Chapter 2
A Retrospective on the University–Industry Innovation Nexus in Japan: Empirical Assessment of Coauthorship in the Light of New Data

Kenneth Pechter

Abstract The role of public research in contributing to the innovation that drives economic development is rightfully a topic of concern for policymakers throughout the world. The huge amount of open research taking place primarily in universities and public research institutes represents a major deployment of research investment, and raises the question of whether the research goes on to support innovation and economic development for the benefit of the people who support that research, and global society as a whole. This has particularly been an issue in Japan, where large public research investments coincided with the onset of prolonged economic recession, and where there has been a dearth of the lauded signs of the university–industry innovation nexus, such as university-originated spin-off companies or lucrative university-held patents. Supported by the lack of these signs, an assumption of a *disconnect* between university research and industrial development emerged as the conventional wisdom, upon which most research policy prescriptions have been based. With this as background, the author conducted a series of research studies from the mid 1990s to the early 2000s during the first of Japan's so-called "lost decades," and demonstrated empirically that the disconnect hypothesis was incorrect. In fact, the university–industry innovation nexus was quite strong as measured via industry support of university research, university–industry coauthored research, and economic development based on university-sourced patents. This finding—particularly the strong and growing trend of university–industry coauthorship of scientific publications over the 1981–1996 time period—was so contrarian to the conventional wisdom that skeptics doubted the veracity of the finding and questioned whether the trend was real or an aberration. Those doubts were debunked at the time based on the available data, but temporal distance would be required for a verification of the robustness in the time trend. With the benefit of two decades of hindsight and a secondary source dataset for the 1981–2004 time period, this new study was finally able to verify

K. Pechter (✉)
Hosei University Business School of Innovation Management, Tokyo, Japan
e-mail: pechter@ieee.org

K. Kijima et al. (eds.), *Systems Research II*, Translational Systems Sciences 27,
https://doi.org/10.1007/978-981-16-9941-2_2

the university–industry coauthorship metrics. The findings of this new study fully reconfirm the 1981–1996 results, and demonstrate empirically that the trend of rising university–industry coauthorship continued unabated through the 2004 end point of the new dataset.

Keywords National innovation systems · Economic development · Research policy · University–Industry linkage · Japan bubble economy

2.1 Introduction

In pop culture, politics, economics, and science & engineering, there was much ado about Japan's national innovation system during the meteoric rise and resounding pop of the Japanese economy in the final decades of the twentieth century. It was this context that first brought me to Japan in 1988 as a Ministry of Education scholar in the Takahara Lab of the Tokyo Institute of Technology, kept me in Japan as a junior faculty member in the Kodama Lab of the University of Tokyo's Research Center for Science and Technology, and carried me on further as a University of Tokyo professor, until I left the academia to pursue a career in industry in the mid-2000s.

The major result of my research back then was empirical measurement of a significant innovation nexus between the university and industry sectors in Japan. This was notable because the widely held conventional wisdom was that the Japanese innovation system suffered from a *disconnect* between academic research and industrial development due to the university sector's irrelevance to industry for anything other than as a supply of new employees.

Now back in academia as professor and Director of the Global MBA Program at Hosei University's Business School of Innovation Management, I look back on the key finding of that research—the empirical measure of university–industry coauthorship in scientific publications, which indicated a strong and rising linkage between the two sectors—and assess how the finding has stood up in the intervening years. In short, with the advantage of hindsight I attempt to answer the question that our contrarian result produced at the time, and remained until now: **Was the trend we found true, and if true would it hold up in the years to follow?**

I also take this opportunity to acknowledge the invaluable support I received from key people in the early part of my research career.

2.2 Why the University–Industry Innovation Nexus?

2.2.1 Global Context

After Japan's bubble economy deflated (at the end of the 1980s or further into the 1990s depending on what indicators are used to make the call), Japan entered an

economic stagnation known as the *lost decade* that then turned into the lost decades, and continues into its third decade today according to certain measures (Morgan, 2021). Prior to the lost decades, consider how Japan's economy was both admired and feared. As a natural resource-poor nation with a small landmass, Japan rose out of its devastation in the Second World War via a non-orthodox capitalist approach—from the dominant US point-of-view—that included government intervention, industry coordination, and managed trade. Critics in the US and elsewhere leveled claims of corporate collusion, dumping of exports at below market costs, and free-riding on the basic research of other nations as reasons for Japan's success.

