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大学における産学連携施策の影響の検討

Academic Entrepreneurship in Japanese Universities
- Effects of University Interventions on Entrepreneurial and Academic Activities -

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Academic Entrepreneurship in Japanese Universities
- Effects of University Interventions on Entrepreneurial and Academic Activities -

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概要

大学の社会への直接的な貢献が要請される中で、政府は 1990 年代以降、日本版バイ・ドール法の施行を始めとした幾つかの抜本的な改革に着手した。これを受けて各大学においても、研究成果の商業化や産学連携を志向した様々な施策が講じられた。これらの取り組みは、大学教員による特許出願や大学発ベンチャーの設立などの点において一定の成果を上げたものの、商業化志向が旧来の科学者コミュニティの価値観を損ない、科学の発展を阻害しているとの批判も少なくない。このような副作用的側面は、主に米国大学を対象とした実証研究によって示唆されてきたが、日本における実証研究は（特に個人レベルのデータにおいて）比較的限定されている。そこで本稿では、近年の大学を取り巻く環境変化が日本の大学研究に及ぼした影響を組織レベルと研究者個人レベルの両面から分析し、今後の政策検討の一助とすることを目的とした。

本研究では、国内大学を対象とした「産学連携等実施状況調査」データ（文部科学省により毎年実施）と、生命科学・材料科学分野の研究者個人 700 名に関するサーベイ・データ（本稿著者の研究グループにより 2009 年実施）を利用し、以下の結果を得た。

＜組織レベルでの活動に対する大学施策の影響＞

- 1990 年代以降、大学レベルでの組織的取り組みは順調に推移し、2007 年頃までに専門組織（TLO や知的財産本部）の設置、関連ガイドラインの制定などは定常状態に達した（図 1）。

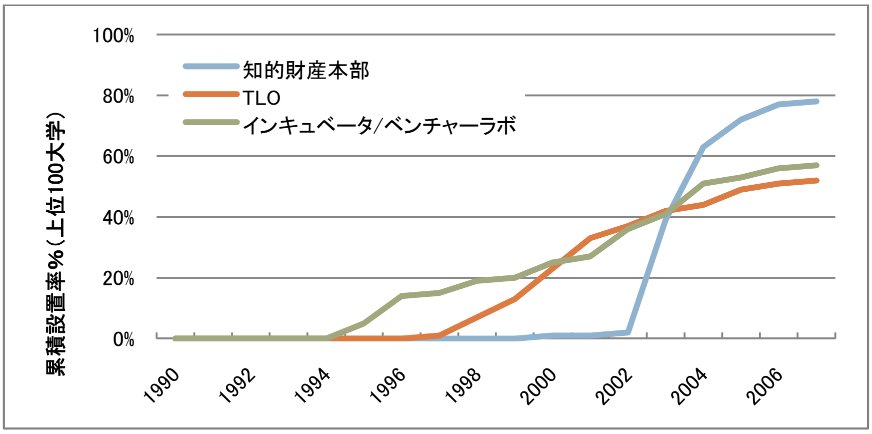


図1　産学連携組織の累積設置率の時系列推移

（注）上位 100 大学とは、科学技術補助金取得額上位 100 大学（2007 年）を示す。

- これと並行して、大学特許の出願数やライセンス収入なども増加したが、同様に 2007 年頃からその成長は鈍化している（図 2A）。特許出願を分野別に見てみると、生命科学分野では継続的な増加が観察されたものの、その他の分野（情報、ナノ、環境）では停滞が示唆された。ライセンス収入については、小規模な収入を中心に件数は増加しているものの、大学レベルでの収入総額が年間

1000 万円を上回るケースは 10～15 大学程度と非常に限定されている（図 2B）。回帰分析の結果、TLO・知的財産本部の設置は、特許出願や技術移転を有意に促進したことが示唆された。

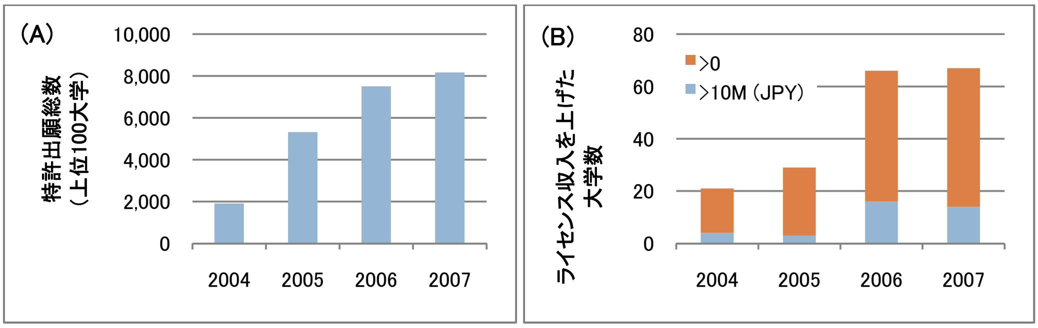


図 2　知的財産権の取得・活用状況

- 科研費取得額上位 45 大学を対象とした生命科学・材料科学分野の研究者個人レベルのデータによると、2007-2008 年の 2 年間に、5 割程度の研究者が企業から研究費を得ており、4 割が特許出願の経験を持ち、また、3 割が何らかの商業的活動に関与していることが示された（図 3A）。これらのうち、商業的活動から何らかの収入を得た研究者は 12%、また、週当たり 10 時間以上を商業的活動に費やす研究者は 7%であった（図 3B）。

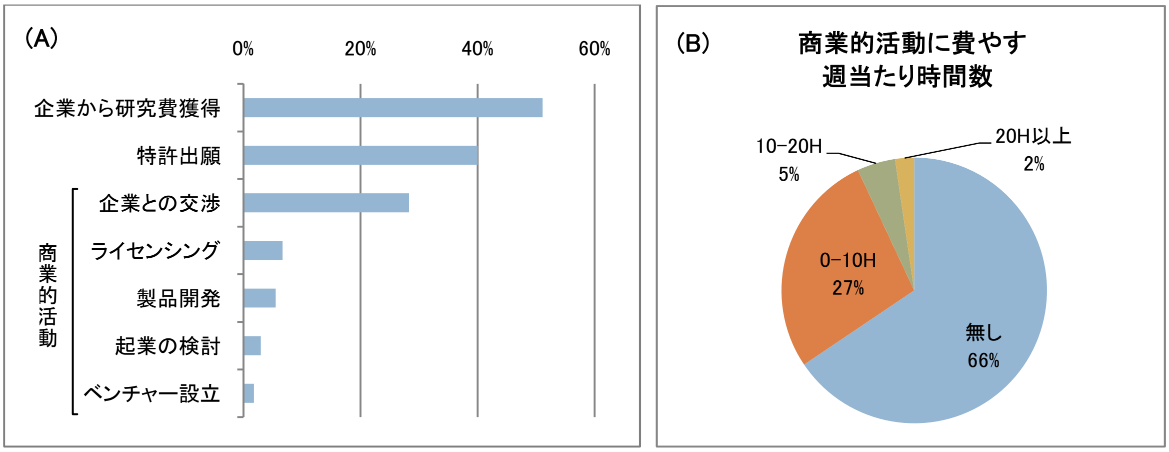


図 3　研究者の産学連携活動

＜研究者個人レベルでの活動に対する大学施策の影響＞

- 続いて、これら研究者個人レベルでの活動に対する大学施策の影響を検討した。幾つかの大学では、政策転換の初期ステージ（1990 年代中頃）から様々なインフラが整備されてきたのに対して、2000 年代に入ってから同様のインフラが整備された大学も少なくない。これらを比較すると、早期からインフラを有していた大学では、教員の産学連携活動（2007-08 年度の 2 年間）を促進する効果が比較的弱いことが示された。従って、大学施策の影響が一過的であり、長期的には研究者は本業の研究活動に回帰している可能性が考えられる。

- さらに、産学連携活動が研究活動を阻害する可能性を検討した。自然科学においては、研究者間で研究材料の共有（マテリアル・トランスファー）が頻繁に行われるが、米国における先行研究によれば、産学連携活動に関与する研究者が研究材料の共有を拒むケースが増加していることが指摘されている。本稿のデータからは、大学研究者の 20%前後が、過去 2 年間にマテリアル・トランスファーの依頼を拒絶した（或いは拒絶された）経験を持つことが示唆された。また、同じく米国において産学連携活動が科学論文の遅滞ない出版を阻害するとの報告がなされているが、本稿のサンプルでは、商業的な価値の保全を目的として過去 2 年間に論文の出版を 1 ヵ月以上遅らせたことのある研究者が 11%、論文から特定の情報を除いたことのある研究者が 17%に上ることが示された（図4）。

- 次に、これらの行動の因果関係を検討するために回帰分析を行ったところ、産学連携活動がマテリアル・トランスファーや科学論文の遅滞ない出版を阻害している可能性が示された。

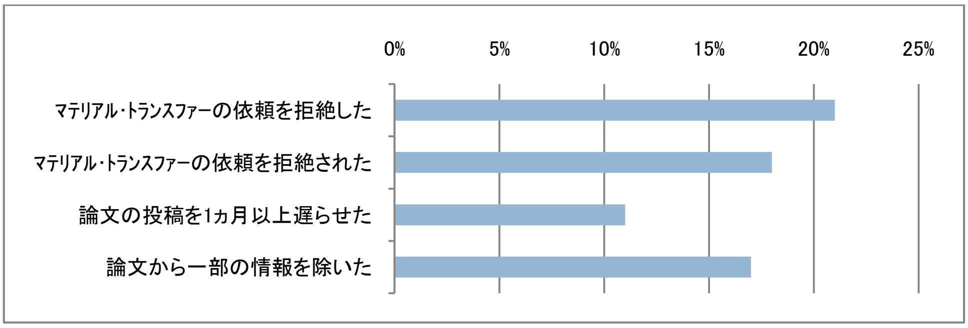


図 4　マテリアル・トランスファー・論文出版の停滞

- 加えて、大学レベルでの諸施策についても、初期段階に TLO/知的財産本部が設置された大学では、論文出版の阻害が比較的顕著なことが示唆された。一方、大学におけるガイドライン・ポリシーの制定は、マテリアル・トランスファーの拒絶を抑制しており、科学コミュニティにおける協力関係の維持に貢献している可能性がある。

1. Introduction

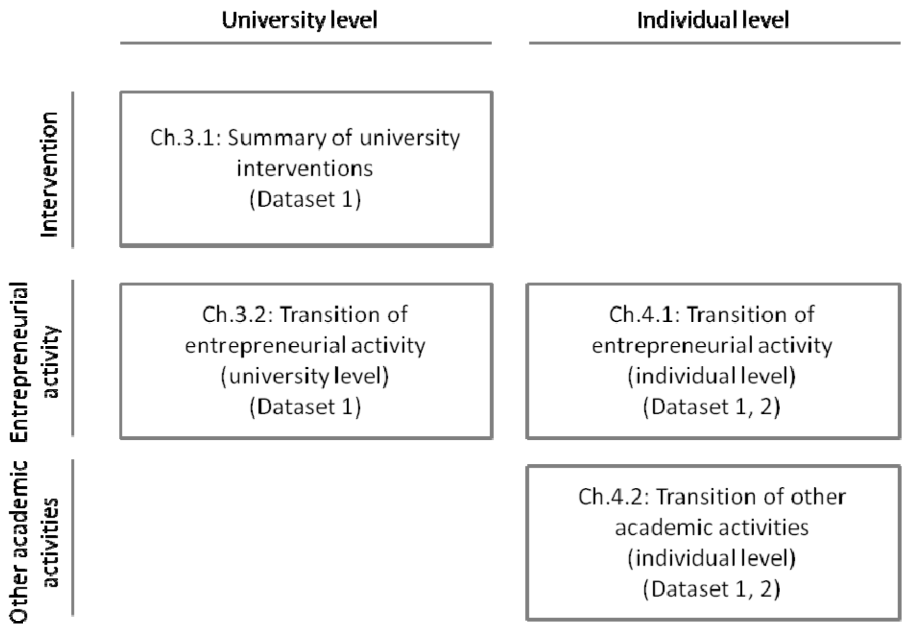
The global trend of academic entrepreneurship has been encouraged scientists to participate in commercial activities and university-industry relationships (UIRs) (Etzkowitz, 1983, 1998; Slaughter and Leslie, 1997). Japan is no exception, and since the 1990s, the government has implemented various mechanisms to promote entrepreneurship (Nagaoka et al., 2009), such as the foundation of special organizations (e.g., TLOs, IP management offices) and the establishment of related guidelines and regulations. Although this regime shift has occurred relatively recently, it has already resulted in certain achievements such as patenting by universities, commercial involvement by faculty members, and technology transfer to the industry (Nagaoka et al., 2009). While some academic scientists and policy scholars have contended that entrepreneurship really drives innovation and has positive impacts on academic activities (NISTEP, 2010), others criticize that entrepreneurship is incompatible with the traditional academic values and harms the advancement of science.

