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Promoting University–Industry Linkages in Japan: Faculty Responses to a Changing Policy Environment[1]

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Abstract *Since the mid-1990s, Japan has instituted a series of policy reforms in order to encourage greater university participation in commercial activity. Using data from a survey of scientists in engineering and biomedical fields in Japanese universities, we find that there has been a significant increase in commercial activity during this period, in particular, links to small- and medium-sized enterprises. We also find that scientists are increasingly considering business potential when choosing projects. However, we find little evidence of the increasing commercialization leading to barriers to access to research tools. We also find that, despite the growing importance of formalized university–industry ties, university–industry linkages continue to be dominated by informal ties and gift-exchange.*

Keywords: innovation; Japan; technology licensing organizations; university–industry ties; university reform

Introduction

It has long been recognized that academic research plays an important role in promoting technological progress and economic growth. In particular, universities play two key roles: they contribute to economic growth through training of skilled personnel, especially in science and engineering; and they produce, store and disseminate research results, which form the basis for follow-on R&D by firms.[2] Recently, increasing global competition has put pressure on all segments of the national innovation system to be more productive. These pressures are especially strong during times of economic stagnation, such as in the USA in the 1970s and early 1980s, or Japan in the post-bubble era of the 1990s and early 2000s. One result has been a push for universities to take on a 'third role': to contribute more directly to economic activity through technology transfer, especially in the highly visible form of the patent–license–startup mode of technology transfer.

Japanese universities have a long tradition of close ties to industry.[3] For example, engineering professors played a major role in the process of learning technology

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from abroad during the rapid catch-up period of the Meiji Era, as well as during the high-growth period after World War II. And, faculty continue to have close ties with industry through various informal channels (such as co-authoring papers with company researchers, hosting company researchers in university labs, organizing study groups, receiving donations from firms, and having firms patent their inventions—see below). However, prior to the recent policy reforms, faculty at national universities (where the bulk of research occurs in Japan) were severely restricted in their ability to engage in overtly commercial activities, such as consulting or working for venture firms. During the 'post-bubble' stagnation of the 1990s, there was a search in the government and policy communities for measures to increase economic performance. Universities were seen as a key resource for innovation and a possible solution to the economic stagnation. At the same time, the contemporary success of the US, following various American policy reforms designed to encourage commercial activity by universities (such as the Bayh–Dole Act, 1980) provided a model for Japanese policymakers trying to reform the Japanese innovation system.[4] Since the mid-1990s, the Japanese government has instituted a series of reforms designed to increase the contribution of universities to economic growth. In part, these reforms were instituted in response to a perception that Japanese universities were underperforming relative to their American counterparts, and that systemic reforms were needed to close the gap.[5] Interestingly, these were initiated in the Ministry of Economics, Trade and Industry (METI), rather than in the science and education ministry (MEXT), which had jurisdiction over universities. During this period, METI created a new section whose purpose was to promote stronger university–industry linkages and develop policies to accomplish this goal. A further impetus for the reforms was the coincidence of the rising role of science for innovation and the reduction in in-house basic research by Japanese firms during the hard times of the post-bubble era, both of which increased the dependence of firms on university research.[6]

The result was a series of reforms over several years, especially during the period from the mid-1990s to 2004, designed to encourage university faculty to more actively engage in commercialization of their research. The Science and Technology Basic Law, 1995, set the stage for these reforms by committing to a major increase in public research funding, with a goal of encouraging technological development and economic growth, in part through university, industry and government cooperation.[7] Early reforms also included subsidies for university–industry research (beginning in the early 1980s) and establishing cooperative research centers at national universities in 1987. The Technology Transfer Law, 1998, allowed the establishment of Technology Licensing Offices (TLOs), independent of, but affiliated with, particular universities. By 2005, there were 41 TLOs, representing nearly all research universities (Figure 1). University-owned inventions could be licensed through the affiliated TLO. And, professors could voluntarily assign their individually-owned inventions to the TLO, although they were not required to do so. Patent fees for universities were also reduced. In 1997, the restrictions preventing professors from starting businesses, or becoming directors or employees of private firms, were relaxed. After 1997, professors could work for companies part-time if the goal was to conduct or guide follow-on R&D.[8] In 2000, the National Public Service Law was amended to allow professors and university researchers to take management positions in university startups and to join Scientific Advisory Boards of for-profit firms. In October 2002, the authority for approving such outside activities was transferred from the National Personnel Authority to the president of the professor's university,