Against this backdrop, the university–industry nexus in innovation came into the spotlight. In the US, the 1990s saw economic output driven at least in part by investments in the university sector, including such famed cases as SUN Computers (**S**tanford **U**niversity **N**etwork), Google (founded by Stanford students Sergey Brin and Larry Page), the genetic revolution kicked off by the now COVID-famous PCR (polymerase chain reaction) at a University of California-related biotech startup, and a host of startup companies coming out of university-anchored regions like Silicon Valley, Route 128 in Boston, and the Research Triangle in North Carolina. The lack of similar university-originated economic success stories in Japan appeared to support the free-riding claim: **Japanese universities simply did not have good enough research to be of interest to industry other than as a supplier of new employees, and Japanese industry was able to make up for this deficiency due to its asymmetric access to the seeds of basic research in the US and elsewhere.**

And note, while such claims generally originated outside of Japan, observers in Japan did not raise strong disagreement with the university part of these claims, and even made innovation-related policy decisions with these claims as basis.

2.2.2 Personal Context

One effect of the Japanese economic miracle was that Japan became a subject of interest all over the globe. Popular and business press, arts including motion pictures and other mass entertainment, trade negotiations, and the attention of people in a variety of locations, vocations and avocations focused on Japan and its role in the world—this author included. As an Electrical and Computer Engineering undergrad in the mid-1980s at the University of California Irvine (at the time the American university with the second highest percentage of Asian students, following the University of Hawaii), and continuing with my advancement to UCI's Graduate School of Engineering to begin my Master's and PhD degree programs, the issue of Japanese competition in technology-based industries such as consumer electronics and autos hit close to home. But I was more bullish on American than fearful of Japan. Instead of thinking of the Japanese as the enemy and disparaging young people in America who no longer excelled in math and science (the term STEM was not yet born), it seemed to me that America's strength was not in topping international math exams but rather in adroitly finding new markets for

new technology. Perhaps the US could learn something from rather than just vilify Japan.

Through good fortune, I had two UCI engineering professors with strong Japan connections. Professor Hideya Gamo was a Todai (University of Tokyo) physicist who was invited to be a researcher at IBM in the 1960s (along with future Noble laureate Reona Esaki and future lauded University of Illinois professor of VLSI system design Saburo Muroga). Professor Roland Schinzinger was born in Japan where his father Robert was a poet, philosopher, and professor of German literature. Incidentally, Roland earned the first UCI doctorate in engineering, under his graduate advisor and founding Dean of the UCI School of Engineering Robert Saunders—who I later found out was awarded a dissertation doctorate from the Tokyo Institute of Technology (more on this later).

Via Professors Gamo and Schinzinger and initially unbeknownst to me, I was nominated then selected as the first University California student out of the nine-campus UC system (now ten with the addition of UC Merced) to participate in a new graduate research exchange program with the Tokyo Institute of Technology. This was a few months into my Master's studies, and I quickly accepted what we expected to be a 6-month stay at TIT ("Japan's MIT," I was told). Before long, however, we found out that I would be receiving a Monbusho Scholarship (Japan's Ministry of Education Scholarship at the time, now called Monbukagakusho or Ministry of Education, Culture, Sports, Science, and Technology), which would require me to stay for 18 months. Since it would not make sense to have an 18-month break in the middle of a 20-month Master's program, I rushed to finish my UCI Electrical & Computer Engineering Master's degree before leaving for Tokyo in 1988 to work under the professor who generously agreed to accept me, Professor Yasuhiko Takahara in the Systems Science Department of TIT's Graduate School of Engineering.