As for the US, where the regime shift occurred almost 20 years before it did in Japan, many studies have indicated that the policy redirection has distracted academic science (Dasgupta and David, 1994; Nelson, 2004). Empirical evidence has shown that entrepreneurial activities discourage academic scientists from sharing their knowledge, research tools, and data with other scientists (e.g., Campbell et al., 2000; Walsh et al., 2007a). Moreover, the literature has indicated that the current academic system with the Bayh-Dole Act as a core mechanism is a suboptimal solution for transferring the academic knowledge into industry (Kenney and Patton, 2009); i.e., the new regime does not effectively function as a driver of innovation. Kenney and Patton (2009) further contend that Japan and European countries have copied the US system without careful examination even if the original system in each country had been relatively efficient.

Although there are many contextual differences between Japan and the US, these negative implications in the US should not be overlooked since Japanese academia might experience the same problem in the near future. Nevertheless, because there is a growing demand for academia to directly contribute to the society, we have to implement somewhat hybrid system to sustain both traditional academic science and practical contribution to the society. Amid this controversy, several studies have been conducted regarding Japanese academia (e.g., NISTEP, 2008; Kanama and Okuwada, 2007). However, most of the previous studies are based on organization-level observations, and we have limited empirical data regarding individual-level phenomena. Hence, this study aims to examine the behavioral change of university scientists in the last decade, specifically in terms of entrepreneurial activities and their influence on academic activities. In so doing, this study intends to offer statistical information for the further development of the Japanese academic system.

To this end, the current paper draws on the following two data sources. The first is a survey conducted annually by the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT), from which we obtain the university-level data regarding infrastructure and systems for entrepreneurship. The other is a survey conducted by the research group of this paper's author in 2009. From this data source, we obtain the data on entrepreneurial activities and other academic activities at the individual level. The details of the data are shown in Chapter 2. Subsequently, using the MEXT survey data, Chapter 3 describes university interventions for entrepreneurship and analyzes their effects on university-level entrepreneurial output. Drawing on our survey data coupled with the MEXT data, Chapter 4 illustrates individual-level entrepreneurial activities and other academic activities, and then analyzes the effects of entrepreneurship on those activities. Finally, Chapter 5 discusses the implications of this study. Figure 1 shows the structure of this paper.

Figure 1 Structure of the paper



2. Data

2.1. Dataset 1

MEXT has annually conducted a survey of Japanese universities on UIRs since 2004 (H15). The survey covers diverse information such as patenting, technology transfer, co-research with industry, and measures to facilitate UIRs. The details of the survey and the summary of the results can be found on the MEXT website.[1] This study draws on the data for 2004 (H15) – 2007 (H18). The survey in 2007 covered approximately 1,300 universities including national, public, private, and four-year and two-year universities. Among these, this study uses 750 four-year universities (87 national, 86 public, and 577 private). Since we were concerned about research-active scientists or universities, most analyses focus on the 100 universities that obtained the largest amount of Grant-in-Aid for Scientific Research in 2007.

2.2. Dataset 2

In 2009, the author's research group conducted a survey, which covered the top 45 Japanese universities with regard to the amount of Grant-in-Aid for Scientific Research in 2007 (the list of universities is shown in Appendix 1). This survey targeted the fields of life science (e.g., basic biology, basic medicine, clinical science, agricultural science, pharmaceutical science) and material science.[2] We prepared a sampling frame including 8,013 full or associate professors who obtained research funds from Grant-in-Aid for Scientific Research in the last five years. We mailed our survey to randomly sampled 1,674 scientists and received 698 responses (42% response rate[3]). The description of the sample is as follows: 83% are life scientists while 17% are material scientists. On average, they obtained their degree in 1988, had worked in 2.8 laboratories in their career, and have been working in their current laboratory for 13 years. The mean number of publications is 5.8 per year.

[1] http://www.mext.go.jp/a_menu/shinkou/sangaku/sangakub.htm

[2] The scientific field of scientists was determined using the database of Grant-in-Aid for Scientific Research. The database records in what scientific field each scientist has obtained research funds (what is called KAKEN code). For each scientist, we chose a single field that was most frequently assigned.

[3] We tested for non-response bias as follows. We obtained publication data from the Web of Science for 100 scientists in each of the response and non-response groups, and checked for differences in publication productivity across the two groups. We find no significant difference (7.4 vs. 9.1 publications per year, $p = 0.22$). However, we did find that full professors were less responsive than associate professors (38% vs. 46%, $p < 0.01$). Therefore, our sample represents the population in terms of productivity but may have oversampled younger scientists.

2.3. Supplementary data

We also draw on the questionnaire information of 2007 Report on the Survey of Research and Development provided by Statistics Bureau Ministry of Internal Affairs and Communications under the Statistics Act Article 33 . The survey inquired about the number of faculty members and scientists, and the size of research budget, and so forth at 674 universities. In our analyses, we use part of the data to control for university-level research intensity.

3. University-level entrepreneurship

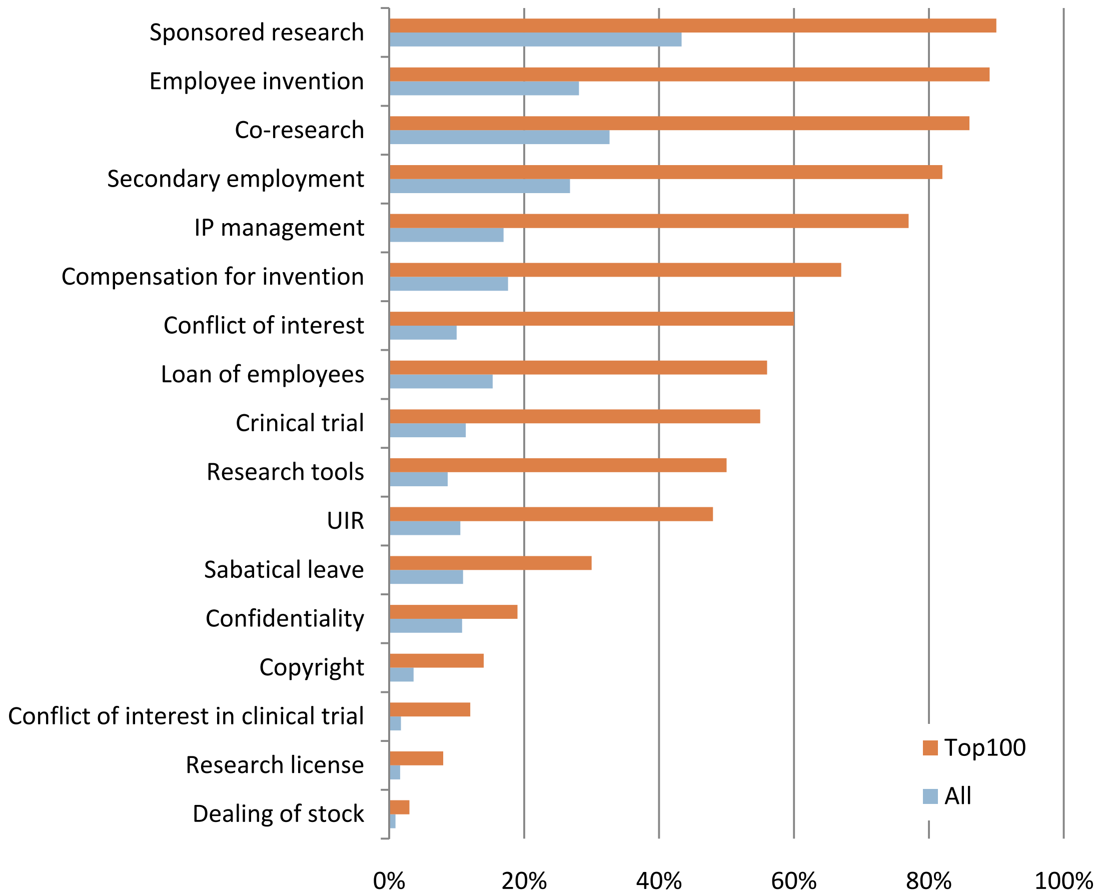
This chapter describes the university-level interventions for entrepreneurship and their outcomes. The analyses draw on dataset 1: the MEXT survey. Since the 1990s, the Japanese government has changed its science policy to accelerate national innovation by efficiently utilizing the resources of academia. Starting with the enforcement of the Science and Technology Basic Law in 1995, several laws were enacted: the Technology Transfer Law in 1998, the Japanese version of the Bayh-Dole Act in 1999, and the Basic Law on Intellectual Property in 2002. Further, national universities were incorporated in 2004. In response to these changes, each university has implemented its own systems and organizations to facilitate entrepreneurship. The MEXT survey inquired about university-level interventions from several angles (Ch.3.1). These interventions have led to a significant increase in entrepreneurial output such as patents, technology transfer, and so forth. We also analyze how the university interventions contributed to this increase in output (Ch.3.2)

3.1. University-level interventions for entrepreneurship

3.1.1. Three stages of infrastructure for entrepreneurship

Policy, regulation, and guideline. As a primary step, university administrations tend to draw up guidelines or regulations and put them somewhere accessible for faculty members. However, they tend not to pay much attention to them, so this type of intervention may not be very influential. Figure 2 shows the percentages of universities in the whole sample and in the top 100 universities that have implemented each policy, regulation, and guideline as of March 2007. The graph indicates that some policies and guidelines have generally been implemented (e.g., sponsored research, employee invention, co-research, etc.) while others are rather rare (e.g., purchase and holding of stocks, licensing, etc.).

