards (*contract*) has a positive but weak effect on *expected_results* and *tech_success*. In contrast to these ex ante project characteristics, ex post characteristics (*commu_quality* and *commitment*) show a positive and significant

[11]However, these studies examine the effect of proximity on *firm* performance, whereas we examine the effect on *project* performance. Thus, we cannot directly compare our results with those of the previous studies. As far as we know, few empirical studies directly investigate the effect of geographical proximity to a research partner in UIC on project outcomes. An exception is Mora-Valentin et al. (2004), who do not find significant effect of geographical proximity to a research partner on project outcomes.

[12]In a similar vein, Zucker and Darby (2001) find no evidence of geographically localized knowledge spillovers in Japan by analyzing biotech patents.

impact on UIC performance except for patent application (*patents*). Thus, ex post characteristics of UIC projects are in general more important for UIC performance than ex ante characteristics (initial conditions). Besides, as mentioned above, we found that these ex post variables mediate the effect of IP policy of the partner university (*univ_ip*).

It is also noteworthy that most of the other project and firm characteristics have no or little effect on UIC performance except for project duration and firm size. We again observe some differences among the dependent variables: patent application (*patent*) is significantly associated with several variables of these project and firm characteristics, while *expected_results* is not correlated with them.

The mean variance inflation factor (VIF) is sufficiently low (1.62 for Specification (1) and 1.70 for Specification (2)), so that we may exclude the multicollinearity problem. The inverse Mills ratio is not significant except for *expected_results*. Thus, we confirm and correct sample selection bias only for this dependent variable. However, the results of the first step are also worth reporting, because sample selection bias is confirmed for a part of the estimations.

6.2. First step: UIC participation

Table 3 shows the empirical results in the first step on the determinants of UIC participation. In the probit model, we include top managers' education and the firm characteristics. We show the marginal effect of each variable on the probability of UIC participation.

[Table 3 around here]

First, we find that top managers' education is strongly related to the propensity of UIC participation. All variables—*univ_soc*, *univ_nat*, *grad_soc*, and *grad_nat*—have a significantly positive impact on UIC participation[13]. In addition, the marginal effects of *grad_soc* and *grad_nat* are larger than those of *univ_soc* and *univ_nat*. This means that a firm managed by a top manager with a higher educational level is more likely to engage in UIC. However, our results also suggest that top managers with university degrees in the human or social sciences are by no means less willing to cooperate with universities

[13]In an unreported estimation, we include education variables of both top managers and top researchers to find that only the dummy for Ph.D. in natural science has a significant impact on UIC participation. Since our sample consists of SMEs, the top manager and the top researcher of a firm may be the same person in several cases. Then the result would be subject to significant multicollinearity.

compared to those with degrees in the natural sciences. This is probably because top managers with a natural science background tend to prefer in-house R&D to UIC because of the "not-invented-here" (NIH) syndrome.

Second, with regard to firm characteristics, the R&D ratio to sales (*rd_ratio*) has a positive and significant impact on UIC participation. Therefore, as we indeed expected, a firm with a higher R&D capability is more likely to participate in UIC. Unexpectedly, however, we find that firm size (*emp*) has no significant impact on UIC participation, which means that small size in itself is not a barrier to UIC.

Finally, we find that the propensity of UIC participation significantly differs across technological fields: Biotech and microelectronics firms are more willing to conduct UIC than software firms. This suggests that technological opportunities matter for engaging in UIC.

7. Concluding remarks

The aim of this paper was to investigate the impact of university IP policy on UIC performance with original survey data from Japanese firms, controlling for potential sample selection bias using Heckman's two-step procedure. The estimation results show that the IP policy of partner universities regarding clearness, equitability, and flexibility indeed matters, but its impact on UIC performance is mediated by the quality of communication between the partners and the level of the firm's commitment to the project. We also found that some other project characteristics significantly affect UIC performance, although the effects differ across the dependent variables and thus depend on how we define UIC performance. Contrary to the results of most previous literature, the distance to the partner is positively correlated with UIC performance. We further found that firms' R&D intensity and top managers' education level are important determinants of UIC participation, while firm size has no influence after controlling for these variables.