Upon arrival in Japan, I will never forgot being picked up at the Yokohama City Air Terminal by a young TIT professor named Junichi Iijima, who brought me to my dormitory and kicked off the most amazing experience of my life. My 18-month stay at TIT was followed by 3 years of PhD study back at UCI while deep-diving into all things Japan (including a great deal of time under the tutelage of Professors Edward Fowler, James Fujii and Akemi Morioka in UCI's highly ranked East Asian Languages and Literature Department, to whom I am eternally grateful); a 1-year Japan Foundation Scholarship to study at the Inter-University Center in Yokohama under the leadership of Director Bruce Batten (I also receive tuition support due to recommendation by Tetsuo Nishide of Japan's Ministry of Economy, Trade, and Industry, the selfless Japanese bureaucrat who incidentally also worked to personally establish the California Institute of Technology Japan Internship Program that has brought Caltech students to work in Japanese companies since the mid-1990s); and withdrawal from my UCI PhD program and my Chancellor's Fellowship to accept a very junior faculty position at the University of Tokyo (a very difficult decision, made less scary due to the guidance of UCI Computer Science professor and founding Dean of the University of Michigan's School of Information, John Leslie King). This turned into 10 years on the Todai faculty, first as a research associate

in the Kodama Lab at the Research Center for Advanced Science & Technology (while a faculty position, more like a research assistant in the US system), and then as associate professor and later professor at the Institute for Social Science and Graduate School of Interdisciplinary Information Studies. I then left academia to pursue what had brought me to Japan in the first place: To experience and learn from the practice of innovation in Japanese industry. It was during the 10 years I spent from 1995 to 2004 at the University of Tokyo that I did my work on the University–Industry Innovation Nexus in Japan.

2.3 University–Industry Coauthorship Linkage in Japan, 1981–1996

With the previous section as background, let us review my research findings up to where I left off 20 years ago at the opening of the twenty-first century.

2.3.1 Research Context

My research at that time came out of several of US–Japan related projects, in which Japan's national innovation system was central to the discussion. The first was as a research staff member of the Japanese side of a series of US–Japan Joint Task Forces, operated under the auspices of the US National Research Council (including the National Academy of Science, National Academy of Engineering, and the Institute of Medicine) and the Japan Society for the Promotion of Science's *Committee on Advanced Technology and the International Environment* (known by its chronological order among the university–industry cooperative research committees formed by the JSPS since 1933, *Committee 149).* I was given this opportunity by my direct superior on the University of Tokyo faculty (unlike the US, junior faculty in Japan do have direct superiors), Professor Fumio Kodama, who was the Principal Investigator of the Japanese team and one of the Directors of the overall project. My particular involvement focused on one of these task forces, the *Joint Task Force on Corporate Innovation.* One aspect of this experience that I still treasure was to attend meetings in Washington D.C. as a member of the Japanese side while the US side had as one of its leaders my former UCI professor F. Sherwood Rowland, a Nobel Chemistry Laureate who at the time was the foreign secretary of the US National Academy of Sciences.[1] The resulting report that summarized the findings

[1] Incidentally Professor Rowland had developed a close research relationship with Japanese researchers following his not well-known connection to the infamous Daigo Fukuryū Maru or Lucky Dragon 5 incident in which a Japanese tuna fishing boat with a crew of 23 men was contaminated by nuclear fallout from a United States nuclear weapon test at Bikini Atoll in 1954.

of the Task Force was published by the National Research Council, *New Strategies for New Challenges: Corporate Innovation in the United States and Japan* (United States-Japan Joint Task Force on Corporate Innovation, 1999).

The next project was a US–Japan research project titled *Universities and Science-Based Industrial Development* (USBID). This project was led by the overall direction of Professor Lewis Branscomb at Harvard University's Kennedy School of Government, Professor Richard Florida then of Carnegie Mellon University, and Professor Kodama, and was funded by the Japan Foundation's Center for Global Partnership. The resulting book that summarized the findings of this project was published by the MIT Press, *Industrializing Knowledge: University-Industry Linkages in Japan and the United States* (Branscomb et al., 1999).