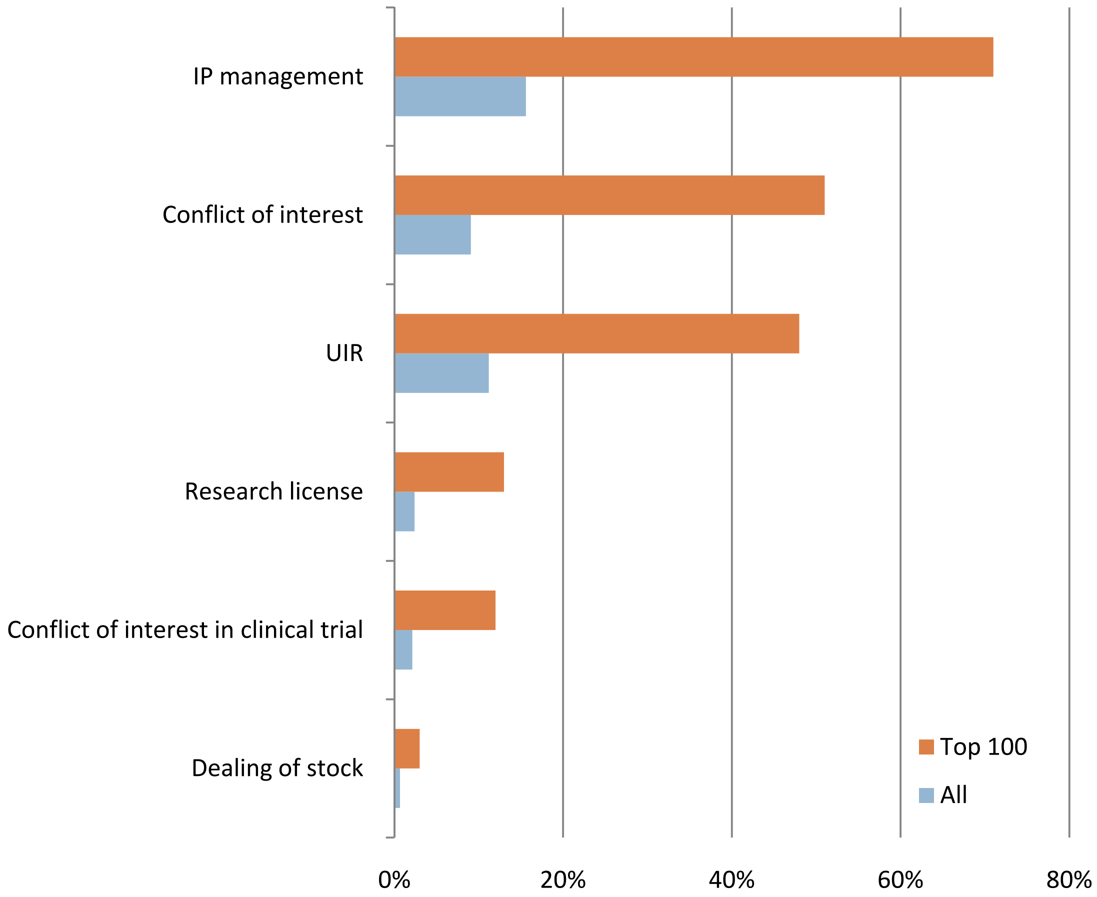
Figure 2 Policy, regulation, and guideline [4]



[4] Source: MEXT survey (H18): Form 8.

Management system. The next step is to organize a system to execute the policies and guidelines. The system is embedded in existing organizations and assigns administrative personnel the tasks of carrying out the policies. Figure 3 shows the percentage of universities that have implemented respective types of management system (as of March 2007).

Figure 3 Management system [5]

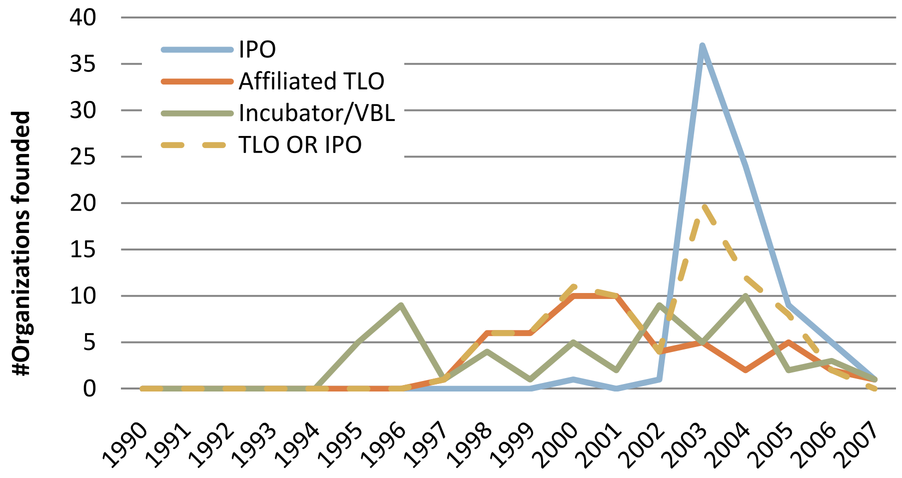


[5] Source: MEXT survey (H18): Form 8.

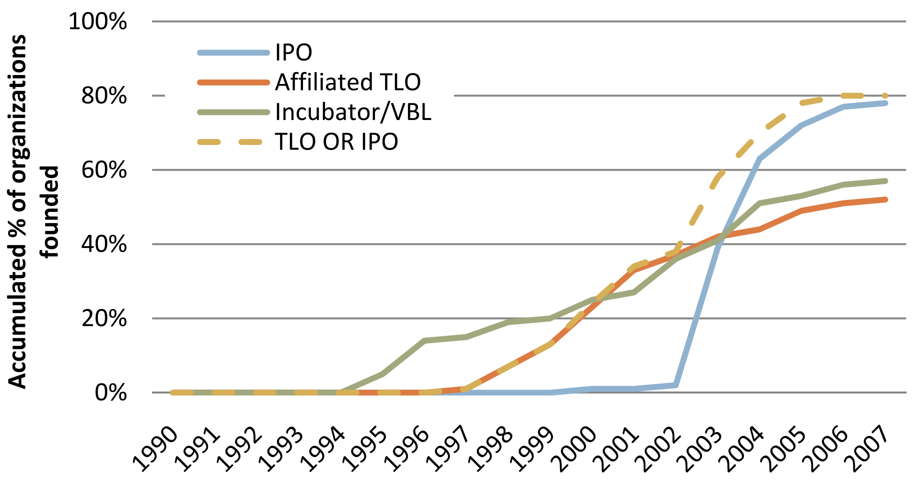
Foundation of special organization. The most advanced stage is to establish special organizations with expert personnel. This includes technology licensing offices (TLOs), IP management offices (IPOs), incubators, etc. Figure 4 illustrates when special organizations for entrepreneurship (i.e., IPOs, affiliated TLOs, and incubators / venture business laboratories (VBLs)) were founded. Figure 4A indicates that TLOs have gradually been founded since 1997 while most IPOs were established in 2003 and 2004. Since TLOs and IPOs share their missions to some extent, the graphs also show the transition of the foundation of a TLO/IPO (the earlier of the two). As of 2007, 80% of the top 100 universities had either an IPO or an affiliated TLO (Figure 4B). Incubators and VBLs have also gradually increased since 1994. In 2007, 57% of universities had an incubator or VBL.

Figure 4 **Special organization for entrepreneurship** [6]

(A) Foundation in each year



(B) Accumulated percentage

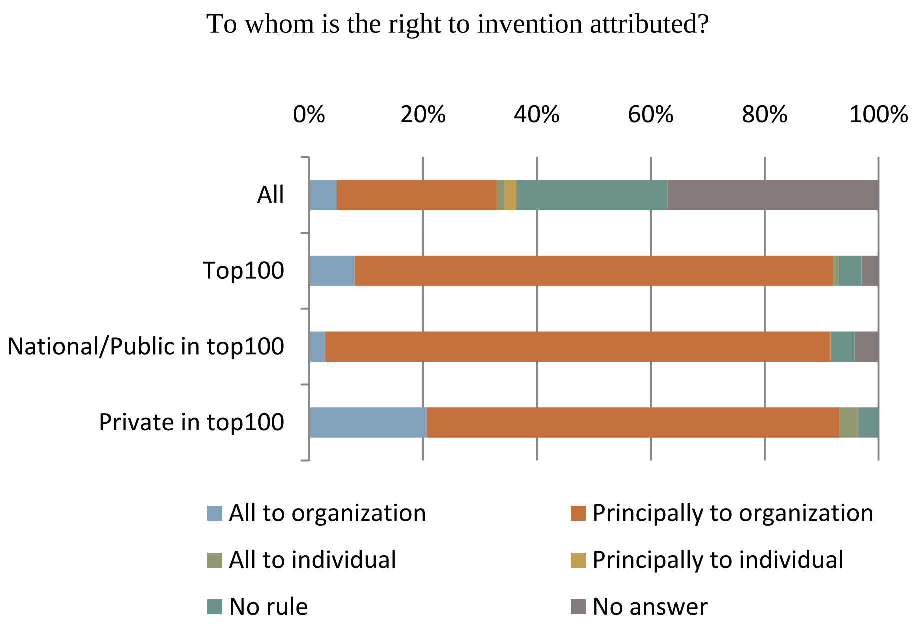


[6] Source: MEXT survey (H18): Form 9. Only top 100 universities.

3.1.2. Other interventions

Right of inventions. Historically, the rights to invention used to be attributed to the nation in national universities, but the Japanese Byah-Dole Act has changed this practice. As of 2007, 33% of universities in the whole sample had attributed invention rights to organizations while only 3% gave the rights to individuals, and 27% had not established a specific rule for this issue (those who did not give an answer might have had no rule) (Figure 5). Of the top 100 universities, more than 90% attributed the invention rights to the universities. Particularly, some private universities in the top 100 attributed the rights to the universities without exception, while it was very rare in national/public universities.

Figure 5 Invention rights [7]

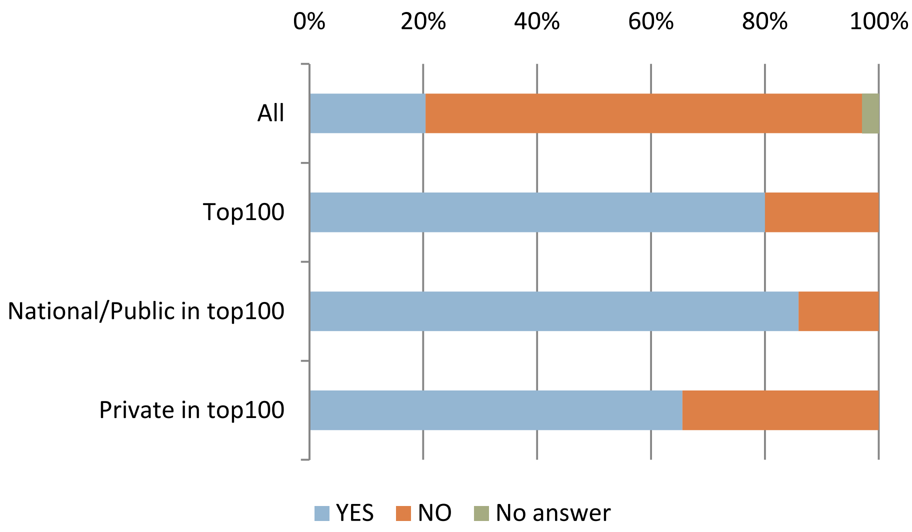


[7] Source: MEXT survey (H18): Form 3.

Intramural training program. The previous literature has indicated that intramural training programs significantly affect the entrepreneurial and academic activities of scientists (Blumenthal et al., 2006). Such a program may include lectures on related legal issues, related administrative processes in each university, and so forth. Figure 6 shows that 20% of universities in the whole sample had an IP-related training program for their faculty. In the top 100 sample, 80% had such programs, so this intervention seems to be heavily associated with the level of research intensity. Among the 100 universities, smaller percentage of private universities offered a program.

Figure 6 Intramural training program [8]

Have you held an intramural seminar or lectures in order to promote the creation of intellectual properties?