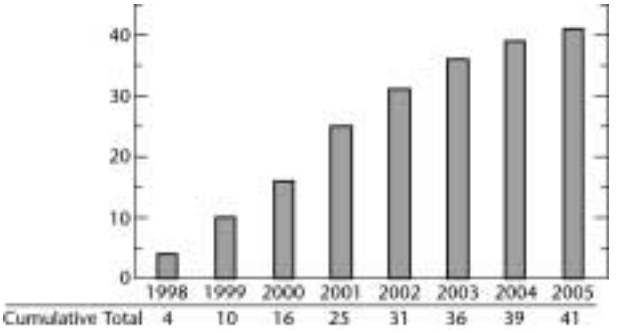

Figure 1. Number of TLOs, 1998–2005.
Source: FY 1998–2004 data from NISTEP, 'Analysis of achievement level of policies that specify numerical goals in the Science and Technology Basic Plans', Report No. 85 (in Japanese), March 2005; FY 2005 data from T. Ysuda, 'Encouraging greater government–academia collaboration', RIETI Fellows Column, No. 114, available at: http://www.rieti.go.jp/en/columns/a01_0146.html, accessed December, 2007.

greatly simplifying the process. The Japanese Bayh–Dole Act, 1999, made it easier for firms to obtain licenses to national inventions. Finally, on 1 April 2004, the national universities (including such leading universities as Tokyo, Kyoto and Osaka universities) became independent legal entities (so-called 'incorporation'). This incorporation of the national universities may result in significant changes in funding, personnel systems and research priorities, although it is still too early to tell. For this discussion, one of the most significant changes was that incorporation gave the universities ownership of faculty inventions, which will make the system of intellectual property (IP) ownership closer to that in the USA.[9] Another important change was that faculty at the newly-incorporated universities were no longer civil servants, freeing them from the burdensome government accounting system and strict civil servant's code of conduct. Another policy initiative designed to encourage university–industry linkages was the *Hiranuma Plan*, initiated by METI in 2001. This plan included a goal of establishing 1,000 university startups in three years (as well as subsidies designed to foster that goal), sending a clear signal to universities. METI budgeted ¥47.6 billion (2002), ¥47.4 billion (2003), and ¥61.7 billion (2004) for the *Hiranuma Plan*.

Thus, this period of the mid-1990s to 2004 was characterized by a series of reforms designed to promote closer cooperation between universities and firms and to encourage universities to commercialize their research results. We will examine the changes in university and professor activity over this period to see how these reforms have affected academics' behavior. Because these several reforms happened at a similar time and there are several with overlapping goals, we cannot test the impact of a specific law. Rather, we are testing the effect of the reform era as a whole, and the associated change in the environment for university research to one that increasingly encouraged universities and their faculty to actively engage in explicitly commercial activity. Thus, these reforms present an opportunity to collect data on faculty research and commercial activities over this period to see how faculty have responded to the changes in the policy environment and to understand how responsive scientific institutions are to policy levers.

In addition to these policy questions, there is the more fundamental question of what, exactly, do universities contribute to technological progress and economic

growth, and how are these contributions accomplished?[10] Universities and firms have multi-plex relationships and the flow of information and materials can take many forms, and, furthermore, can go in both directions, setting up feedback loops that may be key to successful university–industry linkages.[11] In particular, ties between universities and firms can take the form of formal or informal direct linkages, as well as diffuse, indirect, public channels of disseminating the results of university research. We will use our data to examine the relative importance of these various mechanisms for linking firms and universities and how these have changed as a result of the reforms.

Finally, there is, recently, increasing concern about the impact of these reforms on universities.[12] Some have suggested that the increasing emphasis on the university's role as a contributor to economic growth may come at the cost of its more central roles noted above: as a producer of fundamental knowledge and as a producer of skilled labor.[13] Thus, we will address the relations between contributions to public science and private science among Japanese university faculty, and assess whether these roles complement or conflict with each other, and how faculty activity has shifted during the reform period.

Using data from a national survey of university engineering and biomedical faculty, we will examine the ties between universities and other sectors, and how these have changed over time. We will especially focus on ties with firms, patenting, and commercial outcomes. In particular, we will examine changes in both informal and formal linkages between professors and firms. We will also use data from a matched survey of American biomedical researchers to see how Japanese faculty compare to their American peers in terms of university–industry linkages. Finally, we will examine the impact of these reforms on the scientific commons, and the extent to which faculty seem to be moving away from an open science model.