The third project was my own research, leading up to and continuing beyond my University of Tokyo doctoral dissertation, "System Assessment for Innovation Policy Formation: Measuring the University-Industry Linkage in Japan and the United States" (Pechter, 2001c).

In the context of this essay, the key line of inquiry running through all three of these projects is the work I did on empirical measurement of university–industry research linkages with my collaborator at the time, Sumio Kakinuma of the Japan's National Center for Science Information Systems (NACSIS, now called NII, the National Institute of Informatics).

2.3.2 Conventional Wisdom of University–Industry Disconnect in Japan

The issue at stake was: In Japan's remarkable technology-fueled long-term economic growth in the postwar period, did the Japanese innovation system provide insights into an alternative approach to the US innovation system's prescriptions (which was in theory but less so in practice: competitive research and development free from industry collusion or government interference)? Or instead, did Japan's so-called economic miracle derive more from its second mover advantage, and its special Cold War relationship to the United States providing development benefits in the form of asymmetric assess to American research, transfer of US technology, and access to beneficial export markets? Honestly, the answer is some of both. But effective policy formulation demands more specificity than that.

To many key opinion leaders who held with the second half of the above question, Japan was a *free-rider* on American basic research as demonstrated by the perceived

It is also interesting to note that the career of UCI's other Nobel Laureate, my physics professor Frederick Reines—who was awarded for his co-detection of the neutrino and work on neutrino astronomy—was bookended by Japan connections: in the start through his work on the Manhattan Project developing the Hiroshima and Nagasaki bombs, and at the end by Japan's development of the Super-Kamioka Neutrino Detection Experiment for the purpose of observing supernovae.

lack of contribution to Japanese industrial development by Japan's own basic and public research. To these critics, Japan was able to accommodate its own basic research weakness by free-riding on research done in the US and elsewhere, and in the process not provide other nations similar access to its own research (the *asymmetric access* claim).

This view—widely held in the 1990s, and even taking root in popular culture though literature and film such as Michael Crichton's bestselling novel and hit film *Rising Sun*—was premised in both the linear model of innovation, and the partly apocryphal view that university research and university-originated startups drove much of the industrial development in the US innovation system. The linear model of innovation refers to a useful but not entirely sufficient view of the innovation process, in which the results of basic scientific research feed into technological development that in turn leads directly to new products and therefore economic returns.

There are many aspects of this model that match the empirical record. For instance, much was made at the time out of the revenue received by the University of California for its portfolio of university-derived patents. But the lion's share of this revenue came from a small number of hugely successful patents (for instance, polymerase chain reaction or PCR), with the rest of the portfolio arguably draining resources away from the performance of public science. (Is the time a professor spends dealing with the patent process worth the lost research time? Although the US sees huge innovation benefits from university-originated success cases, the answer is **No** more often than **Yes.**)

At the time, US industries from steel to consumer electronics to autos to computer chips were dominated by Japanese companies. This led to a renewed focus on regaining American competitiveness, in which the university–industry nexus was put forth as a key source of innovations via university-based patenting, university spin-off companies, and startup activity leveraging university research results.

The lack of similar signs of a vibrant university–industry nexus in Japan supported the view of Japan as a free-rider benefiting from asymmetric access to US basic research. There is no question that there has indeed been less university-derived startup activity in Japan as compared to the US. But addressing the reasons for this requires going beyond simplistic assumptions. The assumptions were simplistic in that critics did not account for the different status of university faculty in the US and Japan in regard to matters such as consulting, startups and patenting (keeping in mind that at the time, the strongest university research in Japan was done at national universities where at that time faculty were still part of the civil service and governed by civil servant regulations); simplistic data analysis that did not sufficiently account for measurement differences between the US and Japan in the collection and deployment of data such metrics as R&D expenditure; and insufficient treatment of the legal differences in the extent that academic involvement is disclosed on patents in the US and Japan.