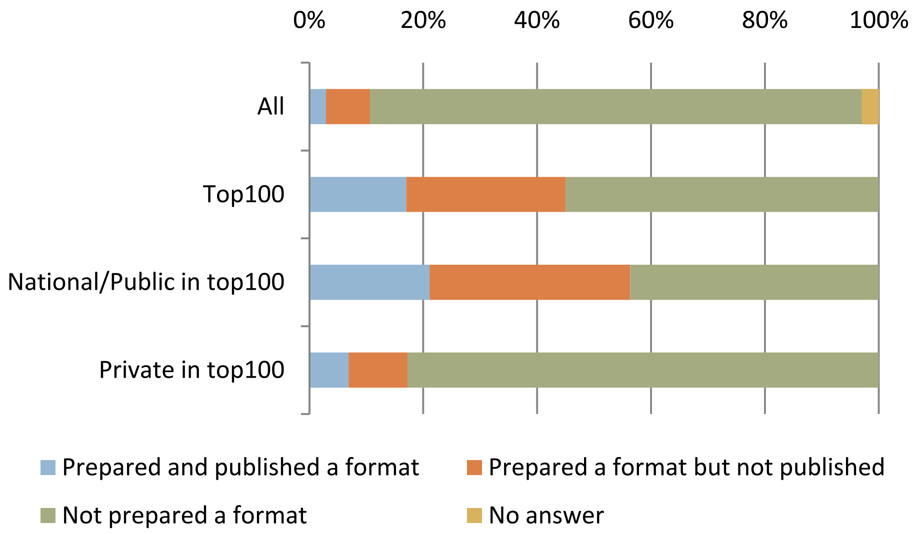


[8] Source: MEXT survey (H18): Form 9.

Material transfer agreement. Material transfer is an indispensable route for university scientists both to cooperate with one another and to provide their resources to industry (National Academy of Sciences, 2003). In order to control the flow of materials and secure the property rights, some academic organizations require their faculty members to make a contract when they send their materials to outside organizations. To this end, some universities prepare and provide a standardized format of contract for the faculty members. Figure 7 shows the percentage of universities that had prepared and published a format for a material transfer agreement. It indicates that only 10% of all the universities had prepared a format and that fewer than 50% had done so even among the top 100.

Figure 7 Format for material transfer agreement [9]

Have you prepared a contract format for material transfer? If so, do you publish it?



[9] Source: MEXT survey (H18): Form 8.

3.2. Accelerated entrepreneurship at the university level (2004-2007)

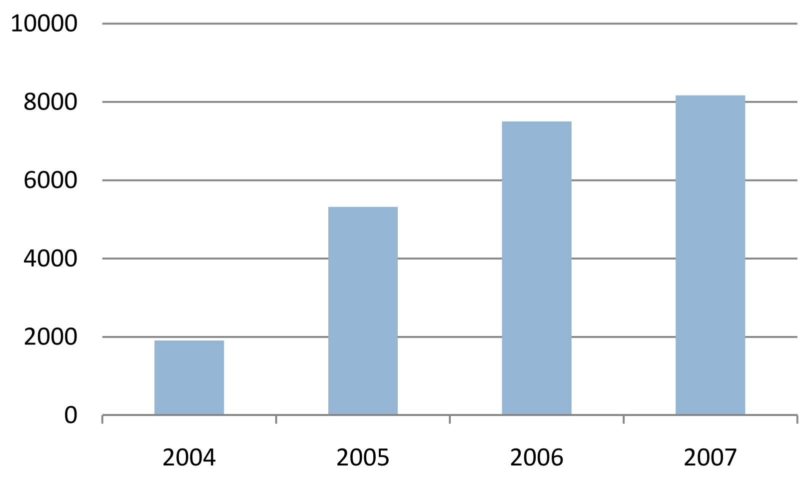
This section analyzes how the regime shift has accelerated entrepreneurial activities at the university level. From the MEXT survey, we primarily focus on two types of entrepreneurial output: (1) inventions and patenting and (2) licensing and technology transfer.[10]

3.2.1. Description of entrepreneurial activities at the university level

Patent application. Figure 8 shows the transition of patent applications. Figure 8A shows the total number of patents applied for by the top 100 universities.[11] It indicates a rapid increase in 2004 - 2006, but it seems that the growth reached steady rate in 2006-2007. In accordance with this view, Figure 8B compares the average number of applications per researcher in each university in 2006 and 2007, indicating that approximately half of the universities were still in an increasing stage (red dots) while the rest were in a steady or decreasing stage (blue dots). Further, Figure 8C examines the transition by field. The graph shows that patent applications in life science were still increasing in 2007, while those in other fields (i.e., nanotech, information science, and environmental science) were merely steady or even decreasing.[12]

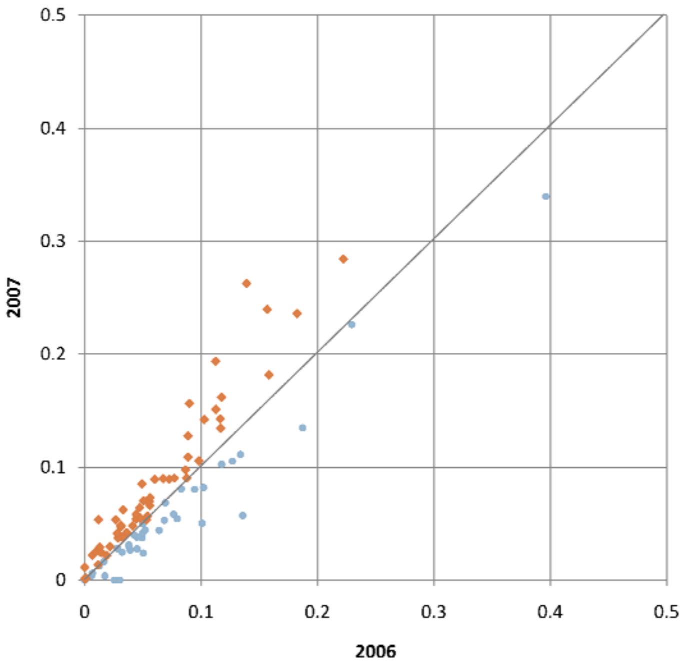
Figure 8 Patenting [13]

(A) Number of patents applied for by the top 100 universities

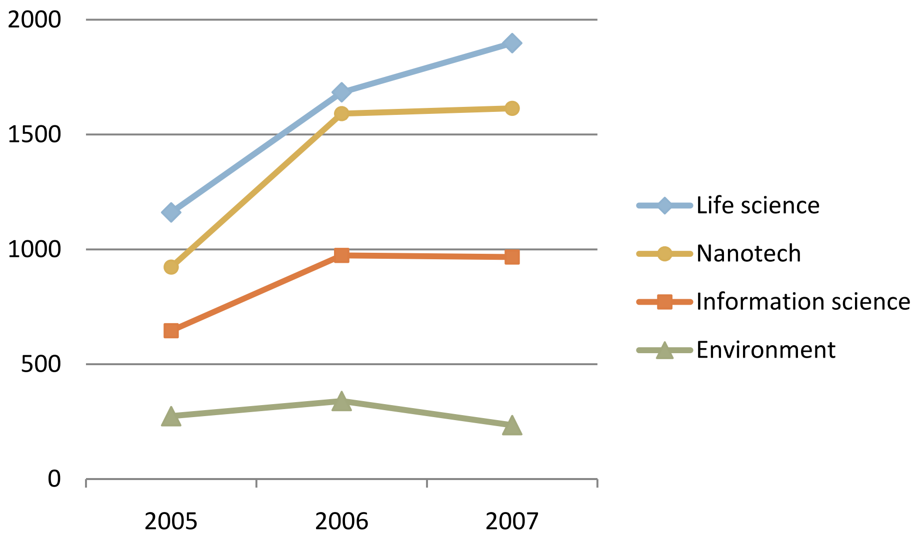


[10] The detailed description is found in NISTEP (2009).
[11] Because the survey of earlier years did not cover as many universities as those of later years, we had to focus on 100 universities covered throughout the survey.
[12] This interpretation needs caution since the field distinction can be ambiguous.
[13] Source: MEXT survey (H18): Form 5. Sum of domestic patent applications and foreign applications.

(B) Comparison between 2006 and 2007



(C) By field [14]



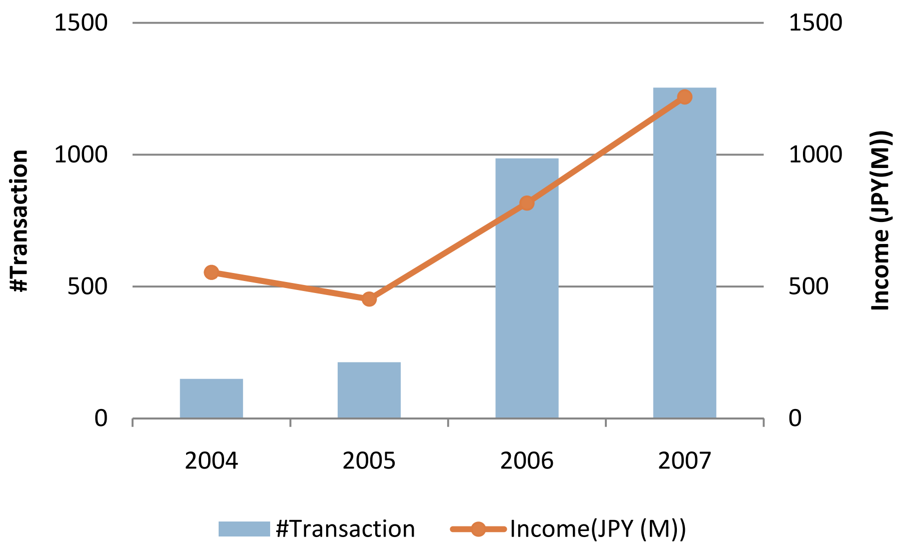
[14] Only national universities are counted.

Technology transfer and license income. Figure 9 illustrates the changes of technology transfer and license income. The transactions include the licensing of patents, designs, trademarks, and other intellectual properties. Figure 9A indicates that the number of transferred technologies and the income from the transfer had increased from 2004 to 2007. However, Figure 9B shows that the average value of transactions has been decreasing significantly, implying that universities were beginning to earn small income from technologies that they used to give away for free.

At the university level, 67 universities out of the top 100 gained in 2007 while only 21 did in 2004 (Figure 9C). Among these 67, only 14 earned more than 10 million JPY. During the four years, only a few universities (the Universities of Tokyo, Tohoku, and Nagoya) have earned more than 100 million JPY per year (this is a certain threshold that the licensing activities could be profitable for a university). The median of license income for the top 100 universities is one million JPY, indicating that licensing activities in Japanese universities have apparently not played a substantial role as an income source. To explain this, our interviewees from university administrations contended that their mission was not making a profit but is to disseminate academic resources.

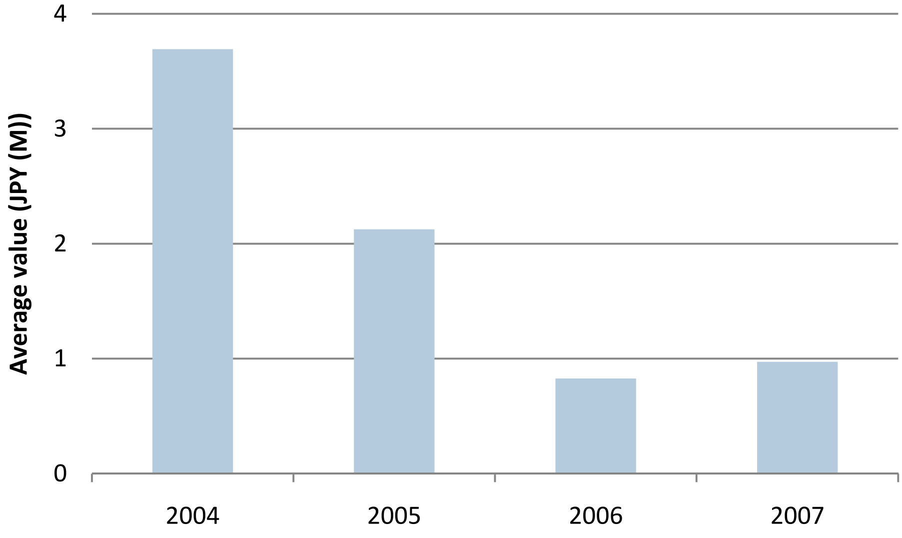
Figure 9 Technology transfer and license income [15]

(A) Number of transactions and amount of income

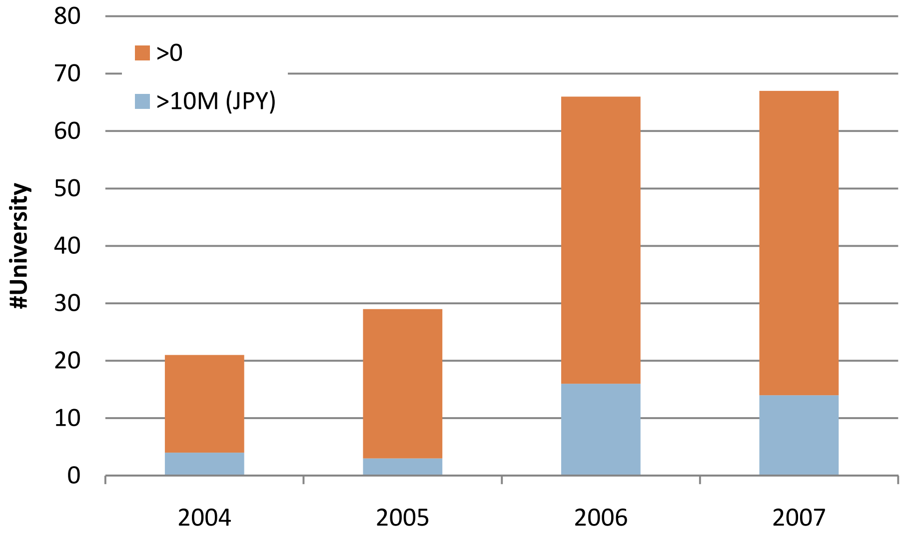


[15] Source: MEXT survey (H18): Form 5.