Growing Commercial Activity by Japanese Universities

These recent university reforms have relaxed some of the restrictions on commercial activity by national universities and their professors, and attempted to formalize some of the transactions between universities (and faculty) and firms. Recent aggregate data suggest that universities have responded. Figure 2 shows the increase in joint research projects between universities and firms, with the number of formally established agreements increasing from about 1,500 in 1995 to about 6,500 in 2003. Figure 3 shows the growth in university–industry cooperative research centers located in universities, increasing from three in 1987 (when they were authorized) to around 60 by 2001. We can also see a significant increase in university-based startups. The *Hiranuma Plan* began in 2001 with a goal of 1,000 startups by 2005. That goal was reached in 2004 (see Figure 4). The number of university patents continued to be modest during this period. For example, in 2002, universities applied for 1,335 patents, yielding about $4 million in royalty income. During the same year, US universities generated 6,509 applications and about $1 billion in royalty income. However, these numbers are very misleading as measures of the impact of university-based inventions. This is because Japanese professors retained a form of professor privilege, so that the vast majority of university-generated patents (about 90% by some estimates) are not owned by the university.[14] Most of these inventions are given to firms, who then patent them with the professor as the inventor (but with the university not listed on the patent). After the incorporation of the national universities in 2004, faculty no longer have this

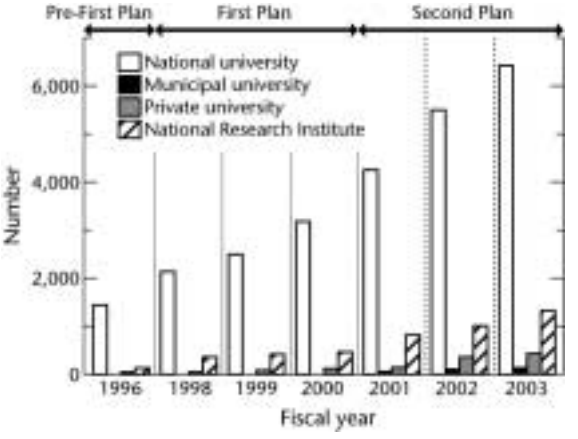

Figure 2. Number of joint research projects between universities and firms, 1995, 2003, by type of university.
Source: National Institute of Science and Technology Policy (NISTEP), 'Study for evaluating the achievements of the Science and Technology Basic Plans in Japan: key figures of the study for FY2003 and FY2004, 2005', available at: www.nistep.go.jp/achiev/ftx/eng/rep083e/pdf/rvst0329.pdf, accessed December, 2007.

professor privilege, and we expect the number and value of university licenses to increase in the coming years.

Thus, based on aggregate data, we see an increase in joint research between universities and firms, the spread of TLOs, and a big increase in university-based startups, all of which suggest that universities are responding to the changing policy environment by strengthening their formal commercial activity. We now turn to the same set of questions at the level of the professor, to see how faculty are responding to these changes.

Data and Methodology

To address these policy and economic issues, we conducted a survey of university faculty (including professors and associate professors, but not instructors or

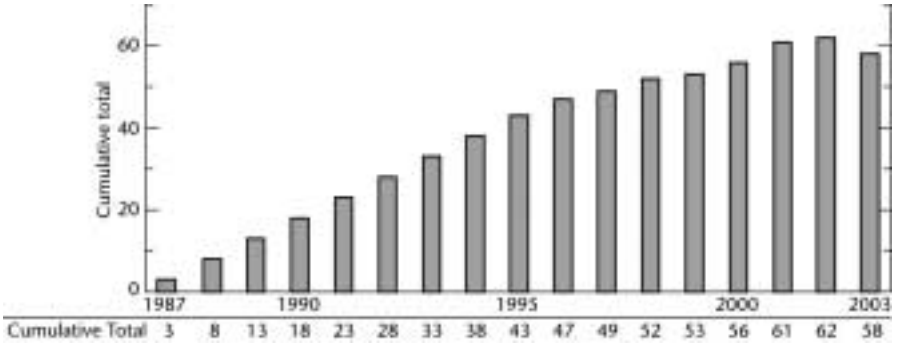

Figure 3. Number of cooperative research centers in universities, 1987–2003.
Source: National Institute of Science and Technology Policy (NISTEP), 'Study for evaluating the achievements of the Science and Technology Basic Plans in Japan', Report No. 83, NISTEP, Tokyo (in Japanese).

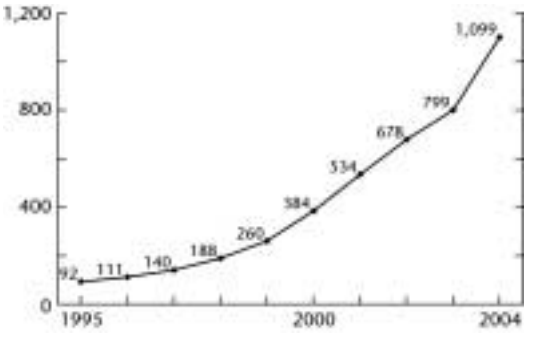

Figure 4. University-based startups, 1995–2004.
Source: D. Higashino, 'Changing environment for Japanese venture business', *Japan Economic Monthly*, May 2005, pp. 1–10.

research associates) in engineering and biomedical departments. We used a two-stage sampling strategy, first drawing a stratified sample of universities (including the top ten national universities and top five private universities, ranked by government research funding), and then drawing a systematic stratified sample of faculty from each of the following departments: material science, information science, mechanical engineering, electrical engineering, and biomedical. This sampling strategy allows us to compare public university faculty (who were most directly affected by the reforms) to faculty in private universities, to see how the impact of the reforms varies across segments of the university sector. The survey was conducted in two waves. The first wave included University of Tokyo engineering faculty, and was collected during the winter of 2003–04. The second wave, conducted during the winter of 2004–05, included the engineering faculty at the other universities and the biomedical faculty at all 15 universities. The sample size was 2,557. We sent a follow-up mailing to those who had not responded after one month. We received at total of 1,446 responses, for a response rate of 57%.