This paper has some major contributions to the literature. First, it sheds light on the effect of the university IP policy on successful UIC, which is important in the context of rapid changes in the university system. Second, it examines the determinants of both UIC participation and UIC performance in an integrative framework and hence checks and controls for sample selection bias in performance estimation. Third, it reveals the role of top managers' education as an important factor of UIC participation. Fourth and last, it focuses on UIC in Japan, on which few empirical studies have been carried out despite the increasing attention and importance of UIC in Japan in recent years.

However, as with most previous studies, our study is based on survey data from the firm side, so that we cannot consider the factors of university researchers. A matched-data analysis using survey data from both sides of UIC would be desirable for further research. Specifically, we measure the characteristics of university IP policy by subjective and retrospective evaluations by partner firms. A more objective measurement should be discussed. Further, the IP policy and other project or partner characteristics are measured as one-shot evaluations. Considering the recent development of university IP policy, future research should address its dynamics more explicitly. Lastly, we cannot exclude the possibility of sample selection bias in the sense that failed attempts of UIC due to poor or unfavorable IP policy of potential partner universities are not observable. We should collect information about failed partnerships to cope with this problem.

Despite such weakness, our findings have the following important implications for managers. First, in searching for a research partner among universities, managers should also look at the IP policy of the universities. Further, initial conditions of the project significantly affect UIC performance. Specifically, it is important to find an optimal partner even if located in a distant area. However, our findings also show how to manage cooperation right during the project may be more important for performance than the initial settings. We also find that firm characteristics and project size do not significantly affect UIC performance. Therefore, how to manage a project is more important for UIC performance than who (which firm) engages in the project. Even if small businesses have limited R&D resources, they can successfully cooperate in R&D with universities with appropriate project management expertise.

Regarding policy implications, our results suggest that it is essential for successful UIC to establish a clear, equitable, and flexibly applicable IP policy. Moreover, given the negative effect of closeness to the partner on UIC performance, it is important for policy makers to encourage and support partner search in UIC in wider geographic areas.

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Appendix 1: Variable construction of partner and project characteristics

univ_ip: mean of the evaluation scores of the following items:
Please evaluate how clearly the partner university's policy on intellectual property rights was defined (where 1 = do not agree and 7 = fully agree).
University intellectual property policies were clear and easily understood.
University intellectual property policies were sufficiently flexible to meet our firm's needs.
University intellectual property policies were equitable in revenue and royalty sharing.

close_relationship: the evaluation score of the following question:
Prior to this UI research collaboration, how close was your relationship with the university partner (where 1 = not at all close and 7 = very close)?

research capability: the evaluation score of the following question:
How did your company evaluate the research capability of your partner university before you entered into a UI research collaboration with it (where 1 = fully disagree and 7 = fully agree)?
We believed they were scientifically leading in their field.

contract: mean of the evaluation scores of the following items:
How clearly were the following issues defined at the beginning of the research collaboration (where 1 = there was no mutual understanding and 7 = the mutual understanding was exactly defined in a written document)?
Roles and responsibilities of each partner
Performance obligations of each partner
Project schedules (timing and deadlines)
Project budget (how it should be used and checked)
Data/secrecy protection, publication of the findings
Profit sharing from new products and processes, etc.
Legal procedures in case a partner does not fulfill his role or obligation
Procedures in case of unexpected events

commuquality: mean of the evaluation scores of the following items:
Overall, the communication between our firm's and the university partner's representatives

was (1–7).
untimely/timely
inaccurate/accurate [you can rely on it]
incomplete/complete

commitment: the evaluation score of the following item:
Please evaluate the communication and interaction with the university research partner in the partnership (if there was more than one partner, please refer to the most important university research partner; 1 = strongly disagree… 7 = strongly agree).
We were very committed to this university partner.

unpre_mkt, *unpre_tech*: the evaluation scores of the following items, respectively
Please respond regarding the extent of market and technological uncertainties surrounding this UI R&D collaboration (1–7).
The market surrounding the research collaboration was very predictable and easy to forecast versus unpredictable and hard to anticipate.

