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the Role of New Technology Based Firms in Japanese National Innovation Reform**

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**Economic Analysis of University-Industry Collaborations: the Role of New
Technology Based Firms in Japanese National Innovation Reform**

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[Abstract]

In this study, quantitative analysis of university industry collaborations (UICs) is conducted in case of Japan by using the dataset from RIETI's UIC Survey and METI's Basic Survey on Business Structure and Activities. A focus is put on comparing new technology based firms (NTBFs), to large firms in terms of the characteristics of UIC activities and the impact of UICs on R&D and production productivity.

It is found that UICs are not simply adaptations of technology at university, but involves significant development activities at industry side. In this sense, UICs used to concentrate in large firm with substantial R&D resources 5 years ago. However, this activity has spread over to small firms recently, and R&D and productivity impacts of UICs can be found more clearly for small and young firm group. UIC activities by NTBFs are promising not only by the growth potential of these firms, but also by playing as agents of changes in Japan's in-house national innovation system toward network based dynamic one.

JEL Code: L25, O32, O33

Key words: University Industry Collaboration, New Technology Based Firm, Productivity, National Innovation System, Japan

1. Introduction

The second Science and Technology Basic Plan, which indicates the basic direction of Japan's science and technology policies for the period 2001 – 2006, strongly advocates national innovation system reform toward network based system by active interactions of innovation actors. Stimulating university-industry collaborations is one of core policy issues in this line. Recently, systemic reforms to strengthen the collaboration of universities and public research institutions with businesses have advanced substantially. For example, the 1998 TLO Law promoted the establishment of Technology Licensing Organizations (TLOs) in universities and public research institutions, and the Law to Strengthen Industrial Technology Capability established in 2000 includes measures for loosening restrictions on rules for researchers at public research organizations including national universities to work for private companies, and those for making it easier for national universities to receive funding from the private sector.

It is true that collaborations between university and industry become popular now in Japan. However, this movement in Japan is still lagging behind the United States, where various policy measures related to university – industry collaboration were put into place in the 1980s. This difference between two countries is mainly due to the lag of policy actions; Japan is in almost 20 years behind in the U.S. At the same time, differences in the innovation systems of Japan and the United States may also matter with the effectiveness of university industry collaborations. In the U.S., capital markets for innovation are advanced through venture capital and other means. In addition, the labor market works better than that in Japan. These factors make collaboration between industry and the public sector easier in the U.S. by utilizing external markets. Meanwhile, in Japan, a firm conducts research and development largely at its own in-house research center, and collaborations with universities and public institutions have not been put to active use. This emphasis on in-house research and development primarily at large enterprises has been pointed out as a factor impeding university industry collaboration in Japan (Motohashi, 2001).

Under these circumstances, new technology based firms (NTBFs), young and relatively small enterprises with actively engaged in research and development, may play a significant role in effective university industry collaborations in Japan. In contrast to large enterprises with significant R&D resources such as research staffs at their own research centers, NTBFs must proactively utilize external resources in their R&D efforts. According to the Survey on Japan's Innovation System conducted by the Research Institute of Economy, Trade, and Industry (RIETI), R&D-focused SMEs that proactively conduct collaborative R&D with universities perform more practical, hands-on research toward the introduction of products than do large

enterprises (RIETI, 2001). In addition, compared to large enterprises, which tend to have bureaucratic decision-making organizations, SMEs can be agents of change, dynamically advancing into new fields by making speedy business decisions (Audretsch, 1999).

This paper will examine the role of NTBFs' to dynamise Japan's innovation system, which is dominated by in-house R&D, by comparing industry-university collaboration activities between large enterprises and NTBFs. University industry collaboration can take various forms, from informal technology consultation, to collaborative R&D on a contractual basis. In addition, the content of such efforts varies widely across technological field. A large-scale survey of businesses conducted in February 2003, RIETI's Survey of the University Industry Collaboration Activities investigated this heterogeneity in order to provide a clear picture of such efforts in Japan (RIETI, 2003). Based on the firm level data from this survey, we examine the difference of such efforts by the size of enterprise. In addition, by linking this dataset with the data from the Basic Survey of Japanese Business Structure and Activities of the Ministry of Economy, Trade, and Industry (METI), we analyze determinants of university industry collaborations and the impact of such efforts on firm's innovation and business performance.

This paper is structured as follows: First, in the next section we characterize the differences in university industry collaborations between large enterprises and SMEs, by using RIETI's Survey on University Industry Collaboration Activities. In section 3, we provide the results of quantitative analysis of determinants of university industry collaborations and the impacts of such efforts on firm's innovation and business performance, by using linked data of the RIETI Survey with the METI's Basic Survey of Japanese Business Structure and Activities. In the final chapter, we summarize the results of this study and conclude with discussion about the role of NTBFs in the reform of Japan's national innovation system.

2. University Industry Collaboration Activities by Firm Size

University Industry Collaboration (UIC) activities can be investigated from both the university side and the industry side. In Japan, several surveys have already been conducted on this subject. An example of a survey of universities is that conducted by Mitsubishi Research Institute (MRI) (2002). Examples of surveys of the industry side include METI (2003a), METI (2003b), and Japan Finance Corporation for Small Business (JFS) (2002). In addition, RIETI (2001) obtained data from both universities and industries on the UIC projects subject to subsidies from the New Energy and Industrial Technology Development Organization (NEDO). These surveys show the level of UIC activities, as well as their objectives, obstacles and effects. In addition, there exist some studies studying UIC activities by investigating the number of companies involved, geographical expansion of such efforts, and the numbers of projects by technology in detail

(Wen and Kobayashi, 2001). However, these examples have only provide qualitative information concerning UIC activities, and they cannot be used to quantitative analysis, such as investigating annual budgets for collaborative research and the numbers of joint research contract. Another issue with prior surveys includes a problem with sampling framework. These surveys have been limited to publicly supported UICs, or they cover only UICs for large enterprises.¹

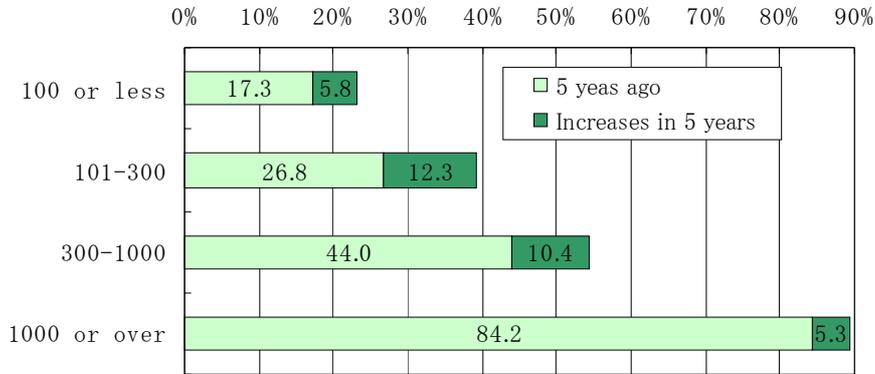
In contrast, RIETI's survey on UIC activities does not suffers from such sampling bias problem, since it surveys almost all firms with R&D activities in Japan (7442 firms). As a sample base, METI's Basic Survey of Japanese Business Structure and Activities, covering all firms in manufacturing, wholesale, and retail industries with fifty or more employees and capital of 30 million yen, is used. In addition, this survey covers quantitative information on UIC activities, such as an annual budget and the number of projects of UICs. The survey was conducted in February 2003 for 2002 fiscal year information, receiving valid responses from 802 firms. The survey consisted of the following three major components: (1) overall information on R&D collaboration with external bodies including other firms, universities and public research institutes, (2) detailed survey on UIC activities, including quantitative information on the size of activities, and (3) qualitative information on objectives, assessments and obstacles of UIC activities.² In this section, observations from this survey, focusing on dimension of the firm size variation, are provided.