The survey included questions about ties to other sectors, including universities, government labs, large firms, small- and medium-sized enterprises (SMEs) and foreign firms and universities. It also asked about changes in the research environment, types of ties with firms, channels of access, patenting and reasons for patenting, and research results, including publications, patents and licenses.[15]

Expanding University–Industry Research Ties

To begin, we show the incidence of university faculties' research ties to other institutions, with ties very broadly defined: including collaboration, contract research, exchanging researchers, consulting, research funds and so on. We ask about ties to other Japanese universities, hospitals (including university hospitals), government labs, large Japanese firms, Japanese SMEs, foreign universities and foreign firms.[16]

As shown in Figure 5, the most common partner institution is another Japanese university, with 83% of our respondents having some tie to another university. We find that research ties to large firms are quite common, with 71% of our respondents reporting such ties. Ties to SMEs are not as widespread as those to large firms

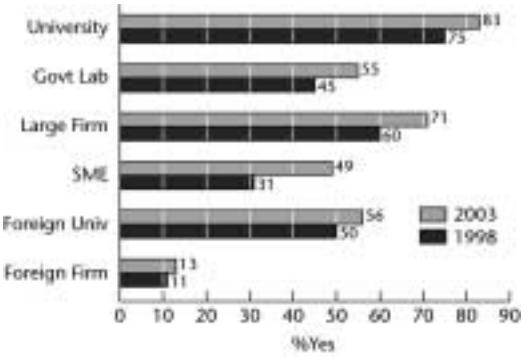

Figure 5. Research ties, by partner, 1998 and 2003.

(49%), although they have increased substantially over the last five years (increasing from 31%, t=12.1, p<0.0001). In fact, ties to all types of institutions have increased in the five year period up to 2003 (see Figure 5).[17] We also see relatively larger changes in ties to Japanese firms (both large and SMEs) than ties to overseas firms, which increase by only two percentage-points. This suggests that, even in an era of increasing globalization of science, policy interventions can tighten links between domestic universities and firms, without those tighter links necessarily spilling over to foreign firms.

We also asked about reasons to collaborate. The surveyed reasons included: access to research funds, to speed-up the research, access to special facilities or equipment, access to skilled personnel, and access to new information.[18] For each type of research partner, we asked respondents to tell us which was the most important reason to work with that institution. Figure 6 shows the results. For links with

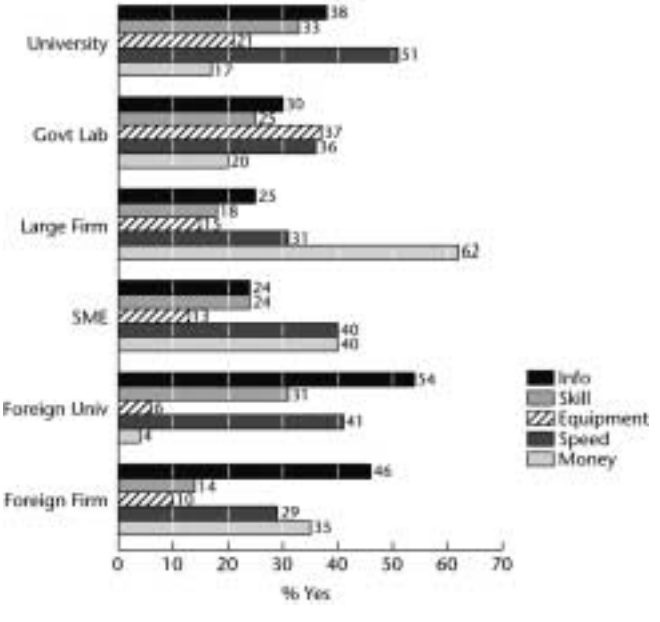

Figure 6. Most important reason to collaborate, by partner institution.