The technological developments surrounding the research collaboration were predictable versus hard to anticipate, or unpredictable.

Table 1: Basic statistics of the variables

Variables	Obs	Mean	Std. Dev.	Min	Max
Dependent var.					
uic	1560	0.17	0.38	0	1
expected_results	255	4.86	1.63	1	7
tech_success	253	5.08	1.66	1	7
patents	256	3.45	2.32	1	7
products	256	4.09	2.14	1	7
Independent var.					
univ_ip	253	4.95	1.64	1	7
national_univ	260	0.83	0.38	0	1
research_capability	254	5.16	1.63	1	7
distance	255	3.21	1.77	1	6
close_relationship	213	5.13	1.75	1	7
contract	256	4.70	1.37	1	7
commuquality	259	5.33	1.31	1	7
commitment	251	4.43	1.83	1	7
number_participants	244	4.62	4.74	2	48
log (*proyr*)	250	3.35	0.65	0.69	4.79
basic research	258	0.20	0.40	0	1
applied research	258	0.41	0.49	0	1
development	258	0.39	0.49	0	1
subsidy	256	0.55	0.50	0	1
unpre_mkt	253	4.64	1.70	1	7
unpre_tech	252	4.70	1.58	1	7
Firm characteristics					
log (*age*)	1549	3.09	0.72	0.69	4.71
log (*emp*)	1525	3.93	0.96	0	7.91
rd_ratio	1437	4.63	12.74	0	100
d_bio	1560	0.23	0.42	0	1
d_micro	1560	0.20	0.40	0	1
d_soft	1560	0.48	0.50	0	1
Top managers' education					
univ_soc	1441	0.30	0.46	0	1
univ_nat	1441	0.33	0.47	0	1
grad_soc	1441	0.01	0.12	0	1
grad_nat	1441	0.09	0.28	0	1

Table 2: Determinants of UIC performance (second step)