First, an overall picture of R&D collaboration by firm size is presented. Approximately 70% of firms engaging in R&D activities conduct R&D collaboration in some form. Approximately 40% of firms engage in such collaboration are those with UIC activities. Although Japan's innovation system is said to be characterized by in-house R&D focus, these figures show that external collaboration in R&D is fairly widespread. This survey also compared such activities with those of five years before. Figure 1 shows the results of the shares of firms with UICs and their change from 5 years before.

¹ One of exceptions is the statistical analysis conducted for the White Paper on Small and Medium-Sized Enterprises in Japan, which covers extensive number of firms (METI, 2003b).

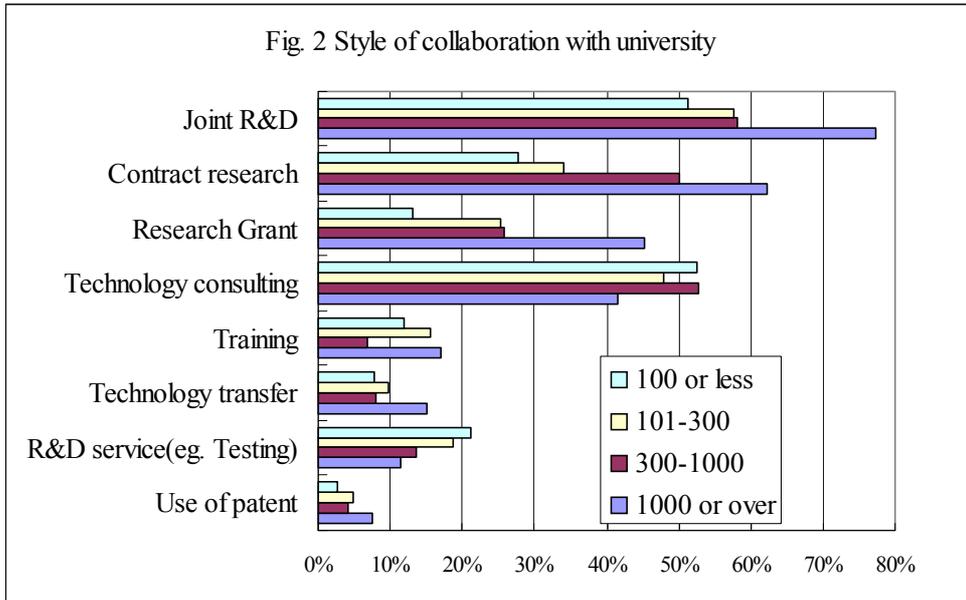
² Refer to the RIETI homepage (<http://www.rieti.go.jp/jp/projects/innovation-system/index.html>), for details of survey methodology including sampling methods and response rates. Although this survey's valid response rate of 10.8% is low, we simultaneously conducted a follow-up survey on non-response samples, which indicated that the effects of the non-response bias on the results were relatively small. The summary tables can be downloaded also from this site.

Fig. 1 Share of firms collaborating with university



One characteristic of UIC activities is that the size distribution is skewed to a greater extent, as compared to between firm collaborations. For example, while 89.5% of firms with more than 1001 employees are collaborating with universities in some form, only 23.1% of firms with 100 employees or fewer take part in such collaboration. In the case of large firms, while 65.0% of firms with more than 1001 employees are collaborating, 26.1% of firms with 100 employees or fewer take part in such collaboration. When we look at the trends in these figures over the past five years, we see that the number of smaller firms with UICs has increased faster. This survey also examines future expectation in R&D collaboration. The percentage of firms planning to strengthen collaboration with universities is 42.3% (with 51.7% planning to maintain current levels of such collaboration and 5.9% planning to reduce it), and this figure is higher than that of any collaboration with large enterprises, SMEs and national research institutes. It appears that UIC activities are spread over to smaller firms and industry has a growing expectation on UICs.

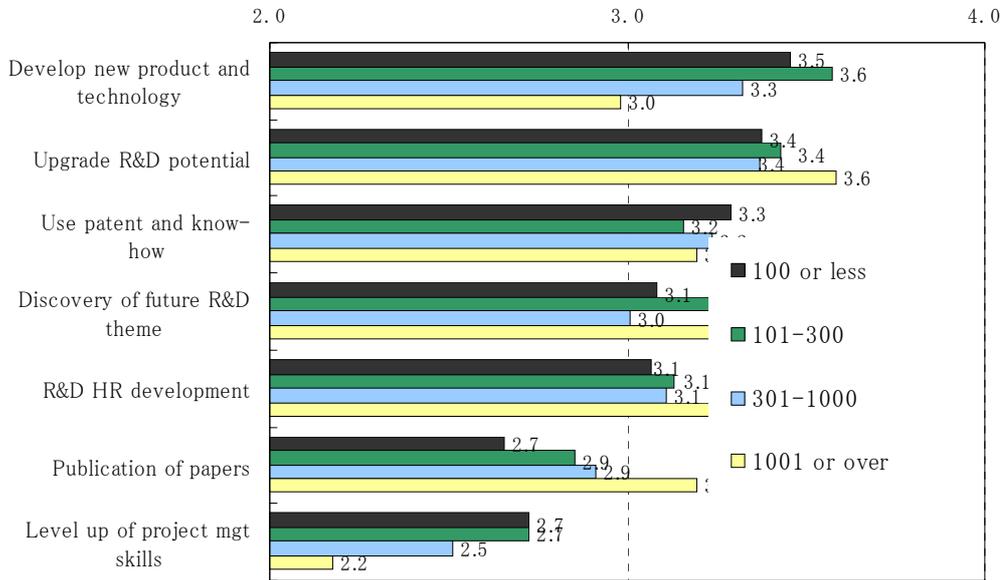
UIC activities can take various forms. They vary from formal forms of R&D collaborations, such as joint research, contracting of research and technology licensing, to more informal communication and technology consultation activities. In addition, exchanging researchers and training of personnel can be included in UIC activities as well. Figure 2 shows the share of firms taking part in each type of UIC activities by firm size.