One example of how frenzied the issue became is illustrated in reference to the aforementioned Crichton novel, *Rising Sun.* Crichton included UC Irvine in the novel as the setting where Hitachi had a corporate research lab into which only

Japanese passport holders were admitted entry—the point being that Hitachi was on campus to access university research, but the university community itself was not welcome into the Hitachi lab. The Hitachi Chemical Research Center was real. The Hitachi people explained to me that the Japanese passport thing was not true. It was just that as a corporation, like any corporation, you had to have business to be there. I had been invited in and do not have a Japanese passport. As I had the benefit of access to Mr. Crichton through my involvement in the Japan America Society of Southern California, I explained this to him when we met, and he told me that he would fix the misrepresentation in later editions. I never checked if he did.

The product of such a contentious environment was the widely held conventional wisdom of a disconnect between university research and industrial development in Japan. And perhaps the most surprising part of this story is that this even became the common view in Japan.

As a simple example, much Japanese innovation policy formulation in the 1990s was premised on the weak research links between Japanese universities and Japanese industry as demonstrated by the declining share of Japanese university R&D expenditure that was funded by Japanese industry (for example, Sakakibara & Ijichi, 2001). As good as the researchers doing the analyses were however—and they were indeed very good in general—they completely failed to consider that the decline was a result of the decline in total industry R&D spending following the collapse of the bubble economy, rather than a decline in interest in the university sector. We see this by looking from the perspective of industry at the share of total industry R&D spending going to the Japanese university sector, and observing quite easily that this percentage continued an upward trajectory signaling a rising not falling interest in the university sector (Pechter, 2001c).

In short, both inside and outside of Japan, the conventional wisdom was that Japanese university research was weak, and Japanese industry not interested in it.

2.3.3 Questioning the Conventional Wisdom of Disconnect

As mentioned earlier, my own experience in Japan started in 1988 in the laboratory of Professor Yasuhiko Takahara in the Systems Science Department of the Graduate School of Engineering at the Tokyo Institute of Technology. I was only there for about 18 months, but in that time I saw clearly that academic researchers were no strangers to industry. The Takahara Lab conducted sponsored research supported by industry funding; industry partners participated in research meetings; and the practice of long-term employment (known as *life-time employment,* in which a university graduate tends to retire from the company they entered when they graduated) meant industry researchers had a career-long span in which to nurture the relationship between their place of employment and their place of graduation. (I have not done the actual analysis, but my sense is that the majority of my TIT classmates back then still work in the company they joined when they graduated 30 years or so ago.)

Furthermore, as a student of Japanese language and culture starting in 1988, it did not take long for me to learn perhaps the first and most important rule for navigating Japanese society: human relationships are at the center of everything. For instance, even the simple act of presenting your business card involves an understanding of your company's level of prestige relative to the company of the person you are greeting, the relative hierarchical status of each of you in your respective companies, how much your own company has benefited or benefited from the other company, and an awareness of any other social connections that might exist between you and the other person. It did not seem to me that "disconnect" would be a likely state of the Japanese university–industry nexus.

Through another series of fortunate events involving the Takahara Lab—particularly the advice to seek out Professor Kodama that I received from Takahara-sensei's own sensei, Professor Takehiko Matsuda[2] —I ended up leaving my University of California Chancellor's Fellowship at the UCI, and becoming a faculty research associate at the Research Center for Advanced Science and Technology at the University of Tokyo, in the laboratory of Professor Kodama. Kodama, best known outside of Japan for his Harvard Business Review book *Emerging Patterns of Innovation: Sources of Japan's Technological Edge* (Kodama, 1995), studied innovation throughout his career from a particular perspective: empirical research. Kodama-sensei believed that no amount of talking about innovation could substitute for hard data on the subject. Under his guidance and throughout the three US–Japan innovation projects mentioned earlier, I was focused on finding ways to shed empirical light on the university–industry disconnect hypothesis in Japan. I eventually landed on three metrics of interest.