domestic universities, the most cited goal (mentioned by 51% of respondents) is to speed up research. In contrast, ties to large firms are mostly motivated by access to research funds (chosen by 62% of respondents). Interestingly, ties to SMEs are motivated either by access to funds or with the goal of speeding up research (40% choosing each). Thus, our respondents' ties to SMEs seem to be about equally split between those that resemble ties of large firms and those that resemble ties to universities. Figure 6 also shows that ties to foreign firms, and to foreign universities, are dominated by a desire to access information (chosen by about half of respondents in each case), rather than funding or speeding-up the research. Thus, universities may be serving an important gatekeeper role of acquiring foreign scientific and technical information, where it is then accessible by Japanese firms.[19]

Types of Ties to Firms

Thus, we see a significant, and increasing, amount of research ties between faculty and firms, both large firms and SMEs. To further explore the nature of these ties, we asked a series of questions about what kinds of relationships our faculty had with firms. We are particularly interested in two questions: (1) have commercial ties increased during the reform era; and (2) have the formalized ties that are the focus of the new policies replaced the informal ties that dominated before the reforms? We asked about a broad range of possible links between an academic and a firm, including: collaborative or contract research; co-authored publications; receiving research funds [donations]; hosting an industry researcher; assigning patent rights to a firm; joint patent applications; granting a license, through the TLO; granting a license without the TLO; paid consulting, officer or management positions in an existing firm; starting a new business; and [participation in an] industry association, consortium or study group.[20] Figure 7 shows the results. Some of these, such as consulting, positions in firms, startups, and licenses through the TLO, are explicitly encouraged by the new policies. Others, such as joint research, donations, hosting a researcher, assigning patent rights, joint patent applications, licensing without the TLO and consortium or study groups, are characteristic of

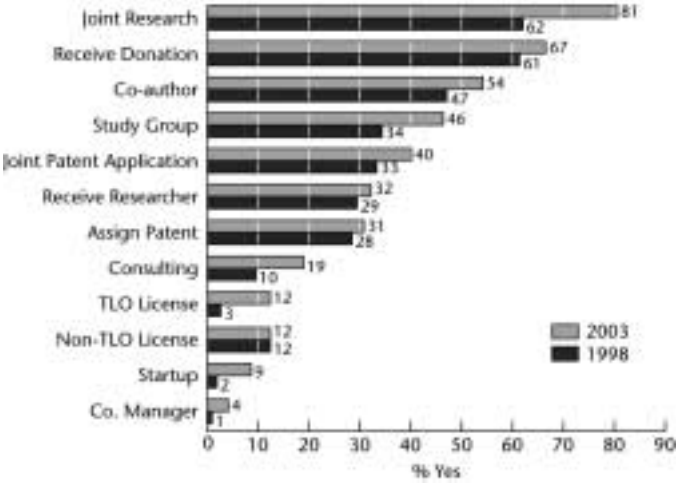

Figure 7. Types of ties with firms, 2003 and 1998.

the pre-reform, gift-exchange relationship between university faculty and industrial labs. We can compare how these have changed during the reform period to see if the reforms are having their intended effects and if these effects are complementary to or substitutes for the prior links between universities and firms.

We find that all forms of ties have increased, with the exception of non-TLO licenses, which have remained unchanged during this period (see below). In particular, all of the behaviors that are the target of the reforms have increased. We see significant increases in company management positions, startups, licensing through the TLO and paid consulting (all changes statistically significant, $p<0.0001$). One interesting finding is that, even after the TLOs were well-established (Figure 1), a significant number of faculty (12%) continue to license without using the TLO, as is their right under the policies in effect before incorporation.[21] Consistent with the aggregate data in Figure 2, we also see a significant increase in the number of faculty doing joint research with firms (from 62% in 1998 to 81% in 2003), which could be a response to the various incentives provided for this research over the reform period.

In addition to these explicitly commercial ties, we also asked about more informal or public science activities. Donations form a key element of the gift-exchange relationship between firms and professors. Typically, firms provide donations to professors' labs and professors give firms needed technical information, including disclosures that can form the basis of firms patenting in the professor's name.[22] According to our data, even after five years of university–industry reforms designed to formalize the informal gift exchange between firms and professors, the number of professors receiving donations has increased slightly (from 61% in 1998 to 67% in 2003, $t=4.16$, $p<0.0001$) as has the number of professors transferring their patent rights to firms (from 29% in 1998 to 32% in 2003, $t=2.18$, $p<0.05$), rather than transferring them to the university and its TLO. We also find that the increase, while small, occurred across all fields (electrical engineering; material science/chemistry; information sciences; and biomedical), suggesting that the trend is widespread.[23] While this increase in assigning patents is small, it is going up, rather than down (which we would expect if professors were giving title to their universities or going through their TLOs), suggesting that the gift exchange system is still operating.

Policy Effects or Isomorphism?