Nearly 80% of enterprises with more than 1001 employees with UIC activities are involved in joint R&D with universities. In addition, contracted research and the provision of research grants follow. On the other hand, technology consulting is relatively popular for smaller firms. As with joint R&D, approximately half of such firms taking part in this type of activities. Regardless of firm size, the share of firms reporting the use of patents is small. It suggests that UICs are not simple existing technology adoption activities, but involve significant development activities in industry side as well, for example by contract base joint R&D.

Figure 3 shows a relative importance of objectives of UICs by firm size. Each point shows an average of the five-point Likert Scale questionnaire, and the larger the value, the more relevant as an objective of UICs.

Fig 3. Objectives of collaboration with university



While, for large enterprises with more than 1001 employees, the scores are high for upgrading one’s R&D potential, smaller firms evaluate highly the development of new products and technology. When we look at this result together with those in Figure 2, we can conclude that smaller firms seek to acquire technology through technical consulting and joint R&D technology that is closer to the final product stage. In contrast, large firms, while using the same joint R&D type of collaboration, place more weight on basic and fundamental types of knowledge that can be expected to lead to long-term innovation, by seeking to upgrade their own research capabilities. One factor leading to this result may be the fact that the time scope for UIC varies between large enterprises with relatively large R&D resources such as in-house research centers, and smaller firms, which do not have such resources. An analysis of U.S. firms by Santoro and Chakrabarti (2002) shows that UICs by SMEs focus largely on resolving issues through the use of such firms’ own core technologies, while those of large enterprises are intended to expand the subjects of research into new fields. The results of our survey of Japanese firms are consistent with these findings.

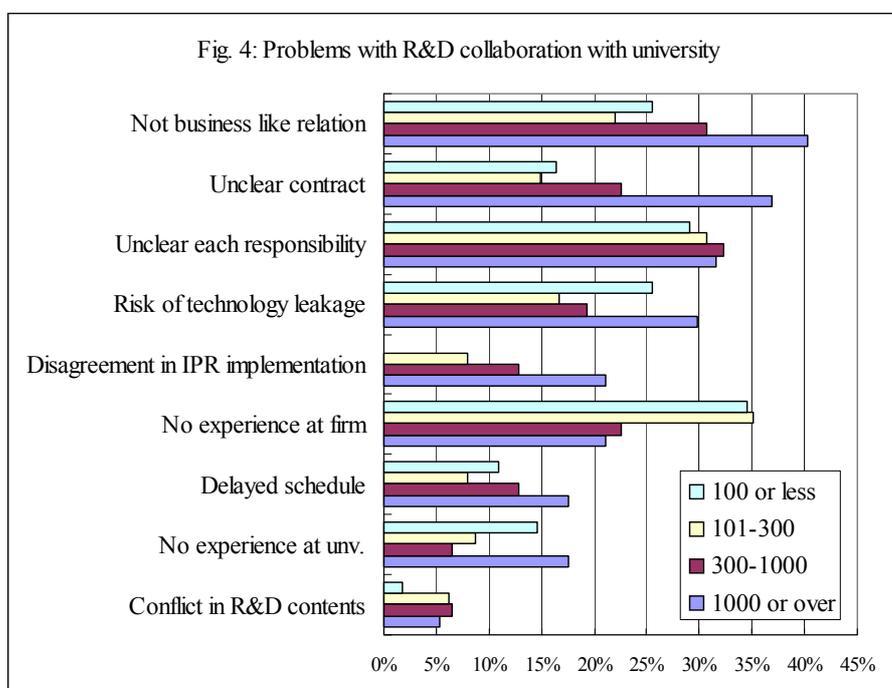
Smaller firms aim at the UICs intended to achieve short-term benefits such as those resulting in new products. However, it is found that the size of joint R&D for smaller firms is not always smaller than that of large firms. Table 1 shows the size of joint R&D by firm size.

Table 1: Collaborative R&D by firm size

	Budget per project (million yen)			Project duration (month)	Share of public fund (%)
	Total budget	# of project			
All	14.1	62.8	4.5	13.5	17.8
100 or less	20.3	34.8	1.7	12.2	20.6
101-300	14.5	33.9	2.3	13.1	19.7
300-1000	6.8	17.9	2.7	12.8	16.8
1000 or over	14.2	226.5	16.0	16.7	9.9

The average per-company figures in 2002 for joint R&D budgets and the number of projects for firm conducting joint R&D are as follows: the average total budget was 62.8 million yen and the average number of projects was 4.5 per company, for an average budget of 14.1 million yen per project. When these figures are examined by firm size, the budget per project does not vary very much. While smaller firms typically conduct smaller number of project, the size of each project is not smaller. Due to the wider scope of R&D for large firms, it is natural to see that they are taking part in large numbers of UICs, presumably spreading over wide ranges of technology fields. In contrast, joint R&D project for smaller firms is more focused, but not always smaller. In addition, it is found that joint R&D projects for smaller firms are more covered by public fund than those of larger firms.

Finally, Figure 4 shows problems with UICs by firm size.



This graph shows the percentage of firms listing each item as problem on UICs for firms conducting joint R&D. Firstly, the share of “no experience with UICs” is larger for small firms. As is already shown, UIC is not a one-way process whereby industry adopts technology and knowledge of university. Instead, industry should play an important role in innovation by providing own development resources, based on university’s technology. In this sense, it is vital to increase its in-house R&D capacity, or “absorptive capacity” in Cohen and Levinthal (1989), in order to conduct effective UICs. Therefore, ‘experience’ matters with joint R&D with universities, and it is natural that established large firm is likely to have more experience than smaller firms, particularly new technology based firms.

On the other hand, the problems pointed out by large firms include “No business like relationship”, “Unclear contract” and “Unclear each side responsibility”. This problem comes from the difficulty in drawing up a clear contract covering division of each responsibility and future outcomes due to significant uncertainty associated with UIC project. Since the projects by large firms tend to cover more basic and fundamental type of contents, the degree of uncertainty and hold up problem due to incomplete contract is assumed to be larger. In addition, there may be an organizational reason as well. According to the results of RIETI survey, small firms pointed out that the roles and responsibilities of each party in carrying out the collaboration are unclear. However, only a few of them express problems with contractual issues. A small firm can overcome incomplete contract problem, because a person who is responsible for collaboration decision negotiates directly with university professors in general. On the other hand, a large firm with bureaucratic organizational structure requires a clearer contract in order to pass through internal decision making process. There are supportive evidences to this hypothesis in interview surveys for university professors involved in UICs (RIETI, 2002).