(B) Average value of technology transfer



(C) Number of universities making income



3.2.2. Effect of university interventions for entrepreneurship

In order to examine the effects of the university interventions for entrepreneurship, we built the following econometric model.

$$EA_{2007,i} = \beta_0 + \beta_1 EA_{2004,i} + \beta_2 \Delta IE_{2004-2007,i} + \beta_3 IE_{-2004,i} + \beta_4 Control_i + \mu_i$$

, where EA stands for entrepreneurial activity shown in the previous section (e.g., patenting) and IE stands for interventions for entrepreneurship described in the previous chapter (e.g., foundation of TLOs). In this model, we intend to examine the effect of the difference in interventions between 2004 and 2007 ($\Delta IE_{2004-2007}$) on the difference in entrepreneurial activity (EA_{2007} controlled by EA_{2004}). As variables for interventions, we used the foundation of organizations for entrepreneurship: (1) a TLO or IPO and (2) an incubator, because these are the only variables for which we have time-series information. We coded $\Delta IE_{2004-2007}$ one if each organization was established between 2004 and 2007, and zero otherwise. In addition, since the interventions may take time to have any effect, we included the interventions before 2004. We coded IE_{-2004} one if each organization was established before 2004. Further, we controlled for the types of universities (national, private, and public) and the input of research activity (the number of scientists[16] and the amount of the research budgets[17]). As dependent variables, we drew on the three indicators mentioned in the previous section: (1) the number of patent applications, (2) the number of technology transfers, and (3) whether a university had a license income.

Table 1 shows the results of the regressions. Models 1-3 include all of the four-year universities while Models 4-6 include only the top 100 universities. Models 1-3 show significant coefficients for most of the independent variables, but this may be simply because of a general difference between entrepreneurially-active universities and non-active universities. In order to examine the effects more precisely, we focused on research-intensive universities (i.e., the top 100 universities) in Models 4-6. Model 4 indicates that the foundation of TLOs or IPOs significantly increased the number of patents ($b = 1.21$, $p < 0.01$). Model 5 does not show a significant effect of the difference in interventions. Model 6 indicates a weakly significant effect ($b = 2.53$, $p < 0.1$). In addition, Models 4-6 show that TLOs/IPOs founded before 2004 strongly increased entrepreneurial activities in 2007. These results imply that affiliated TLOs or IPOs contribute to the production of entrepreneurial outputs. The effect of having incubators is not as clear.

[16] Scientists include faculty members, Ph.D. students, and medical doctors. Scientists in the fields of social sciences and humanities are not counted for this study because they are rarely involved in entrepreneurial activity.
[17] The total amount of research budgets used inside the organization.

Table 1 **Prediction of entrepreneurial output at the university level** [a]

	All 4-year university						Top100 university					
	ln(# Patent application)		ln(# Technology transfer contract)		License income (Yes/No)		ln(# Patent application)		ln(# Technology transfer contract)		License income (Yes/No)	
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Control												
#Scientists	.00 **	(.00)	.00 ***	(.00)	.00	(.00)	.00 ***	(.00)	.00	(.00)	.00	(.00)
Research budget	.00	(.00)	.00 †	(.00)	.00 *	(.00)	.00 *	(.00)	.00	(.00)	.00	(.00)
Private school	-.63 ***	(.13)	-.38 ***	(.08)	-2.19 ***	(.59)	-.07	(.26)	-.53 *	(.25)	-2.20 *	(1.07)
Public school	-.52 **	(.18)	-.39 ***	(.10)	-1.98 *	(.95)	-.42	(.35)	-.70 *	(.32)	-2.50 *	(1.06)
EA (2004)												
Patent application$_{2004}$	.55 ***	(.05)					.45 ***	(.08)				
Tech. transfer$_{2004}$			.32 ***	(.06)					.39 **	(.13)		
License income$_{2004}$					2.10 *	(.84)					2.23	(1.36)
IE (-2004)												
TLO/IPO$_{-2004}$	.86 ***	(.12)	.35 ***	(.07)	2.96 ***	(.60)	1.42 ***	(.29)	.73 **	(.26)	3.15 **	(1.17)
Incubator$_{-2004}$	.76 ***	(.17)	.54 ***	(.09)	.82	(.62)	.46 †	(.27)	.37	(.24)	.53	(.90)
ΔIE (2004-2007)												
TLO/IPO $_{2004\text{-}2007}$	.87 ***	(.18)	.01	(.10)	2.66 ***	(.78)	1.21 **	(.36)	.23	(.33)	2.53 †	(1.48)
Incubator$_{2004\text{-}2007}$	1.10 ***	(.30)	.67 ***	(.17)	3.64 †	(1.97)	.58	(.44)	.50	(.40)	.36	(1.49)
F/χ^2 test	168.60 ***		146.06 ***		265.16 ***		31.81 ***		23.14 ***		65.13 ***	
Log likelihood	-446.31		-231.41		-65.96		-116.76		-106.96		-30.85	
Adjusted/Pseudo R^2	.80		.78		.67		.74		.68		.51	
N	381		381		387		97		97		100	

[a] Standard errors in parentheses. †: p<0.1, *:p<0.05, **:p<0.01, ***:p<0.001. OLS regressions except for Models 3 and 6 (logit regressions).

4. Transition of entrepreneurship and other academic activities at the individual level

This chapter illustrates the entrepreneurial activities and other academic activities at the individual level in 2007-2008 using dataset 2, and analyzes how the university-level interventions affected them. By this time, most research-intensive universities had already implemented their strategies to facilitate entrepreneurship. Nevertheless, the level of interventions differed by university to some extent, and moreover, we expect that there still was flux and deviation at the individual level because it takes time to change the culture and customs in the scientific community.

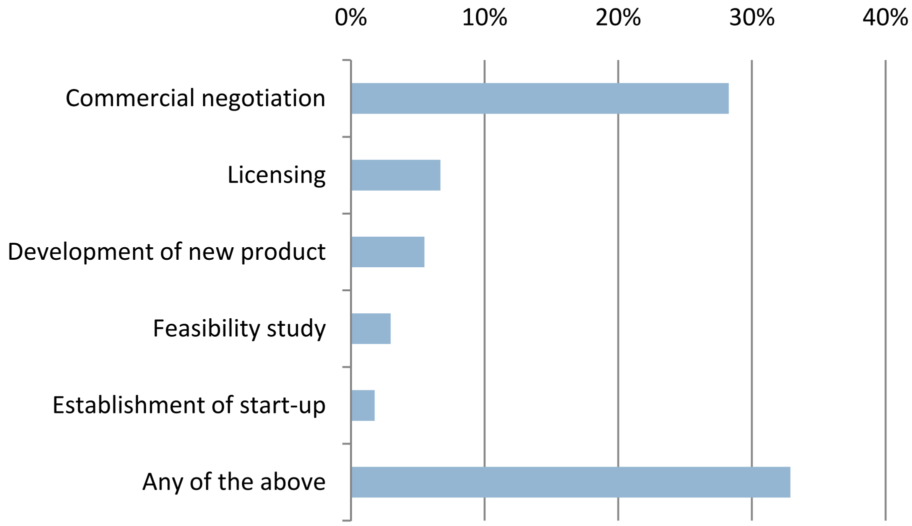
4.1. Transition of entrepreneurial activities at the individual level

4.1.1. Description of entrepreneurial activities

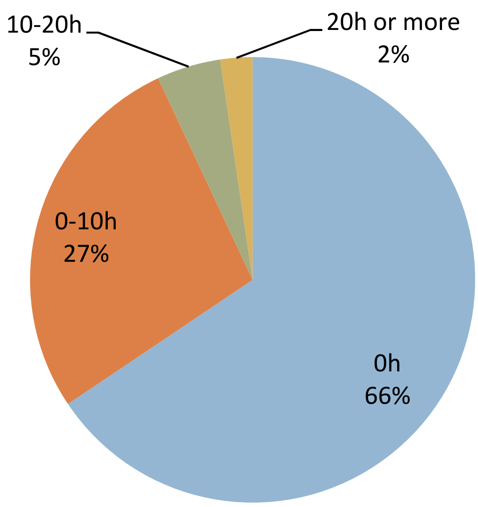
Commercial involvement. Figure 10 illustrates the involvement of our respondents in commercial activities. The survey inquired about the type of commercial activities respondents were involved in during 2007-2008. As a whole, one in three scientists was involved in certain forms of commercial activities: negotiations with industry as for the commercial use of research results (28%), feasibility study of business plan (3%), licensing (7%), establishing a start-up (2%), and developing new technologies for market (6%) (Figure 10A). Among these types of commercial activities, the last three types can lead to commercial income (which we call late-stage commercial activity), but only 12% of respondents had been involved in at least one of those activities. Comparing with previous literature on the US academia, the involvement in late-stage commercial activity seems limited. For example, Walsh et al. (2007a) has indicated licensing (18%) and establishing start-up (8%). For those who had been involved in at least one type of commercial activity, Figure 10B examines the average time spent on the activities, indicating that a fairly limited time was spent on commercial activities. On average, the respondents spent 1.8% of their time on commercial activities, while Walsh et al. (2007a) indicates 3% in the US data. Only 7% of the respondents answered that they spent more than 10 hours per week. In addition, Figure 10C shows the ratio of commercial involvement (any type) in several fields, which indicates a difference between basic and applied fields.