Thus, we have some evidence that the reforms are having the intended effect, since we see an increase in all of the behaviors associated with the reform targets (such as consulting, licensing, startups and company management). Because these reforms were aimed at national universities, we can use our data on public and private universities to further test the extent to which university faculty are responding to the new regulations specifically, or to more general isomorphic pressures to adopt a commercial orientation. For example, Mowery *et al.* argue that in the US case, the increased commercial activity after the Bayh–Dole Act and related legislation of the 1980s could in large part be attributed to the signaling effect of the public declaration that such activity was now legitimate, even expected.[24] They also suggest that the changing nature of academic science (in particular, the molecular biology revolution) made the commercialization of basic research more likely, independent of any policy change (we explore this issue in the next section). Thus, in the case of Japan, if we see a big increase in commercial activity by national university

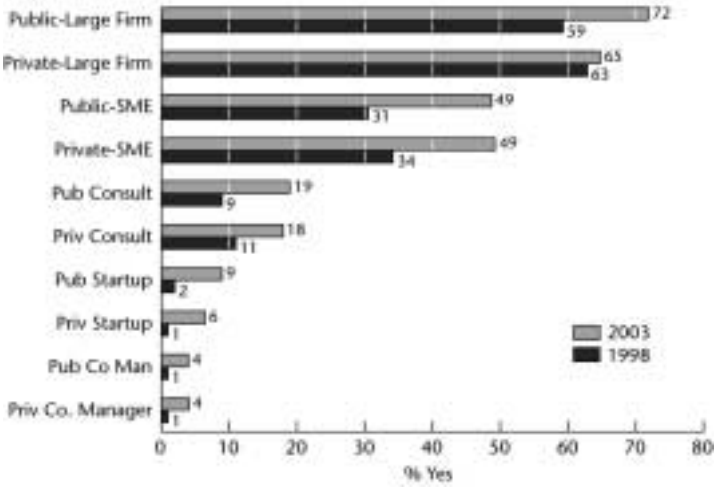

Figure 8. Commercial ties, 2003 and 1998, for private and public universities.

faculty and little change for those in private universities (which had more freedom to engage in commercial activity before the reforms), this would suggest the specific policies were responsible for the changes, while if the changes occur in both segments, then it suggests universities generally are responding to institutional pressures toward commercial activity. Figure 8 compares commercial ties for public and private universities between 1998 and 2003. We see that all types of commercial ties increased for both public and private university faculty. However, the increases are somewhat bigger for the faculty at public universities, where the reforms were most directly relevant. For example, we see that the percentage of public university faculty with ties to large firms increased from 59% to 72%, a 13 percentage-point change, while for private school faculty, the change was only two percentage-points (difference in difference t=2.88, p<0.01). We also see a somewhat larger increase in consulting, although the difference is not statistically significant (a 10 point change for the public university faculty versus a seven point change for the private university faculty, t=1.12, p<0.30). The other measures also all show a slightly larger increase for the public university faculty (except for company management, where the change is equal). Thus, we have some evidence that the reforms are having a larger impact on public university faculty, as expected, but the difference is small, and we observe changes even in the private university faculty. This suggests that the change may be in part a result of institutional isomorphism, as 'promoting university–industry linkages' was in the air during this period. For example, as noted above, METI had established a special section devoted to promoting university–industry linkages, and the Science and Technology Basic Plans explicitly declared the goal of encouraging closer links between universities and firms.

Comparing Japan and the US: Catching Up or Pulling Ahead?

As noted above, these reforms in Japan were instituted in part because of a perceived performance gap between Japanese and American universities in terms of influence on industrial innovation. It is generally believed, on both sides of the ocean, that American universities outperform Japanese universities in this regard.[25]

However, empirical work has often shown that the gap is not so wide, and that Japan may even be ahead in terms of university–industry links.[26]

Our data allow us to address this empirical debate, and thereby shed some light on the process by which such policies might have been implemented. We use data from the Walsh *et al.* survey of biomedical researchers in the USA (collected in 2004).[27] To increase comparability, we limit the American sample to respondents from universities (N=309). This comparison has the additional advantage of allowing us to rule out some rival explanations for the increase in university–industry linkages in Japan observed above. One possible explanation, in addition to the policy changes, is that there has been a shift in the underlying science, such that university research is now more relevant and more easily transferred to firms.[28] Thus, if we see similar changes in both the US and Japan during recent years, this suggests that the underlying science may have shifted, since this would likely affect scientists in both countries. However, if we see a big increase in Japan and little or no change in the US (where the policy reforms had largely been completed by our reference year of 1998), this suggests that the Japanese researchers are responding to the policy changes, or to other Japan-specific changes (such as a change in firm policies toward basic research and increasing reliance on public research to complement in-house research).