3. Determinants and impacts of university industry collaboration

(1) Data

The results of RIETI’s University Industry Collaboration Survey show that large enterprises primarily use such collaboration for joint research projects aimed at strengthening their in-house technological capabilities and achieving long-term benefits, while a higher percentage of SMEs use technical consulting and take part in joint R&D aiming at projects that are closer to the final-product stage. In this section, we link the data from RIETI’s Survey with ones from METI’s Basic Survey of Business Structure and Activities, to quantitatively analyze the factors contributing to the decision to take part in UICs and the economic impacts of such efforts from

the view point of participating enterprises. Among various styles of UICs, we proceed with our analysis focusing on university industry collaborative research.³

As the sample for RIETI's UIC Survey is derived from companies subject to METI's Basic Survey of Japanese Business Structure and Activities (BSBSA), the data can be linked directly. BSBSA started in 1991 and has been conducted annually since the 1994 survey. The most recent data available is that for 2000. In addition to financial-statement data for measuring the productivity and profitability of firms, it also provides innovation-related data such as R&D investment and the number of patents held, as well as three-digit industry codes and the year of establishment.

We conduct our analysis by using the linked data of RIETI's UIC Survey and METI's BSBSA for the period from 1995 to 2000. However, due to factors such as the entry and exit of firms and cut off points of BSBSA samples in terms of the number of employees and the amount of capital, the number of linked data sample varies from year to year. Table 2 shows the numbers of samples used for this analysis.

Table 2. Number of samples by timing of BSBSA

BSBSA data year	# of samples
1995	687
1996	702
1997	720
1998	759
1999	801
2000	751

(2) Determinants of UICs

A firm's decision concerning whether to take part in UICs may depend on various factors. Since the technology and know-how possessed by universities would not lead directly to new products, but would require additional R&D by firms for commercial use adaptation, firms may first need their own technological absorptive capacity. However, there is also a possibility of substitution effect of R&D resources, whereby large enterprises with significant in-house R&D resources would not take part in external collaboration involving high transaction costs. In contrast, incentives for UICs would be higher for new technology based firms (NTBFs), which tend to lack innovation-related management resources with greater necessity to seek for external technological seeds. In the U.S., there are some existing studies on UICs by size of firm. For example, Cohen et al. (2002) showed that large enterprises were more active in taking part in

³ Refer to Bozeman (2000) for an overall review of university industry collaboration analysis.

UICs than SMEs.⁴ In contrast, Acs et al. (1994) showed that, concerning innovation activities such as the introduction of new products, SMEs more effectively utilized the results of university research and that companies with poor in-house R&D resources tended to be more active in utilizing external resources.

In this section, we test various factors including firm size and age as determinants of UICs to disentangle between complementarity and substitution effects associated with internal and external R&D resources. Table 3 shows the results of regression analysis with each of the following items as dependent variables: (1) whether the firm participated in some type of collaboration with a university in 2002; (2) whether the firm conducted joint R&D with a university in 2002; (3) the number of joint R&D projects with universities; and (4) the amount budgeted for joint R&D projects with universities (using natural logarithms). Independent variables used here are as follows.⁵

- Firm size in 2000: natural logarithm of the number of employees (BSBSA)
- R&D investment in 2000 (natural logarithm) (BSBSA)
- Amount of R&D outsourced in 2000 (natural logarithm) (BSBSA)
- Number of patents held in 2000 (natural logarithm) (BSBSA)
- Dummy variable whether firm has its own independent R&D center in 2000 (BSBSA)
- Firm age as of 2000 (natural logarithm) (BSBSA)
- Interaction terms of firm size and firm age as above
- 9 types of R&D strategy focus (see Table 3) (UIC Survey)
- 40 industry dummy variables

It should be noted that dependent variables in regression analysis here, taken from RIETI's UIC Survey are those of 2002, while most independent variables from BSBSA are those of 2000, the most recent timing of available data. Therefore we can interpret the results as correlation with 2 year lags, or simultaneous correlation by assuming that the value of independent variable is stable over time.

(Table 3)

Firstly, when we examine the results of our analysis concerning whether the firm participated in some type of collaboration with a university in 2002 and whether the firm conducted joint R&D with a university in 2002 (models 1 – 8), while the statistically significant items vary, we

⁴ The exceptions were medical-related startup firms (founded within five years and with 500 employees or fewer), which actively took part in industry-academia collaboration.

obtained similar results. The values for both R&D expenditures and the number of patents held are positive and statistically significant, indicating that technological capacity is a vital factor in determining whether to take part in UICs. R&D outsourcing is also positive, indicating that, in addition to technological capacity, firms with a higher willingness to collaborate with external parties in R&D were more likely to conduct UICs. Concerning the relationship with enterprise size ($\log[\text{emp}]$), in the models in which company age ($\log[\text{age}]$) is not inserted, but after controlling for R&D size ($\log[\text{RD}]$), we found statistically significant and positive coefficients. This indicates that, in addition to technological capacity, there are still some firm size effects. However, the effects of company size ($\log[\text{emp}]$) are negative and statistically significant in the models including company age ($\log[\text{age}]$) and the interaction of size and age. When we examine the results of this regression analysis using the partial derivative of $\log(\text{emp})$ in order to clarify this relationship (for example, $-0.80+0.29\log[\text{age}]$ in Model 3), it is shown that the value of the coefficient was negative for young firms, indicating that the smaller a firm, the more active its participation in UICs. In the same way, when we examine the results of this regression analysis using the partial derivative of $\log(\text{age})$ in order to examine the effects of company age (for example, $-1.52+0.29\log[\text{emp}]$ in Model 3), we find that the value of the coefficient is negative for small enterprises, indicating that the younger a firm, the more active its participation in UICs. In this way, the linear relationship between company size and participation in UICs does not hold in the group of young firms, showing tendencies similar to the characteristics of startup firms found by Cohen et al. (2002).⁶

The RIETI UIC Survey also collected the data on R&D strategy (specifically, the nine items shown in Table 3). We also analyzed the relationships between these items and UICs. Our results show that firms placing emphasis on shortening R&D lead times, focusing R&D themes, and seeking new R&D themes are more active in UICs.

Models 9 – 12 in Table 3 show the results of regression analysis using the data for the size of UICs (i.e., the number of joint R&D projects with universities and the budgeted amounts for such projects) as dependent variables. Basically, these results are similar to those for models 1 – 8. However, the effect of the number of patents held is fairly strong for models 9-12. In addition, in the models using the number of joint R&D projects as the dependent variable (model 9 and 10), no effects of enterprise size or age can be observed.

⁵ Substantial number of firms have values of 0 for two of these independent variables (the amount spent on R&D outsourcing and the number of patents held). In this case, we replace this by 1.

⁶ Although the tendency of startup firms to actively take part in UICs as shown by Cohen et al. (2002) was apparent in the medical industry only, here it is indicated for the manufacturing industry as a whole

The next analysis is to investigate changes in determinants of UICs over time. As shown in Table 4, we conducted similar regression analyses using data in five years before. The RIETI UIC Survey collected the data on UIC activities five years before as well. We used this variable as a dependent variable, and used as independent variables from BSBSA in 1995, 5 years before the year 2000 in previous analysis.