2.3.4 Measuring the University–Industry Linkage

For my dissertation research at the University of Tokyo—which I did while I was on the faculty—I focused on the three empirical metrics of R&D expenditure, patents, and scientific publication. All these metrics point to critical aspects of the innovation process. For each of these, it is possible to look from the perspective of the University–Industry Linkage (for instance, industry contribution to university R&D funding; university researcher contributions to patenting by industry; and university–industry coauthorship). And for each of these, given the conventional wisdom of a dysfunctional University–Industry Linkage in Japan, they had been insufficiently investigated (overly simplistic analyses of industry support of academic research and university involvement in industry patenting had already

[2] A student of Herbert Simon's at Carnegie Mellon University, a former president of TIT, a founder of the Operations Research Society of Japan, and, he later told me, that by coincidence he was closely involved in the awarding of the dissertation doctorate to UCI's founding Dean of Engineering, Professor Saunders, who I mentioned earlier.

concluded the linkage was broken, and insufficient attention had been paid to university–industry coauthorship).

Details on the results can be found in Pechter and Kakinuma (1999 MIT), Pechter and Kakinuma (1999), Kakinuma and Pechter (1999), Pechter (2000a, b, 2001a, b, c, 2002a, b, c). In short, however, for R&D expenditure and patents, our analyses indicated much stronger industry contribution to academic funding and more academic involvement in industry patenting than had been appreciated.

This essay specifically focuses on the third metric, coauthorship, since it was the finding of my earlier research that most challenged the conventional wisdom—and the one I have been wondering about for two decades since I left academic to pursue an industry career.

2.3.5 Main Findings of the 1981–1996 Dataset

The key finding of the earlier research with my collaborator Sumio Kakinuma was the substantial and increasing university–industry coauthorship ratio as seen from the industry perspective. We defined this ratio is the percentage of all research papers authored by someone in Japanese industry that also had coauthors from universities, whether the universities were in Japan or outside of Japan. In other words:

$$\begin{aligned}&\text{Japanese University-Industry Coauthorship Ratio}\\&\text{as seen from the Industry Perspective}\\&\quad=\frac{\text{Number of papers with a Japanese industry author coauthored with authors in universities of any country}}{\text{Number of papers with a Japanese industry author}}\end{aligned}$$

The particular need for empirical analysis to inform the significant national innovation system-directed policy decisions being made at the time explains our focus on the *industry perspective.* Due to the conventional wisdom that Japanese university research was of minimal interest to Japanese industry, even those in Japan took this view as given with or without factual substantiation—and were introducing policy solutions to a possibly misdiagnosed problem. It was therefore imperative to generate empirical assessment of just how much university researchers were connected to the research and development activities of Japanese industry. **For this reason, in this essay, whenever the term university–industry coauthorship ratio is used, it should be understood that this refers to this *industry perspective*.** Our key finding of the university–industry coauthorship ratio is shown in Fig. 2.1.

For the reasons described above, this was a remarkable finding. Dr. Lewis Branscomb (former Director of the US National Institute of Standards and Technology, former Chief Scientist of IBM, former Chair of the Program on Science, Technology and Public Policy at the Belfer Center for Science and International Affairs in Harvard University's Kennedy School of Government), who was Co-

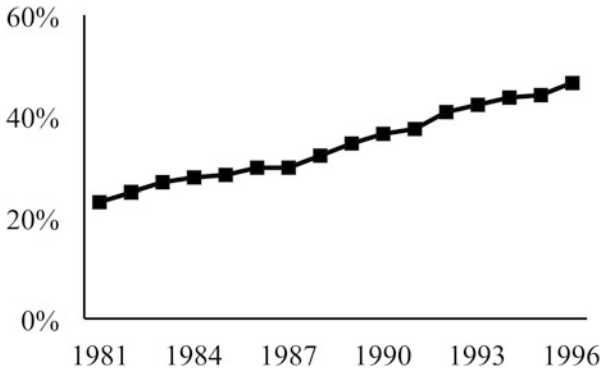

Fig. 2.1 University–industry coauthorship ratio in Japan, 1981–1996. (Source: original data, also in Pechter and Kakinuma (1999 MIT), Pechter and Kakinuma (1999), Pechter (2001c))

Principle Investigator on the Universities and Science-Based Industrial Development (USBID) Project that I co-directed, described the chapter written by my collaborator Sumio Kakinuma and me in our MIT Press book this way (Branscomb, 1999):