Figure 9 shows the comparison in terms of ties to other universities, large firms and SMEs, both 'now' (2003/2004) and five years ago. We can see that even five years ago Japanese university faculty were more likely to have ties to firms, especially to large firms. During the reform era, the gap increased even more. For example, the Japan–US difference in ties to large firms is 30 percentage points in 1998/1999, and it increases to 40 percentage points in 2003/2004. For SMEs, the gap increases from five percentage points to 14 percentage points. Thus, we see a significant change in Japanese faculty, while for faculty in the US (which was not facing similar policy changes) we see a much smaller growth in university–industry linkages. These results suggest that it was, in fact, the policy reforms, or isomorphic pressures, rather than changes in the underlying science, that were driving the closer university–industry ties in Japan during this period. Figure 10 looks at more formalized types of technology transfer for biomedical researchers, including patenting, startups, having products in the market and having licensing revenue. We find very similar levels of formalized transfers in the two countries. In particular, the percent of

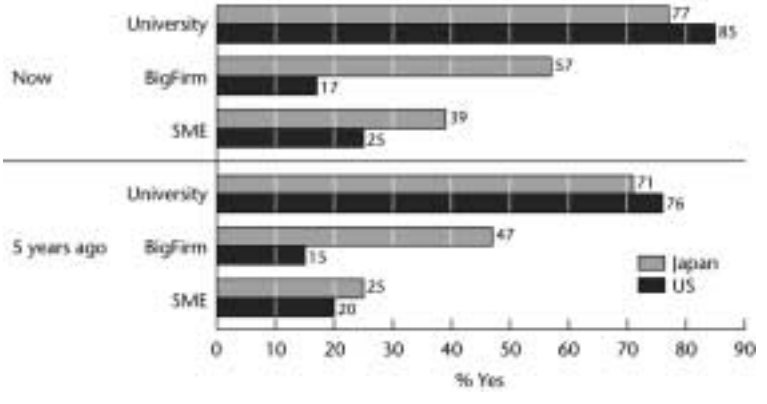

Figure 9. Collaboration, BioMed, US v. Japan, now and five years ago.

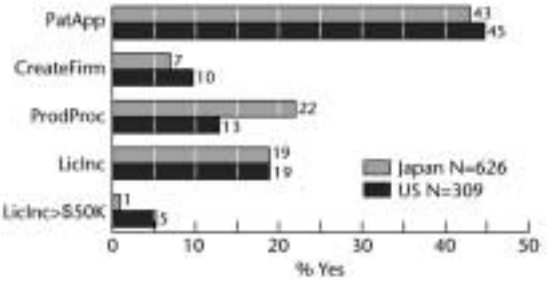

Figure 10. Commercial activity, BioMed, US v. Japan.

biomedical researchers who have been involved in creating a firm is about the same in both countries (with the US being slightly higher, 10% v. 7%). Also, while the percent in each country with any licensing income is about the same (19%), the percent of Americans with substantial licensing income (more than $50,000 in total) is somewhat higher (5% v. 1%). Thus, for formalized transfers, we see the gap between the US and Japan is much smaller, suggesting that, in both countries, there is substantial formalized transfers, but that informal transfers are greater in Japan. These results are also consistent with an interpretation that the changes in Japan may be broader but not as deep, or that the contributions of Japanese faculty, at least in biomedical research, may not be directly commercially relevant (such that they would lead to startups or licenses), but rather that faculty are playing a more consulting role, consistent with the older, gift-exchange model of university–industry linkages. These results also suggest that the claim that Japanese universities were underperforming relative to the US may have been more a policy myth than empirical fact.

Effects of the New University–Industry Environment on Open Science

While there is a strong push to make universities more entrepreneurial, there is also a growing backlash, especially in the US.[29] The concern is that the increased focus on commercial concerns comes at the cost of the university's core mission of promoting 'open science'.[30] One important issue in the debates on the proper role between university research and commercial activity is the question of if these roles are complementary or if engaging in commercial activity detracts from participation in open science.[31] There is substantial concern that emphasizing technology transfer may undermine the scientific norms of autonomy and communism.[32]

We asked our respondents if, compared to five years before, they had changed their likelihood of engaging in each of several behaviors that reflect a rejection of the 'open science' perspective.[33] Figure 11 reports the results. In Japan, we see a significant increase in the likelihood of considering the business potential when choosing a project, with 55% saying they are more likely than five years ago to include this when considering projects. We also find that 30% of respondents say they are more likely to delay publication for business reasons than they were five years ago. There is less evidence of a surge in patents impeding research, with only 3% reporting that patents are more likely to block their research than was the case five years ago.[34] Unlike in the USA,[35] there seems to be little increase in secrecy about on-going research in Japan, with only 7% reporting an increase. Similarly,

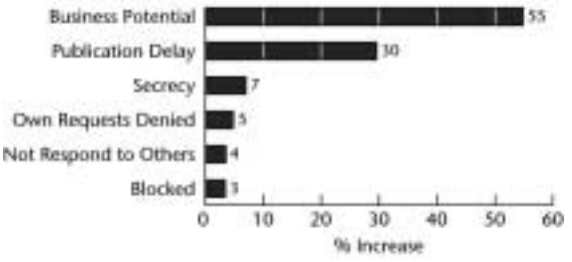

Figure 11. Changes in research environment of Japanese science.

there is little increase in the likelihood of scientists not sharing research tools, again in contrast to the US case.[36] Only 5% of respondents said they were more likely to have their requests for research materials denied, and only 4% said they were more likely to deny others' requests.