(Table 4)

There are similar patterns between Table 3 and Table 4, showing the major effects of technological-capacity factors ($\log[\text{RD}]$) and external R&D collaboration factors (RD outsourcing). Although the effects of company-size factors ($\log[\text{emp}]$) are also apparent, unlike in the current situation, virtually no nonlinear relationship with company age is apparent. Another characteristic of the data from five year before is the fact that the coefficient for the existence of a firm's own research center, which was not statistically significant for the recent data, is both positive and statistically significant. The existence of a firm's own research center can be considered to indicate both a company's R&D capacity and investing in basic research by its own resources. These results suggest that, in five years before, a large firm with own research center were actively taking part in UICs. In order to examine the changes in determinants of UICs over the past five years, we conduct a regression analysis similar to that shown in Table 4, using a dummy variable whether a firm started UICs in this five-year period, as a dependent variable (Table 5).

(Table 5)

The existence of a firm's own research center is both negative and statistically significant in all models. In other words, companies with large R&D capacities and their own research centers had already taken part in UICs before 5 year ago, and the firms that started UICs in this five year period are mainly firms that do not have their own research centers. In addition, the coefficients of $\log(\text{RD})$ concerning technological capacity are not statistically significant, and in Model 2, the coefficient concerning company age is negative and statically significant. These results indicate that over this five-year period, UICs have been spread to relatively small and young firms with smaller amount of own R&D resources.

(3) Impact of UICs on R&D productivity

R&D productivity can be determined by treating the amount of R&D investment as an input and development of new products and production technologies as outputs of knowledge production function. Here, we analyze the effects of UICs on the productivity of R&D activities, using the number of patents developed by a firm as an output.

We used the natural log of patents held and developed by the company as a dependent variable, and the amount of R&D investment (natural log), company size (natural log of the number of employees), the amount spent on outsourced R&D (natural log), UIC dummy variable (whether the company collaborated with a university in 1997), company age (natural log), and the interaction of the company age and the UIC dummy variable as independent variables. Tobit model is used for regressions with 40 industry dummy variables. Table 6 shows the results of our regression analysis conducted for cross-sectional data in each year from 1997 to 1999, for all variables except UIC dummy variable.⁷ Next, we pooled the data from all years and conducted regression analysis, separately for three categories of firms by company age as follows⁸,

- Group 1: companies founded before Japan's rapid postwar growth period (1950 or earlier)
- Group 2: companies founded during Japan's rapid postwar growth period (1951 – 1970)
- Group 3: companies founded after Japan's rapid postwar growth period (1971 or later)

(Table 6)

Due to the existence of lag between R&D inputs and outputs, it would be better to use the weighted average of time-series R&D data with an appropriate lag structure. However, it can be assumed that serial correlation is ordinarily strong in R&D data, so that using R&D data in the same timing as patent data, would not cause serious bias due to the difference in the timing. (Hall and Ziedonis, 2001) As is seen from Table 6, we have obtained fairly stable results across years of analysis, which support this assumption underlining in the analysis.

Concerning the effects of UICs on R&D productivity in cross-sectional analyses (Models 1 – 3), positive coefficients are found in all years, while statistically significant one is that only for 1999. In addition, it is observed that R&D productivity is higher for larger firms. The number of patent held and developed can be interpreted as an outcome from cumulative R&D efforts of firm. Therefore, it is natural to see the number of patent held per one-time R&D investment is higher for old and established firms.

In order to control for this age effect of R&D productivity, Models 4 – 6 in Table 5 are conducted separately by firm age category. Except for model (5), positive and statistically significant coefficients are found for UIC variable. In addition, negative and statistically

⁷ In contrast to previous year data, the 2000 BSBSA did not survey the number of patents held that were developed by the company. For this reason, we conducted this analysis using data through 1999.

⁸ In this regression model, we inserted data-year dummy variables in addition to industry dummy variables.

significant coefficients for the interaction terms of UIC and company age are also found in these models. In order to understand this relationship clearly, taking a partial derivative by Co-RD in Model 4 gives us the results of $11.82 - 2.94 \log(\text{age})$. This means that the younger a company the larger this coefficient becomes, so this result indicates that the younger a company, the greater the effects of UIC for R&D productivity. The same thing can be said to Model 6. In Model 5, which shows the results of calculation for the group of companies founded during Japan's rapid postwar growth period, a clear impact of UICs on R&D productivity cannot be observed. For this group, there are not so much variation in company age, which can explain no clear pattern in firm size and age. In addition, there may be a problem with using the patent count as a dependent variable, since the quality of each patent has not been taken into account in this analysis.⁹ However, this section can be concluded that in general, UICs have a positive impact on R&D productivity and this impact become greater for younger firms.

(4) Impact of UICs on production productivity

If UIC activities increase R&D and innovation productivity, then in turn they may also affect the productivity of the firm's production activities. Our analytical framework in this section is based on production function theory, with the firm's value added serving as an output and factors of production such as labor and capital stock serving as inputs. We have estimated the following extended Cobb-Douglass production function:

$$\ln VA_i = \alpha \ln EMP_i + \beta \ln CAP_i + \gamma \ln RD_i + \mu UNIV_i + \nu UNIV_i * \ln RD_i + \zeta UNIV_i * AGE_i + \text{Ind_dummy} + \beta_i \quad (1)$$

Here, VA represents the value added; EMP represents the number of employees (not including R&D employees); CAP represents the amount of tangible fixed assets; RD represents the amount invested in R&D; UNIV is a dummy variable representing whether the firm participated in UIC five years ago (1997); AGE represents the age of the company; and ind_dummy for 40 industry dummies. Natural logarithms were used for all variables except dummy variables, and estimation was conducted using cross-sectional data from the period from 1997 to 1999. For each year, the results of this estimation with all firms included in the sample and the results with firms grouped by company age (using the same three groups as in the previous section) are presented in Table 7.

(Table 7)

⁹ Concerning the quality of patents, although analysis has proceeded using patent citation data in the U.S. (Hall, Jaffe, and Trajtenberg, 2001), no database similar to that in the U.S. has been developed in Japan.

When we examine the results of analysis for all firms (Models 1, 5, and 9), we see that the intersection of UICs and R&D is positive and statistically significant for all years, indicating that the elasticity of R&D to value added is greater for firms taking part in UICs. Although the coefficient for UIC itself is positive, it is not statistically significant. From these results can be interpreted that the effects of UICs do not directly affect the productivity of all factors for the firm, but contribute to the company's performance by increasing the elasticity of R&D outputs.

When we look at the results of the analysis separately done for each firm age group, we observe that in the youngest group (the group of firms founded in 1971 or later), the coefficient of interaction term of UIC and R&D is the greatest. In other words, the effect of UIC on the elasticity of R&D outputs is particularly noticeable among young companies.