Figure 10 Involvement in commercial activities

(A) Type of commercial activities

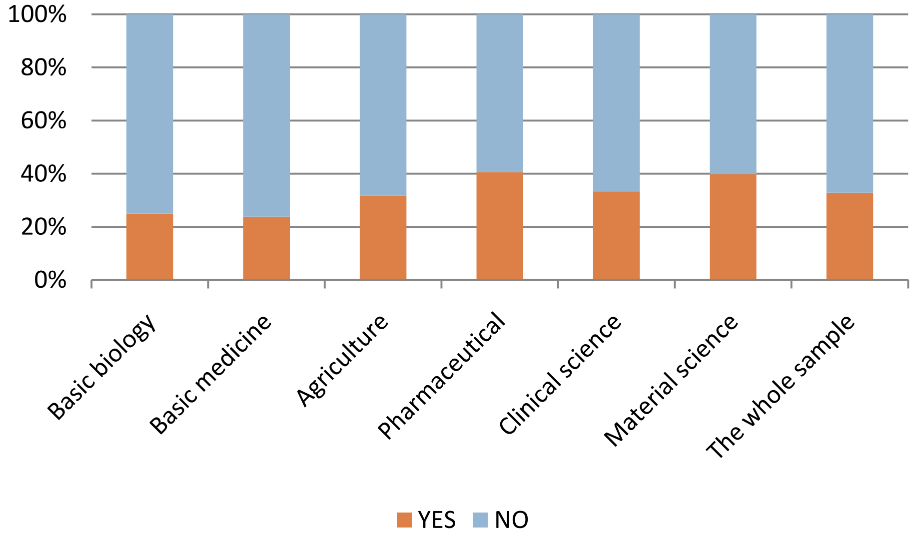


(B) Time spent on commercial activities (hours/week) [18]



[18] Only the respondents who answered that they had been involved in commercial activities in (A) are counted.

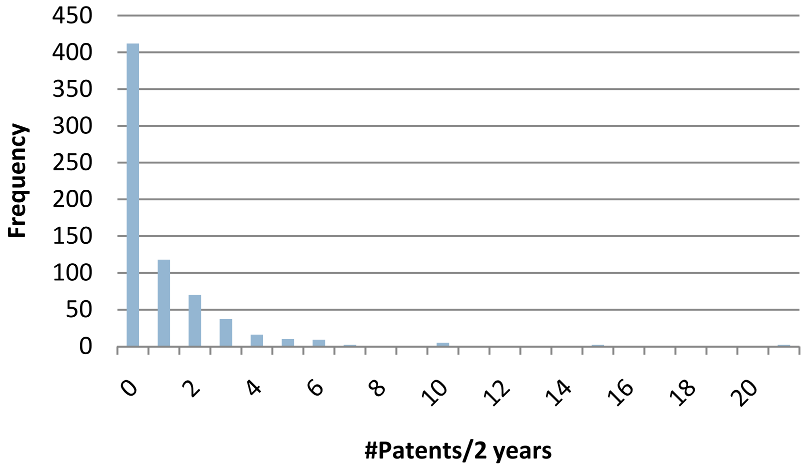
(C) Field differences (have been involved in at least one type of commercial activity)



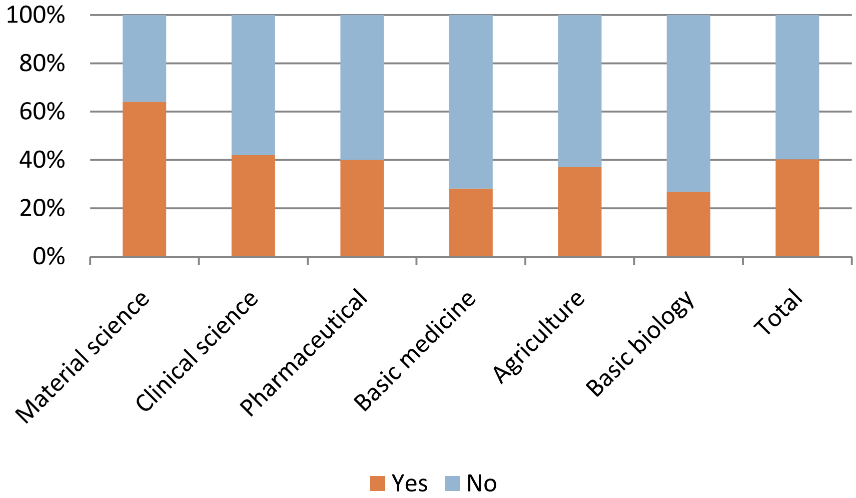
Patent application. Next, Figure 11 illustrates patenting by scientists. Figure 11A shows the frequency distribution, indicating that a majority (60%) of scientists had never applied for patents and that most of the rest had done so 1-3 times in two years. The average frequency of patent application was 1.15 times in two years. Of all the patents, 53% were applied for with industry partners. Figure 11B shows the percentages of patentees (who have applied for at least one patent) by field. It indicates that patenting is relatively common in some fields such as material science (64%) but not in other field such as basic medicine (28%).

Figure 11 Patenting

(A) Frequency distribution



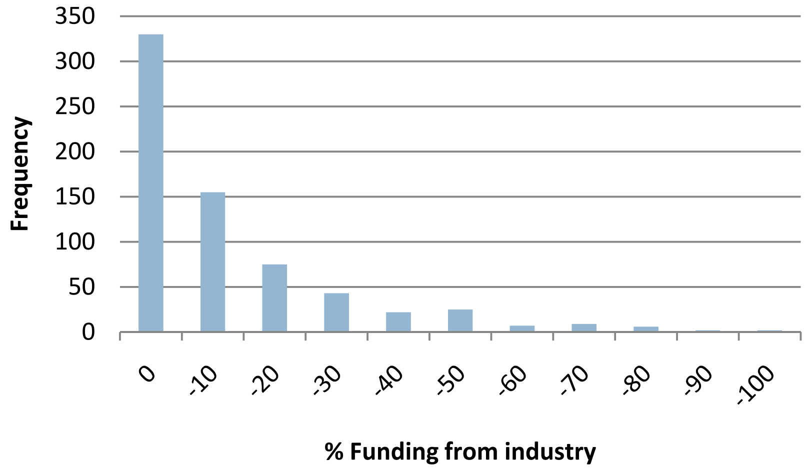
(B) Field differences (have applied for at least one patent)



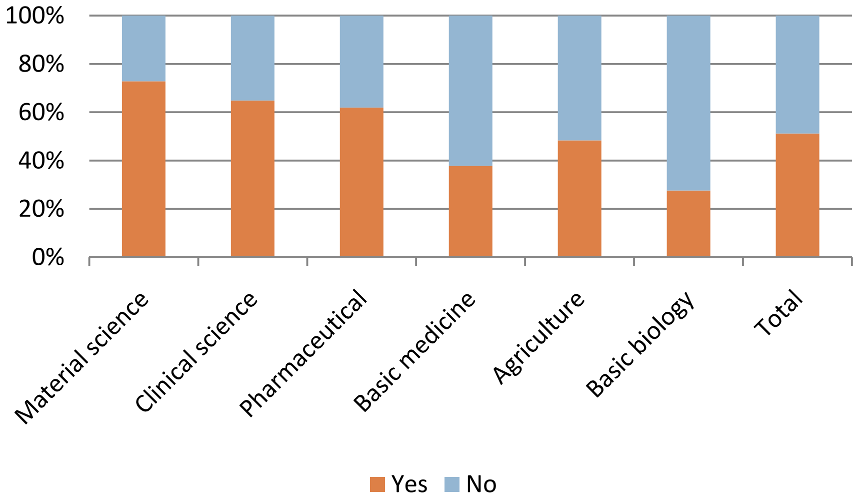
Industry funding. Figure 12 illustrates the funding of research budgets from industry. As a whole, 51% of the respondents received some amount of industry funds. The amount of industry funds significantly varies from scientist to scientist as shown in Figure 12A. Half of them had no industry funding, and the rest received part of their budget from industry. For those who received funding from industry, on average, industry funds accounted for 22% of their research budget. The ratio significantly differs by scientific field from the lowest in basic biology (28%) to the highest in material science (73%) (Figure 12B).

Figure 12 Industry funding

(A) Frequency distribution



(B) Field differences (received funding from industry)



4.1.2. The effect of university interventions

We examined whether the above-mentioned individual-level entrepreneurial activities were influenced by university-level interventions using regression models. We regress several indicators for entrepreneurial activities on three variables of university-level interventions. By 2007, most research-intensive universities had founded certain forms of organizations for entrepreneurship. Thus, we use the number of years since such an organization was founded (*#years since foundation*).[19] A large number for this variable may indicate an established culture for entrepreneurship, or it could imply the obsolescence of university interventions. In addition, we included a dummy variable coded one when a university had founded at least one organization by 2007 and zero otherwise (TLO/IPO/Incubator$_{-2007}$). Finally, to examine the effect of a non-organizational form of intervention, we included a variable for policies and guidelines related to entrepreneurship (*policy & guideline*). [20] We controlled for several variables at the individual level: the amount of research funds that respondents obtained at the individual level (¥ *funds*), whether respondents had a permanent contract (*permanent contract*), whether their affiliation is a private school (*private school*), the number of publications (*# publication*), and scientific fields. In addition, to control the university-level research intensity, we included *research budget per scientist*.

For the three types of entrepreneurial activities discussed in the previous section, we prepared 2-4 dependent variables. Regarding commercial activity, we had (1) any commercial activity, (2) early-stage commercial activity (negotiation or feasibility study), (3) late-stage commercial activity (the rest), and (4) whether a scientist spent any time on commercial activity. As for patent applications, we used (5) whether a scientist had applied for at least one patent in the last two years, (6) the number of patents applied for, (7) whether a scientist had applied for a patent with an industry partner, and (8) the number of patents applied for with an industry partner. For industry funding, we had (9) whether a scientist obtained any funds from industry and (10) the percentage of funds obtained from industry.

Table 2 shows the result for the regressions. Models 1-4 indicate negative coefficients of *#years since foundation* (Model 1: $b = -0.07, p < 0.05$; Model 2: $b = -0.11, p < 0.05$; Model 4: $b = -0.10, p < 0.05$), suggesting that commercial activities are more common in universities that founded organizations for

[19] The number of years since a TLO, IPO or incubator was first founded.

[20] We examined which policies and guidelines each university had implemented before 2007 among those regarding (1) research licensing, (2) research tools, (3) UIRs, (4) conflict of interest, (5) compensation for invention, (6) employee inventions,(7) IP management, (8) co-research, and (9) sponsored research. Then, we calculated this variable with the number of implemented policies and guidelines divided by nine.

entrepreneurship more recently. The same tendency is observed in the models for patent application (Models 5-8) and in those for industry funding (Models 10). One interpretation for these results is that university intervention in the early stage of entrepreneurial regime was counterproductive and the negative effects had long remained. This agrees with the criticism on university administration at that time that it imposed excessive red tape and deterred entrepreneurial activities. Another interpretation is that the effects of university interventions last only for a short term. Scientists might have overreacted to the university interventions and been involved in entrepreneurial activities at the beginning but tended to return to their original states as time passed.

As for the effects of policies and guidelines, the models indicate two significant effects. Model 8 shows a significantly positive coefficient on the number of patent with industry partner ($b = 1.26$, $p < 0.1$). However, the sign is opposite of Model 7 (dependent variable is a dummy of patent with industry partner), so this effect is not very clear. Model 10 shows a negative coefficient of policies and guidelines ($b = -10.09$, $p < 0.05$), implying that university intervention deterred industry from providing research money for university scientists. Model 10 also shows a significantly positive coefficient of $\textit{TLO/IPO/Incubator}_{-2007}$ ($b = 16.64$, $p < 0.01$). Coupling with the coefficient of *#years since foundation*, this indicates that the effect of special organizations is generally positive for industry funding but decreases as time goes.