	expected_results		*tech_success*		*patents*		*products*	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
univ_ip	0.287***	0.127*	0.290***	0.167**	0.333***	0.282**	0.220**	0.178*
	0.081	*0.067*	*0.070*	*0.071*	*0.115*	*0.127*	*0.110*	*0.105*
national_univ	0.710*	0.270	0.626**	0.361	−0.267	−0.471	1.034**	0.839
	0.371	*0.383*	*0.320*	*0.327*	*0.519*	*0.565*	*0.525*	*0.554*
research_capability	0.136*	0.062	0.159**	0.114*	0.158	0.125	0.046	0.023
	0.079	*0.076*	*0.068*	*0.065*	*0.111*	*0.116*	*0.113*	*0.114*
distance	0.101	0.094	0.146***	0.124**	0.058	0.070	0.087	0.057
	0.066	*0.063*	*0.057*	*0.054*	*0.093*	*0.095*	*0.095*	*0.093*
close_relationship	0.105	0.025	0.153**	0.073	−0.104	−0.118	0.106	0.009
	0.074	*0.073*	*0.064*	*0.063*	*0.105*	*0.111*	*0.106*	*0.109*
contract	0.169*	0.147*	0.141*	0.087	−0.006	−0.006	0.028	−0.030
	0.094	*0.089*	*0.081*	*0.077*	*0.134*	*0.136*	*0.135*	*0.133*
commuquality		0.468***		0.312***		0.189		0.273*
		0.111		*0.096*		*0.168*		*0.165*
commitment		0.097*		0.162***		−0.045		0.184*
		0.056		*0.057*		*0.102*		*0.100*
number_participants	0.012	0.011	0.043	0.039	−0.090	−0.088	−0.039	−0.050
	0.040	*0.037*	*0.034*	*0.032*	*0.056*	*0.057*	*0.057*	*0.056*
log(proyr)	0.056	0.153	0.204	0.318*	0.987***	0.985***	0.430	0.621**
	0.192	*0.191*	*0.165*	*0.165*	*0.272*	*0.294*	*0.275*	*0.288*
appliedresearch	0.230	0.375	0.667**	0.743***	0.938*	1.019**	0.121	0.173
	0.341	*0.321*	*0.293*	*0.276*	*0.482*	*0.491*	*0.488*	*0.481*
development	0.121	0.313	0.232	0.331	−0.238	−0.162	0.662	0.629
	0.344	*0.326*	*0.294*	*0.280*	*0.483*	*0.495*	*0.489*	*0.485*
subsidy	0.012	0.055	−0.235	−0.227	0.719*	0.762**	−0.153	−0.132
	0.271	*0.253*	*0.234*	*0.218*	*0.383*	*0.386*	*0.388*	*0.378*
unpre_mkt	−0.021	0.017	−0.083	−0.042	−0.179	−0.176	0.001	0.057
	0.085	*0.080*	*0.073*	*0.069*	*0.120*	*0.123*	*0.122*	*0.121*
unpre_tech	−0.047	−0.049	0.023	0.038	−0.049	−0.073	−0.124	−0.135
	0.085	*0.080*	*0.074*	*0.070*	*0.120*	*0.123*	*0.122*	*0.121*
log(age)	0.001	−0.045	−0.028	−0.010	−0.462	−0.515*	−0.282	−0.166
	0.217	*0.214*	*0.173*	*0.169*	*0.282*	*0.294*	*0.285*	*0.288*
log(emp)	−0.258*	−0.224	−0.242**	−0.247**	0.448**	0.497**	−0.234	−0.262
	0.155	*0.150*	*0.124*	*0.119*	*0.200*	*0.204*	*0.201*	*0.2*
rd_ratio	−0.023	−0.021	−0.012	−0.012	0.012	0.016	−0.032*	−0.028
	0.015	*0.014*	*0.012*	*0.011*	*0.019*	*0.019*	*0.019*	*0.018*
d_bio	−0.214	−0.537	0.411	0.126	1.648**	1.697**	0.575	0.360
	0.653	*0.643*	*0.518*	*0.505*	*0.819*	*0.851*	*0.827*	*0.832*
d_micro	−0.114	−0.351	0.566	0.353	−0.052	−0.033	0.604	0.364
	0.514	*0.497*	*0.410*	*0.392*	*0.650*	*0.662*	*0.656*	*0.648*
constant	4.039*	2.973	1.207	0.200	−1.359	−1.960	2.314	0.609
	2.337	*2.331*	*1.874*	*1.854*	*2.997*	*3.176*	*3.025*	*3.109*
Uncensored obs	127	125	127	125	128	126	128	126
Censored obs	1112	1112	1112	1112	1112	1112	1112	1112
Wald chi2 test	75.85***	111.83***	146.27***	191.86***	61.39***	58.79***	37.75***	46.03***
Mills	−1.398*	−1.457*	−0.479	−0.564	−0.439	−0.220	−0.252	−0.117
	0.822	*0.902*	*0.747*	*0.717*	*1.199*	*1.227*	*1.209*	*1.201*
Mean VIF	1.62	1.70	1.62	1.70	1.62	1.70	1.62	1.70

Note 1: Level of significance: *** 1%, ** 5%, * 10%

Note 2: Standard errors are indicated in italics

Table 3: Determinants of UIC participation (first step)

	Marginal effect	Robust S.E.
Top managers' education		
univ_soc	0.064**	0.030
univ_nat	0.079***	0.029
grad_soc	0.358***	0.129
grad_nat	0.088**	0.050
Firm characteristics		
log (*age*)	−0.020	0.014
log (*emp*)	0.006	0.010
rd_ratio	0.004**	0.002
d_bio	0.179***	0.034
d_micro	0.156***	0.033
N	1309	
Log pseudolikelihood	−494.155	
	Wald chi2(9) = 86.23 (p=0.000)	

Note: Level of significance: *** 1%, ** 5%, * 10%