Cross section regression by using equation (1) is based on the assumption that an error term in each regression model is independent from the independent variables. However, in fact, there exist unobservable variables such as managers' capabilities and firm specific intangible asset, which are typically correlated with independent variables such as EMP, CAP and RD. In this case, the coefficients of these variables are overestimated as compared to the true values. In order to mitigate such bias, we estimated regression formula using the rates of growth of both dependent and independent variables as well. The formula used was as follows:

$$\ln VA_{it}/VA_{i}^{t-1} = \alpha \ln EMP_i/EMP_i^{t-1} + \beta \ln CAP_i/CAP_i^{t-1} + \gamma \ln RD_i/RD_i^{t-1} + \mu UNIV_i + v UNIV_i * \ln RD_i/RD_i^{t-1} + Ind_dummy + Ind_year + \varepsilon_i \quad (2)$$

Although the independent and dependent variables are basically the same as in equation (1), each is treated here as a rate of growth. In addition, the value added was deflated by using three-digit industry deflator and the capital stock was deflated by capital stock deflator.¹⁰ We estimated the growth rates for each of the following three periods beginning in 1997: one year (rate of growth from 1997 to 1998), two years (rate of growth from 1997 through 1999), and three years (rate of growth from 1997 through 2000).

(Table 8)

If unobserved variables in equation (1) are time invariant and this is reasonable assumption in a short period, model (2) provides consistent coefficients for each independent variable. However, another problem associated with fixed effect transformation comes in, i.e., attenuation effect due to errors in observations (Woodridge, 2002). For example, negative values for capital stock coefficients may be subject to this bias. In general, this effect becomes larger, the shorter the

¹⁰ Details of deflators are described in Motohashi (2003a).

interval is and the larger the errors in variables are (Griliches and Hausman, 1986). Therefore, when we look at the results for Models 4 – 9 with longer interval, such problems should be smaller. In these models, the interaction term of UIC and R&D has a positive coefficients but not statistically significant. In contrast, we can find negative and statistically significant coefficients to the interaction term of UIC and Age. This indicates that the younger the firm, the greater the effects of UIC on the rate of growth in productivity. This finding is consistent with the results of the cross-sectional analysis shown in Table 7.

4. Conclusions

The results of our analysis are summarized as follows:

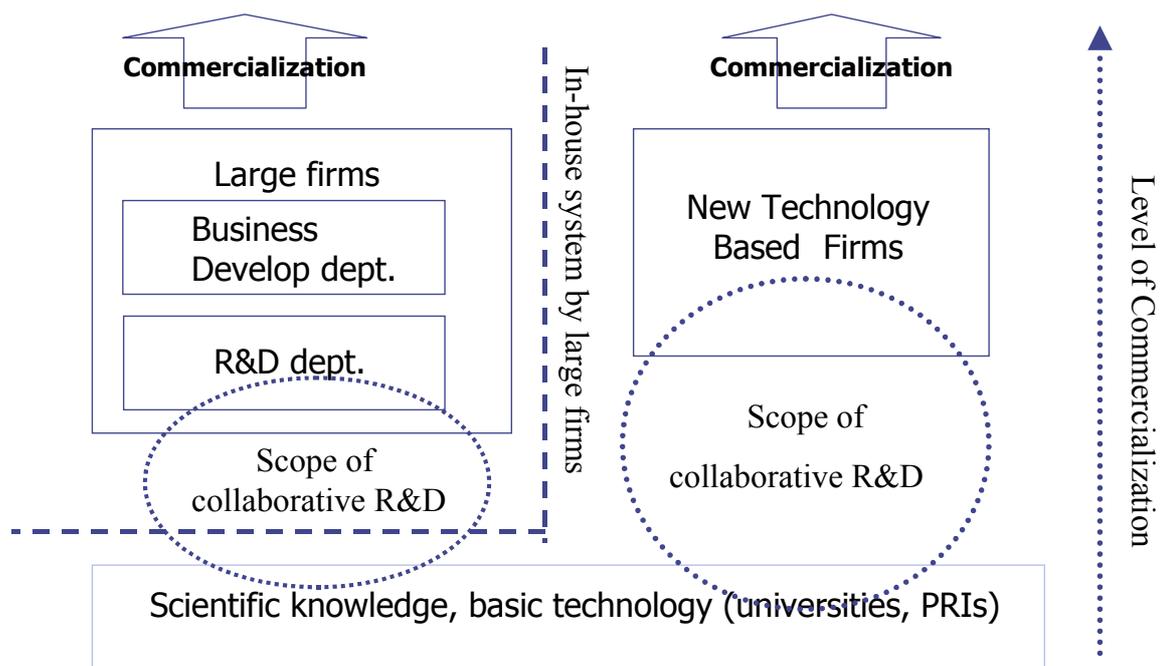
- With regard to the form of UIC activities, for large firms, a focus is put on joint research intended to provide long-term benefits such as increasing firm's in-house R&D potential. In contrast, for smaller firms, the percentage of firms conducting joint R&D and using technological consulting for achieving more practical results, such as the development of new products, is higher.
- As for determinants of UIC activities, it is observed that own R&D resource factors such as R&D investment, as well as with company-size factors, have positive relationship. However, when we insert firm's age and the interaction term of firm's size and age, it turns out that among smaller firms, the younger a firm, the more active it is in UICs.
- In term of changes in determinants of UIC activities over time, it is found that they have spread over among relatively young and small firms without their own research centers, and thus with a relatively smaller R&D capacity.
- As for UIC's impact on R&D productivity, as measured based on the number of patents held that were developed by the company, positive but not so strong impacts can be found. In addition, UICs' effects on R&D productivity are observed particularly for younger firms.
- A positive relationship exists also between UICs and the productivity of a company's production activities. Our analysis indicates that the elasticity of R&D investment outputs is higher among companies taking part in UIC activities. This tendency is more noticeable among younger firms.

Due to the nature of university, devoting its resources into fundamental research activities, it does not supply ready made technology for new product to industry. UICs are not merely technology purchasing activities, but involve significant development activities on industry side. Therefore, UICs used to be concentrated in large firms with sufficient own R&D resources in

five years ago. However, UICs have been spread to smaller firm recently. New technology based firm (NTBF) becomes to have higher R&D and production productivity by UICs, as compared to other small firms. Because such firms cannot compete with large firms in terms of resources such as funding and human resources, they seem to actively take part in UICs, with more practical goals such as the development of new products. Even though NTBFs focus on practical projects, UICs not bringing commercial outcomes instantly, are risky business for them. Relatively higher premia of UICs on R&D and production productivities among young and small firms may simply reflect ex-post outcomes from risky investments. Or, only NTBFs with superior innovation management capability can take risks associated with UICs.

In any case, such firm can serve as an agent of change in context of Japan’s innovation system reform, which has been dominated by large firms. Table 5 compares large firms and NTBFs in the pattern of UICs in the framework of Japan’s innovation system.