Table 2 Prediction of entrepreneurial activity at the individual level [a]

	Commercial activity								Patent application								Industry funding			
	Any commercial activity (Yes/No)		Only early stage (Yes/No)		Late stage (Yes/No)		Spent time on commercial activities (Yes/No)		At least one patent (Yes/No)		# Patent		Patent w/ industry (Yes/No)		# Patent w/ industry		Industry funding (Yes/No)		Industry funding ratio	
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7		Model 8		Model 9		Model 10	
Control																				
¥ Funds	.30 ***	(.07)	.24 **	(.08)	.40 ***	(.09)	.24 **	(.08)	.40 ***	(.07)	.24 ***	(.05)	.37 ***	(.08)	.27 ***	(.08)	.30 ***	(.07)	-.10	(.51)
Permanent contract	.11	(.21)	.04	(.25)	.10	(.30)	.04	(.26)	-.06	(.21)	-.35 *	(.16)	.05	(.24)	-.32	(.22)	.13	(.20)	-.39	(1.54)
Private school	.18	(.39)	.12	(.46)	.44	(.57)	1.06 *	(.44)	.87 *	(.38)	.85 **	(.31)	.62	(.42)	1.04 *	(.43)	.05	(.38)	.24	(2.92)
# Publication	.03 **	(.01)	.03 **	(.01)	.02 *	(.01)	.01	(.01)	.03 **	(.01)	.03 ***	(.01)	.03 **	(.01)	.06 ***	(.01)	.04 **	(.01)	.20 **	(.07)
¥ Research budget per scientist	-29.20	(40.77)	-9.03	(49.08)	-47.11	(57.56)	-26.78	(50.09)	-4.59	(40.47)	-35.48	(30.00)	7.35	(46.49)	-71.63 †	(42.14)	-54.13	(40.08)	419.52	(301.79)
IE (-2007)																				
TLO/IPO/Incubator$_{-2007}$	.17	(.68)	.79	(.80)	-1.06	(.97)	.32	(.80)	.86	(.68)	-.28	(.50)	.44	(.74)	-.52	(.70)	.48	(.66)	16.64 **	(5.19)
# Years since foundation	-.07 *	(.04)	-.11 *	(.04)	.00	(.05)	-.10 *	(.05)	-.09 *	(.04)	-.05 †	(.03)	-.10 *	(.04)	-.07 †	(.04)	-.03	(.04)	-.57 *	(.27)
Policy & guideline	.04	(.64)	.07	(.75)	.49	(.96)	1.01	(.83)	-.39	(.62)	.59	(.50)	-.09	(.73)	1.26 †	(.70)	-.53	(.61)	-10.09 *	(4.67)
χ^2/F test	78.77 ***		57.08 ***		49.29 ***		45.96 ***		134.46 ***		162.77 ***		115.51 ***		135.02 ***		123.04 ***		8.21 ***	
Log likelihood	-377.64		-281.77		-211.23		-260.48		-380.99		-849.30		-304.24		-559.12		-390.98		-2800.00	
Psuedo/Adjusted R^2	.09		.09		.10		.08		.15		.09		.16		.11				.13	
N	669		568		645		656		664		664		664		664		653		653	

[a] Standard errors in parentheses. †: p<0.1, *:p<0.05, **:p<0.01, ***:p<0.001. Dummy variables for scientific fields are omitted from the table. Logit regressions except for Models 6 and 8 (negative binomial regression) and Model 10 (OLS).
[b] Scientists involved in late-stage commercial activities are excluded.

4.2. Transition of other academic activities at the individual level

Among various factors which can be affected by the entrepreneurial regime, we specifically focused on the sharing of research tools, or material transfer, because it is a particularly unique and important form of cooperation in natural science (National Academy of Sciences, 2003). Also, since this form of academic cooperation involves the requests for and movement of physical substances between scientists, the transaction can be measured with limited ambiguity. In addition, we inquired about the openness or secrecy of publication. Previous studies have shown that scientists tend to exclude part of their research results from publications and delay publications in order to keep scientific leads or protect commercial values (Blumenthal et al., 1997; Blumenthal et al., 2006).

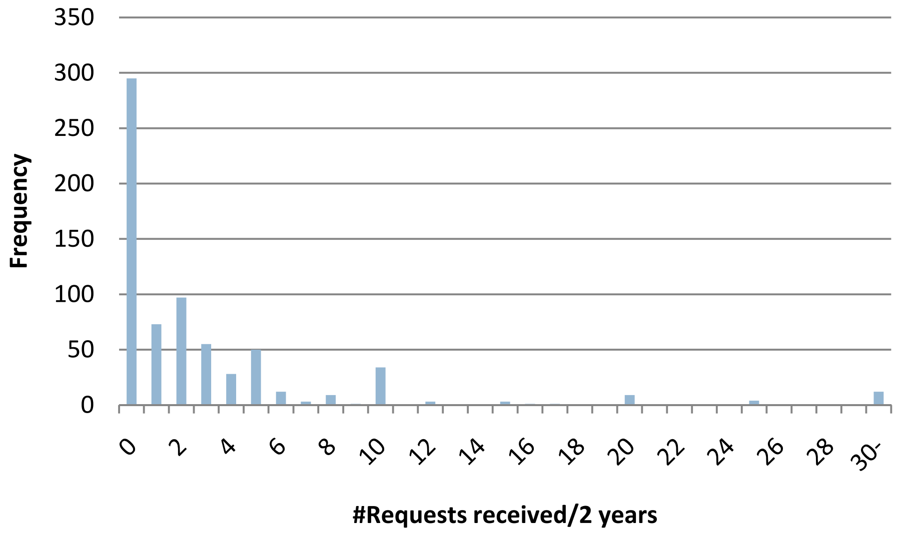
4.2.1. Description of other academic activities

Sharing of research tools. Figure 13 describes the Japanese case of material transfer. Figure 13A illustrates the frequency of material transfer. Approximately 60% of the respondents had received a request for material transfer at least once in the past two years. On average, they had received 2.4 requests per year. We also asked whether they had denied or had been denied requests for material transfer. Figure 13B shows that about 20% of the scientists had had such an experience in the past two years. The likelihood of denial for the requests that our respondents had received from other scientists was 8.3%.

Similar studies for US academia have shown that academic scientists share research tools slightly more frequently: e.g., 3.4 times per year in agriculture (Lei et al., 2009), 3.5 times per year in biomedicine (Walsh et al., 2007b), and 3.0 times per year in life science (Campbell et al., 2002). The literature has reported that the entrepreneurial regime has deterred this cooperation. In the US genomics field, 18% of requests for material transfer were denied in 2003-2004 (Walsh et al., 2007b), while the denial ratio was approximately 10% a decade ago (Campbell et al., 2002), suggesting that the cooperative relationship among the academia has been compromised. With this regard, the denial ratio in Japan was somewhat closer to that in the US 10 years ago than it is today.

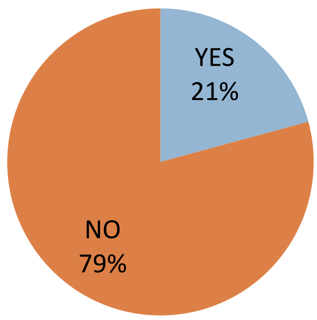
Figure 13 Material transfer

(A) Frequency distribution

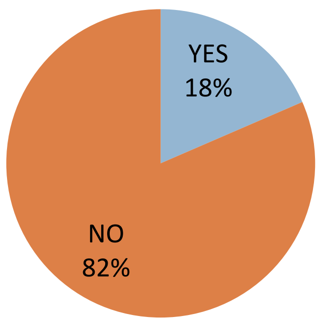


(B) Experience of denial

Have you had at least one of your material requests denied by other scientists in the last 2 years?



Have you denied at least one material request from other scientists in the last 2 years?



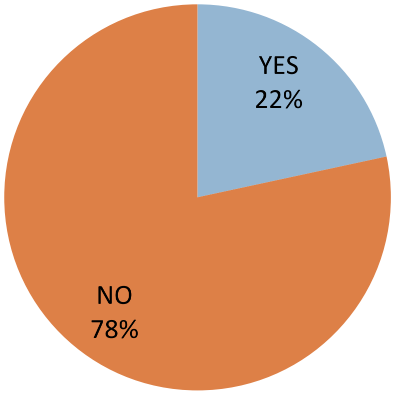
Public sharing of research tools. In order to solve the problem of not sharing research tools, the use of central repositories has been recommended (Furman and Stern, 2006). If scientists place their research tools in a repository under the management of a third-party organization, any scientists can basically access the research tool. This system is also beneficial for supplier-side scientists in that they can outsource the work of preparing, storing, and sending tools. More importantly, repositories can disseminate tools in the long term so the original suppliers can obtain credits from users in the long term (Furman and Stern, 2006). Despite these benefits, the use of central repositories has not been very common, and most transactions of material transfer continue to occur between specific individual scientists.

We examined the attitude of Japanese scientists regarding the sharing of research tools in a public space. To this end, we inquired whether our respondents had research tools which were provided widely for anyone who needed it without charge, and how they provided other scientists access to the tools. Figure 14 shows that 22% of our respondents answered that they offered material through a publicly accessible channel for free. Figure 14B describes the media through which the respondents provided their materials or the information of their materials: (1) 8.3% made an announcement at conferences, (2) 3.1% posted some information about their material on their websites, (3) 2.2% registered their material information with special organizations, (4) 1.7% used central repositories to outsource material, and (5) 0.6% made an announcement in journals. Among these routes, (3) and (4) are mediated by third-party organizations, and thus, are the most readily accessible. Of all our respondents, only 3.4% used such a route, implying that public sharing is still fairly restricted and that improvement in this practice may expand the sharing of research tools.

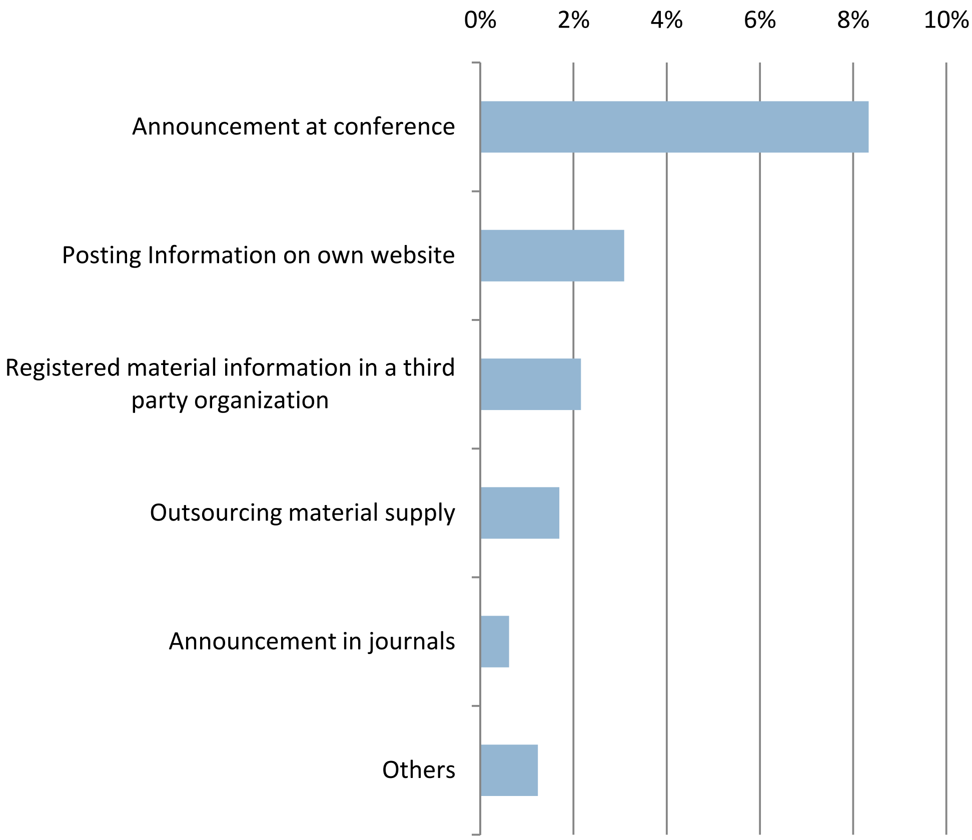
Figure 14 Publicly shared material

(A) Ratio of public sharing

Do you have research tools that you provide without charge and widely for anyone who needs them through publicly accessible channels?