Thus, we see some evidence of adverse effects in the norms of open science during the reform era (especially redirecting research and publication delay), although hoarding data or materials or using patents to block others has not increased substantially in Japan.

Conclusions

The last 15 years or so in Japan have been characterized by a series of policy initiatives designed to promote university–industry linkages and the commercialization of academic research. Our results suggest an increase in commercial activity by Japanese engineering and biomedical faculty during this reform era. In particular, there has been an especially large increase in links to SMEs, which may have been disadvantaged in the old systems of gift-exchange between firms and professors. However, we also see that informal ties between professors and firms remain strong, suggesting these new activities are supplementing, rather than replacing the old gift-exchange system. This finding is consistent with prior work that suggests that universities play a broad and diffuse role in national innovation systems.[37] Furthermore, comparisons between public and private universities, and between Japan and the US, suggest that this increase in commercial activity is being driven by the policy changes, or perhaps by institutional isomorphism, rather than by changes in the underlying science. During this period there has been a general shift in norms toward more emphasizing university–industry linkages, in addition to teaching and publication, and universities in Japan have been responding by putting more emphasis on this 'third role'. We also find that university–industry links are at least as strong in Japan as they are in the US, suggesting that the push for reform may have been more political and rhetorical than based on an empirical performance gap. There is also some evidence of adverse affects from these reforms, especially in terms of publication delays and redirection of research toward commercial ends (although the latter is one of the goals of the reforms).

These results suggest that the reforms have had the intended effects, and also that scientific norms may be vulnerable to changes in the policy environment. We should examine more closely the potential positive and negative impacts of these new activities in the universities and see how they are complementing or undermining the traditional activities of the universities. We also still need to study the

impact on firm innovation of this new mix of activities in order to fully evaluate the impact of the policy changes. From a policy perspective, we need to be careful to balance the short term gains from commercializing university-research against the potential long term loss due to redirection of scientific effort and the decline in open-science norms. While Pasteur's quadrant has great value for both science and society, we should be careful not lose access to Bohr's quadrant of science for science's sake.[38]

Notes and References

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15. Because there are self-reported survey responses, we should be aware that there may be some response biases. In order to limit this, we will generally look for with-in respondent differences, rather than absolute values, when making inferences. The cross-national comparison may be especially sensitive to differences in understanding question wordings and so on. To limit this, we tried to be specific about the content of words such as 'research tie' by giving several examples of possible research ties (see below). However, we should be sensitive to possible response biases and socially desirable response effects when interpreting results, especially absolute averages, which are likely to be biased upwards for many items.
16. The question was: 'We would like to ask you about your research ties (including joint research, contract research, personnel exchanges, consulting, etc.) with researchers from other organizations. For each of the following, do you currently have a research tie to such organizations? Did you have a tie with someone from these organizations five years before?'
17. We were concerned about a particular form of response bias resulting from younger respondents being more likely to say 'no' to questions about any kind of tie from five years ago. To check whether our results on changes are due to cohort effects, we reran this analysis for only those respondents with 10 or more years seniority. Not surprisingly, the percent having research ties with firms were higher for more senior scientists (83% having ties to large firms and 55% having ties to SMEs in 2003). However, the change over the last five years was quite similar for the older respondents compared to the whole (see Figure 5). For the more senior scientists, who were at risk for having ties in both 1998 and 2003, we find a 12 percentage-point increase in ties to large firms (compared to an 11 point increase for the whole sample) and a 20 percentage-point increase in ties to SMEs (compared to an 18 point change for the whole sample) [results available from the contact author]. These similar findings for the senior researchers suggest that the observed change is not due simply to younger scientists reporting activity in the later period but not the earlier period due to being not at risk for ties five years ago, giving us more confidence that our findings are not due to this type of response bias.
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33. The question was: 'In your research over the last five years how have the following changed?' Specific items included: consideration of the business potential when choosing research projects; likelihood of delaying publication due to business considerations; likelihood of your requests for research materials being denied; likelihood of your responding to other's requests for research materials (reverse coded); willingness to discuss ongoing research with those outside the collaboration (reverse coded); having to stop research because of someone else's patent. The answers were on a five-point scale, from 'substantial decrease' to 'substantial increase'. We recoded the answers as 'increase' (four or five on the five point scale) or 'no increase' (one, two, or three).
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