Table 5. NTBFs, UICs and Japan’s national innovation system



Japan’s innovation system faces systemic impediments to active R&D collaboration due to inflexible labor market and underdeveloped capital and technology market. Therefore, innovation activities are mainly conducted within large firms with sufficient R&D resources from fundamental research to commercialization activities. However, it is the fact that in-house type innovation strategy for Japanese firms lead to lost in international competition in IT industries, because such innovation system does not work effectively in fields where technological advances proceed swiftly (Ando and Motohashi, 2002). Moreover, in the

pharmaceuticals R&D process, which is changing rapidly due to advances in biotechnology, it is vital to effectively collaborate with universities and other institutions that have scientific knowledge in fields such as genetic engineering (Motohashi, 2003b). In-house innovation system is not effective either in this area. Therefore, Japanese innovation system needs to change toward dynamic and network based system with active external collaboration with various innovation actors.

In this sense, UIC activities by NTBFs are promising. Because NTBFs do not have extensive R&D resources, they have a strong incentive to tap on external resources, even though they have to overcome systemic impediments to networking. In addition, NTBFs needs to have clearer focus on UICs, since they cannot afford to invest in long term fundamental research project with universities. UICs by NTBFs are beneficial to university side as well. A strong policy push on Japanese universities for active commercialization of their research is put on recently, and university's professors' mind setting is gradually changing toward to active engagements in UICs for commercialization of their research. In this sense, stimulation of NTBFs' UICs can be a great momentum for the reform of whole innovation system toward network based one. Further progress in policies in this area is beneficial not only to NTBFs innovation activities but also to whole Japanese society by improving innovation environment in a world of dynamic international competition.

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Table 3: Determinants of University Industry Collaboration in 2002

	Collaboration with university in 2002 (Probit)				Joint R&D with university in 2002 (Probit)				# of co-R&D projects (Negative binomial)	Log (co-R&D budget) (Tobit)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		(9)	(10)	(11)
Log(employment)	0.25 (0.0%)	0.26 (0.0%)	-0.80 (7.2%)	-0.75 (10.8%)	0.28 (0.0%)	0.27 (0.0%)	-0.69 (12.8%)	-0.68 (14.8%)	-0.04 (93.7%)	0.18 (70.7%)	-2.08 (12.6%)	-1.97 (14.6%)
Log(R&D investment)	0.12 (0.0%)	0.12 (0.0%)	0.12 (0.0%)	0.10 (0.3%)	0.05 (9.2%)	0.05 (9.6%)	0.05 (9.2%)	0.03 (35.4%)	0.07 (8.2%)	0.06 (19.6%)	0.30 (4.8%)	0.16 (27.8%)
Log(R&D outsourcing)	0.16 (0.5%)	0.16 (0.5%)	0.17 (0.4%)	0.19 (0.3%)	0.07 (12.8%)	0.08 (12.1%)	0.08 (12.0%)	0.08 (14.8%)	0.12 (7.0%)	0.11 (10.6%)	1.47 (0.8%)	1.41 (1.1%)
Log(# of patent owned)	0.07 (5.6%)	0.07 (4.9%)	0.06 (10.6%)	0.05 (18.1%)	0.04 (22.0%)	0.04 (25.9%)	0.03 (45.3%)	0.02 (64.2%)	0.11 (4.8%)	0.11 (5.9%)	1.28 (0.4%)	1.30 (0.3%)
Separate R&D center	-0.07 (71.3%)	-0.06 (73.2%)	-0.11 (54.5%)	-0.11 (56.2%)	0.04 (82.2%)	0.03 (85.1%)	-0.01 (96.6%)	-0.03 (86.4%)	0.24 (40.1%)	0.23 (41.6%)	-0.31 (62.7%)	-0.28 (65.8%)
Log(age of firm)		-0.06 (57.6%)	-1.52 (1.4%)	-1.46 (2.4%)		0.09 (48.7%)	-1.24 (4.7%)	-1.23 (5.9%)	-0.85 (21.5%)	-0.55 (43.9%)	-3.62 (5.5%)	-3.56 (5.7%)
Log(emp)*log(age)			0.29 (1.7%)	0.27 (3.0%)			0.25 (3.2%)	0.25 (4.2%)	0.13 (26.5%)	0.07 (56.8%)	0.64 (6.5%)	0.62 (7.3%)
Shorten lead-time of R&D				0.25 (3.7%)				0.23 (6.3%)		0.05 (78.1%)		0.91 (3.6%)
Focus R&D theme				0.24 (4.8%)				0.22 (8.2%)		0.36 (6.1%)		0.72 (9.3%)
Cost reduction of R&D				-0.13 (35.0%)				0.00 (98.0%)		0.14 (55.4%)		0.01 (98.2%)
Reduction of R&D staffs				-0.01 (96.0%)				-0.08 (76.3%)		-0.18 (64.1%)		-0.48 (60.2%)
Explore new research fields				0.57 (0.0%)				0.60 (0.0%)		0.71 (0.0%)		1.17 (0.7%)
Identify marked needs				0.08 (51.0%)				0.18 (14.0%)		0.06 (75.4%)		-0.05 (90.8%)
Commercialization of R&D seeds				0.23 (13.2%)				0.18 (29.0%)		0.12 (63.1%)		0.14 (80.5%)
Upgrading technology foundation				0.17 (28.4%)				-0.07 (67.3%)		0.11 (65.8%)		0.73 (19.7%)
Absorbing external technologies				0.15 (34.3%)				0.09 (57.0%)		0.06 (81.2%)		0.85 (11.1%)
Industry dummy	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
# of observations	724	724	724	724	679	679	679	679	751	751	751	751

Note: Each cell shows regression coefficient and probability > |t-value|. Bold type if it is statistically significant at 10%.

Table 4: Determinants of UIC in 1997

	Collaboration with univ. in 1997 (Probit)		
	(1)	(2)	(3)
Log(employment)	0.22 (0.3%)	0.22 (0.4%)	-0.33 (48.3%)
Log(R&D investment)	0.06 (8.6%)	0.06 (8.6%)	0.06 (8.2%)
Log(R&D outsourcing)	0.24 (0.0%)	0.25 (0.0%)	0.25 (0.0%)
Log(# of patent owned)	0.10 (2.1%)	0.10 (2.9%)	0.09 (4.1%)
Separate R&D center	0.35 (7.1%)	0.34 (8.4%)	0.32 (10.7%)
Log(age of firm)		0.09 (47.4%)	-0.70 (30.0%)
Log(emp)*log(age)			0.15 (23.5%)
Industry dummy	yes	yes	yes
# of observations	629	628	628

Table 5: Determinants of UIC starting from 1997 to 2002

	Started collaboration with univ in these 5 years (PROBIT)		
	(1)	(2)	(3)
Log(employment)	0.04 (69.1%)	0.06 (49.1%)	-0.01 (98.1%)
Log(R&D investment)	0.03 (47.1%)	0.03 (48.7%)	0.03 (49.2%)
Log(R&D outsourcing)	-0.09 (24.1%)	-0.10 (18.9%)	-0.10 (19.4%)
Log(# of patent owned)	-0.02 (77.4%)	-0.01 (85.3%)	-0.01 (84.3%)
Separate R&D center	-1.24 (0.4%)	-1.22 (0.4%)	-1.23 (0.5%)
Log(age of firm)		-0.23 (8.2%)	-0.34 (67.3%)
Log(emp)*log(age)			0.02 (89.0%)
Industry dummy	yes	yes	yes
# of observations	575	574	574

Note: Each cell shows regression coefficient and probability > |t-value|. Bold type if it is statistically significant at 10%.