(B) Media of dissemination

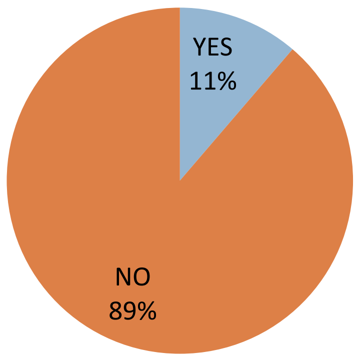


Secrecy in publication. Figure 15A shows that 11% of our respondents admitted that they had delayed publications for commercial reasons. In addition, Figure 15B indicates that 17% of our respondents had intentionally excluded some information from publication.

Figure 15 Adverse effect on publication

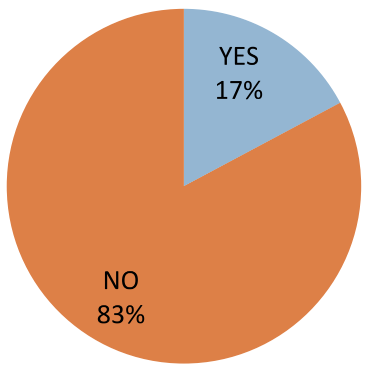
(A) Delay of publication

Have you delayed publication for commercial reasons in the last 2 years?



(B) Exclusion of information from publication

Have you intentionally omitted some information from publication in order to protect your scientific leads or commercial benefits in the last 2 years?



4.2.2. The effect of entrepreneurship

In order to examine the effects of entrepreneurship on the academic environment, we drew on regression models in Table 3. Models 1 and 2 use *denial for the latest request received* as a dependent variable, which is coded one if a respondent denied the most recent request for material transfer they had received. The models include as a control variable the number of requests they had received in the last two years. Model 1 examines the effect of university interventions and shows a significantly negative coefficient of *policy & guideline* ($b = -2.69$, $p < 0.05$), suggesting that policies and guidelines related to entrepreneurship contributed to the maintaining of the cooperative relationship in academia. Model 2 add individual-level entrepreneurial activities as independent variables. The model shows a significantly positive coefficient of *commercial material*, which is coded one if the requested material was related to the commercial activities of the respondent ($b = 2.11$, $p < 0.01$). This agrees with the previous findings that commercial activities deter academic cooperation. However, the model also shows the counterintuitive result that collaboration with industry significantly decreases the likelihood of denial ($b = -1.11$, $p < 0.05$).

Models 3 and 4 use *publicly accessible material* as a dependent variable, which is coded one if a scientist made an effort to provide his/her material through any publicly accessible channels listed in the previous section. The models do not show any significant effect of university-level interventions. Model 4 shows that *at least one patent* and *commercial activity* are positively associated with the attitude to disseminate their materials broadly ($b = 0.75$, $p < 0.01$; $b = 1.46$, $p < 0.001$, respectively). This might be because commercially-active scientists tend to possess broadly applicable materials and share them to the extent which they can enjoy commercial benefits. This implies that entrepreneurial activities may not be necessarily inconsistent with the traditional norm for contribution to academia.

Models 5 and 6 use *delay of publication*, and Models 7 and 8 use *exclusion of information from publication* as dependent variables. Models 6 and 8 indicate positive coefficients of *at least one patent* ($b = 1.90$, $p < 0.001$; $b = 1.26$, $p < 0.001$, respectively) and *commercial activity* ($b = 1.15$, $p < 0.001$; $b = 1.28$, $p < 0.001$, respectively), suggesting that entrepreneurial activities at the individual level directly deter open publication. Models 5, 6, and 8 show positive coefficients of *#years since foundation* ($b = 0.09$, $p < 0.1$; $b = 0.17$, $p < 0.01$; $b = 0.12$, $p < 0.05$, respectively), suggesting that scientists tended to delay publication and withhold information from publication more often when their university has been entrepreneurially active for a longer term. Thus, in universities with a long history of entrepreneurship, there might have emerged a climate that allows secrecy. Coupled with the results in Table 2, this result may imply that university interventions were not effective enough to facilitate entrepreneurial activities in the long term but were effective to create a secretive climate.

Table 3 **Prediction of academic environment at the individual level** [a]

	Denial for the latest request received				Publicly accessible material				Delay of publication				Exclusion of information from publication			
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7		Model 8	
Control variables																
¥ Funds	-.28 †	(.17)	-.35 †	(.19)	.15 *	(.07)	.02	(.08)	.17 †	(.09)	-.08	(.11)	.19 *	(.07)	-.03	
Permanent contract	.55	(.57)	.63	(.56)	.14	(.23)	.09	(.24)	.02	(.32)	.09	(.36)	.14	(.27)	.09	(.31)
Private school	.13	(.78)	.48	(.80)	.35	(.42)	.26	(.47)	.89 †	(.51)	.80	(.68)	.95 *	(.44)	.98 †	(.58)
# Publication	.12	(.20)	.17	(.21)	.11	(.11)	-.02	(.12)	.35 **	(.12)	.23	(.15)	.26 *	(.11)	.14	(.13)
Research budget per scientist	-173.11 *	(87.23)	-183.47 *	(86.10)	-24.51	(44.75)	-33.74	(47.13)	-53.57	(56.65)	-53.56	(56.03)	-55.05	(47.02)	-57.36	(50.93)
# Request received	-.21 **	(.08)	-.22 *	(.09)												
IE (-2007)																
TLO/IPO/Incubator$_{-2007}$	-1.93	(1.43)	-1.73	(1.72)	-.11	(.86)	-.52	(1.01)	-.23	(1.25)	-.70	(1.29)	-.82	(.84)	-1.28	(1.00)
# Years since foundation	.09	(.07)	.08	(.07)	.01	(.04)	.05	(.05)	.09 †	(.06)	.17 **	(.06)	.05	(.05)	.12 *	(.05)
Policy & guideline	-2.69 *	(1.31)	-2.91 *	(1.43)	.43	(.70)	.71	(.74)	.13	(.99)	.60	(1.12)	.00	(.81)	.35	(.91)
EA (2007-2008)																
Funding from industry			.55	(.50)			-.09	(.25)			.66	(.41)			.56 †	(.31)
collaboration with industry			-1.11 *	(.53)			-.34	(.25)			.33	(.32)			.19	(.27)
At least one patent			-.14	(.52)			.75 **	(.25)			1.90 ***	(.42)			1.26 ***	(.30)
Commercial activity							1.46 ***	(.26)			1.15 ***	(.33)			1.28 ***	(.27)
Commercial material [c]			2.11 **	(.80)												
χ^2 test	29.90 *		41.39 **		16.63		79.90 ***		52.17 ***		81.83 ***		52.32 ***		100.09 ***	
Log likelihood	-97.77		-91.92		-315.10		-277.81		-203.84		-159.00		-275.43		-222.70	
Pseudo R^2	.16		.21		.03		.13		.12		.29		.09		.24	
N	402 [b]		395 [b]		622		605		666		645		666		645	

[a] Standard errors in parentheses. †: p<0.1, *:p<0.05, **:p<0.01, ***:p<0.001. Dummy variables for scientific fields are omitted from the table. Logit regressions.
[b] Scientists who received no request for material transfer are excluded.
[c] As a measure of commercial activity, Model 2 uses commercial material (specific to the latest request), while Models 4, 6, and 8 draw on commercial activity (any involvement in two years).

5. Discussion

This study draws on the data of university-level interventions for entrepreneurship and their output (e.g., patents) and individual-level entrepreneurial activities and other academic activities, whereby it attempts to examine the relation between the interventions of universities and the behaviors of scientists.

At the university level, this study confirms that, by 2007, most research-intensive universities have implemented certain types of infrastructure to facilitate entrepreneurship such as special organizations (e.g., TLOs) and related policies and guidelines although the level of the infrastructure still differed from university to university. The output of entrepreneurship (i.e., patents and technology transfer) has been growing in accordance with the university interventions. The regression analyses suggest that TLOs/IPOs contributed to the increase in patent application and technology transfer, indicating that these special organizations have functioned as intended. The data also indicates that there was a plateau in 2006-2007 in the number of patent applications and the income from technology transfer. This implies that we have arrived at a stage to discuss whether further interventions are necessary to boost the trend and whether any redirection of strategies is required.

The data accordingly suggests that, entrepreneurial activities at the individual level (e.g., technology transfer, consultation for industry, start-ups, and participation in corporate management) are common in 2007-2008. Although many scientists are somehow engaged in certain forms of entrepreneurial activities, but that the extent of their involvement is limited in most cases. Only 7% of the scientists spent more than 10 hours per week for commercial activities and only 12% could earn income from commercial activities (licensing or income from their own firms). Regarding the effects of university interventions, the regression analyses seem to suggest that special organizations (i.e., the foundation of TLOs, IPOs, and incubators) founded in the earlier stage had negative effects on individual-level involvement in entrepreneurial activities. One interpretation for this is that university interventions in the earlier stage tended to be counterproductive because of excessive interference or workload for administration work, which scientists often complained about. Another interpretation is that scientists tended to overreact to the university interventions and start being involved in entrepreneurial activities but return to their original state as time passed. In other words, the effect of university interventions did not last over the long term.

We also analyzed how entrepreneurship affected the cooperative relationship among academic scientists. The results indicate that individual-level entrepreneurial activities deterred academic cooperation (material transfer) and fostered secrecy in publications. The results also suggest that old special organizations (e.g., TLOs) increased secrecy in publications, but that policies and guidelines related to entrepreneurship mitigated this malfunction of academic cooperation.

These results may have the following implications. First, the data suggest that the early-stage university interventions might have been poorly or even negatively carried out. In this respect, the data also indicate that the university systems for entrepreneurship have been improved over time. This is encouraging news for university administrators. However, the results can also be interpreted in a different way, that the effects of interventions tend to be transitory and that scientists who had become entrepreneurially active may turn out to be inactive later on, instead concentrating on ordinary academic work. This implies that the overshooting reaction of scientists to the regime shift has reached equilibrium. If this is the case, it is worth considering sustainable mechanism to promote entrepreneurship. Of course, this argument depends on whether or not academic entrepreneurship is desirable in the first place. Second, the results generally suggest that when scientists become involved in entrepreneurial activities, they tend to become secretive and hesitate to cooperate with each other. This is highly consistent across many studies in the US. Thus, despite the potential positive aspects of entrepreneurship, certain countermeasures to address those adverse effects must be implemented. Our data indicates that certain guidelines related to entrepreneurship mitigated the negative effects. Drawing on these results, we might need to learn more about the mechanisms to suppress unfavorable outcome while facilitating intended effects.

The results of this study need to be interpreted with caution because of the following limitations. First, our data structure does not completely address the time-series nature of the phenomena. Although we attempted to make use of time-series information from our datasets, future research should prepare a more complete form of panel data. Especially, it would be interesting to conduct a follow-up survey of the same respondents in future research. Second, datasets 2 was not originally designed for the purpose of this study, so the survey instruments may have room for improvement for the objective of this study. Third, individual-level data (dataset 2) depends on self-report survey, which can cause bias. Thus, future research should validate the results using more objective types of data.

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Appendix.1 List of universities in dataset 2

U Tokyo, U Kyoto, U Tohoku, U Osaka, U Hokkaido, U Kyushu, U Nagoya, U Okayama, U Chiba, U Kanazawa, U Kobe, U Hiroshima, U Tsukuba, U Nagasaki, U Tokushima, U Kumamoto, U Niigata, U Sinshu, U Gifu, Tokyo Inst Tech, Keio U, U Kogoshima, U Yamaguchi, U Tottori, Yokohama City U, Nihon U, Kitazato U, U Toyama, U Gunma, U Yamagata, Osaka City U, Tokyo Med & Dent U, Tokai U, Nagoya City U, Juntendo U, U Hirosaki, U Ehime, U Kinki, U Mie, Nihon Med U, U Kurume, Jichi Med U, Teikyo U, U Miyazaki, U Shimane (ordered by the amount of Grant-in-Aid for Scientific Research in the related fields)

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