Table 6: University industry collaboration and R&D productivity

	Patent (by year)			Patent (by age groups of firm)		
	1997	1998	1999	-1950	-1970	1971-
	(1)	(2)	(3)	(4)	(5)	(6)
Log(R&D investment)	0.38 (0.0%)	0.43 (0.0%)	0.55 (0.0%)	0.60 (0.0%)	0.47 (0.0%)	0.30 (0.0%)
Log(employment)	0.61 (0.0%)	0.59 (0.0%)	0.44 (0.0%)	0.48 (0.0%)	0.13 (21.8%)	0.28 (7.9%)
R&D outsourcing	0.17 (1.6%)	0.13 (5.9%)	0.09 (18.7%)	0.24 (0.0%)	0.04 (61.3%)	0.23 (1.8%)
Co-R&D with Univ in 1997	1.43 (33.7%)	0.42 (76.6%)	2.39 (6.8%)	11.82 (2.1%)	-2.63 (46.9%)	4.05 (0.8%)
Log(age of firm)	0.84 (0.1%)	0.58 (1.0%)	0.73 (0.2%)	0.03 (97.4%)	0.85 (16.6%)	1.26 (0.0%)
Co-RD in 97*Log(AGE)	-0.25 (54.1%)	0.05 (89.0%)	-0.47 (19.3%)	-2.94 (2.2%)	0.94 (34.9%)	-1.13 (4.0%)
Industry Dummy	yes	yes	yes	yes	yes	yes
Year Dummy	-	-	-	yes	yes	yes
Number of observations	707	744	786	1188	1630	819

Note: Each cell shows regression coefficient and probability > |t-value|. Bold type if it is statistically significant at 10%.

Table 7: University industry collaboration and production productivity level

	Cross section (1997)				Cross section (1998)				Cross section (1999)			
	all firms	-1950	-1970	1971-	all firms	-1950	-1970	1971-	all firms	-1950	-1970	1971-
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Log(employment)	0.77 (0.0%)	0.73 (0.0%)	0.73 (0.0%)	0.75 (0.0%)	0.78 (0.0%)	0.77 (0.0%)	0.73 (0.0%)	0.76 (0.0%)	0.75 (0.0%)	0.80 (0.0%)	0.70 (0.0%)	0.71 (0.0%)
Log(capital stock)	0.18 (0.0%)	0.23 (0.0%)	0.23 (0.0%)	0.14 (0.0%)	0.17 (0.0%)	0.23 (0.0%)	0.20 (0.0%)	0.11 (0.1%)	0.18 (0.0%)	0.21 (0.0%)	0.22 (0.0%)	0.13 (0.0%)
Log(R&D investment)	0.05 (0.0%)	0.05 (0.1%)	0.04 (1.3%)	0.06 (0.6%)	0.05 (0.0%)	0.02 (23.1%)	0.04 (0.6%)	0.09 (0.1%)	0.09 (0.0%)	0.05 (2.5%)	0.08 (0.0%)	0.11 (0.1%)
Co-R&D with Univ in 1997	0.22 (26.2%)	-0.38 (65.6%)	0.23 (78.3%)	0.63 (20.0%)	0.16 (45.2%)	-0.35 (69.1%)	-1.18 (17.5%)	0.69 (27.5%)	0.14 (47.0%)	0.26 (78.2%)	-0.86 (34.2%)	-0.32 (42.9%)
LogRD*Co-R&D in 1997	0.03 (1.1%)	0.02 (31.6%)	0.03 (18.8%)	0.08 (4.5%)	0.03 (4.2%)	0.04 (10.7%)	0.02 (35.0%)	0.04 (46.3%)	0.03 (3.9%)	0.02 (36.7%)	0.04 (16.5%)	0.09 (8.5%)
Log(Age)*Co-R&D in 1997	-0.07 (19.6%)	0.09 (66.3%)	-0.07 (77.4%)	-0.32 (5.2%)	-0.05 (35.8%)	0.07 (77.1%)	0.32 (17.7%)	-0.27 (22.7%)	-0.08 (14.8%)	-0.10 (68.3%)	0.20 (42.4%)	0.04 (77.6%)
# of observation	705	234	318	153	741	239	333	169	786	249	351	186

Note: Each cell shows regression coefficient and probability > |t-value|. Bold type if it is statistically significant at 10%.

Table 8: University industry collaboration and productivity growth

	Growth from 1997 to 98			Growth from 1997 to 99			Growth from 1997 to 2000		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log(employment):growth	0.49 (0.0%)	0.49 (0.0%)	0.49 (0.0%)	0.60 (0.0%)	0.59 (0.0%)	0.58 (0.0%)	0.50 (0.0%)	0.50 (0.0%)	0.49 (0.0%)
Log(capital stock):growth	-0.09 (10.0%)	-0.09 (10.0%)	-0.10 (8.7%)	0.01 (88.8%)	0.01 (83.8%)	0.01 (88.8%)	0.12 (0.4%)	0.12 (0.4%)	0.12 (0.5%)
Log(R&D investment): growth	0.01 (11.1%)	0.01 (13.2%)	0.01 (13.1%)	0.01 (20.5%)	0.00 (70.9%)	0.00 (70.4%)	0.00 (50.4%)	0.01 (25.3%)	0.01 (25.1%)
Co-R&D with Univ in 1997	-0.01 (74.5%)	-0.01 (76.5%)	0.23 (76.5%)	-0.02 (45.8%)	-0.03 (27.0%)	0.55 (27.0%)	0.02 (40.6%)	0.02 (44.7%)	0.54 (44.7%)
LogRD*Co-R&D in 1997 growth	- -	0.00 (76.6%)	0.00 (77.0%)	- -	0.03 (13.7%)	0.03 (20.7%)	- -	-0.01 (34.6%)	-0.01 (22.3%)
Co-R&D*Log(Age)	- -	- -	-0.06 (10.8%)	- -	- -	-0.16 (0.1%)	- -	- -	-0.14 (0.8%)
Industry dummy	yes	yes	yes	yes	yes	yes	yes	yes	yes
# of observations	688	688	688	705	705	705	664	664	664

Note: Each cell shows regression coefficient and probability > |t-value|. Bold type if it is statistically significant at 10%