> This paper, entitled "Coauthorship Linkages between University Research and Japanese Industry," will have great impact on American thinking about Japanese innovation and the relationship of university research to industrial innovation in Japan. While American scholars point to the relatively low number of university patents licensed to industry and note that relatively little academic research in the national universities receives support from industry, they have missed the crucial evidence that Pechter and Kakinuma have uncovered. Their analysis of multi-authored Japanese technical literature finds that in papers with the first author from industry, the probability that one of the other authors is from a university is actually higher than in the United States. This observation and other data developed for this book will cause American politicians to rethink their position on the need for "symmetrical access" in US-Japanese technology relations.

For the reasons spelled out in our research papers, we chose *bibliometrics* (the application of statistical methods to the study of bibliographic data) as a prime empirical tool for illuminating the issue. Specifically, we analyzed the institutional affiliation at the level of university, industry, or other sector (primarily government research institutions) of the authors of scientific publications. We did this to characterize the university–industry linkage by analyzing events in which a paper published in the peer-reviewed science and engineering literature was submitted by at least one author affiliated to a Japanese industrial enterprise jointly with at least one author affiliated to a university (the university either inside or outside of Japan).

In order to assess the level of university–industry research interaction through bibliometric data, the analysis utilized the Science Citation Index database acquired from the Institute of Scientific Information (ISI) in the United States and maintained by the National Center for Science Information Systems (formerly NACSIS, now NII or National Institute of Informatics) in Japan. The database contained the set of Science Citation Index data for the years 1981–1996 in which at least one affiliation of a paper's authors is to an organization located in Japan. This set contained data

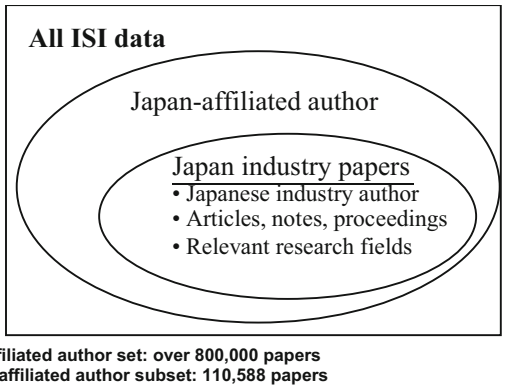

Fig. 2.2 Schematic of the bibliometric dataset in our earlier research. Japan-affiliated author set: over 800,000 papers. Industry-affiliated author subset: 110,588 papers

on approximately 800,000 papers. Note that this dataset came from the databases acquired and maintained by NII (NACSIS), and not from the web version.

Our analysis identified the industry subset out of these 800,000 papers according to three criteria:

1. Papers with at least one Japanese industry affiliation.
2. Papers categorized as *articles*, *notes*, or *proceedings papers* (the Science Citation Index also includes publications classified as *reviews*, *letters*, etc., but much of these are not the presentation of research).
3. Papers from the journals of all fields other than economics and business, education, law, psychology/psychiatry, and social sciences-general (the Science Citation Index classifies publications into fields of study on the basis of the specific journal in which each publication appeared).

This means that all papers without at least one Japanese industry author are immediately removed from the scope of analysis. The resulting study subset obtained based on these criteria contains 110,588 papers (Fig. 2.2).

With this data in hand, we were able to analyze key patterns in Japan's university–industry innovation nexus, revealed in the following figures.

The first figure shows the trend in number of papers. Note that based on the dataset, all of these papers have at least one author affiliated to an industry organization located in Japan, but the coauthoring organizations may be both domestic and international collaborators of the Japan-based firms (Fig. 2.3).

It is readily apparent from the figure the hat university–industry coauthorship mode of publication shows the strongest growth.

It is also useful to combine the inter-firm and intra-firm papers in order to make the data comparable to similarly disaggregated data on the US over the same time period, as shown in Figs. 2.4 and 2.5.

It is notable how similar the Japan and US data are, with the major difference being a slightly declining industry component in the US compared to a growing and then declining industry component in Japan (thought to be a result of the growth and then deflation of Japan's bubble economy).

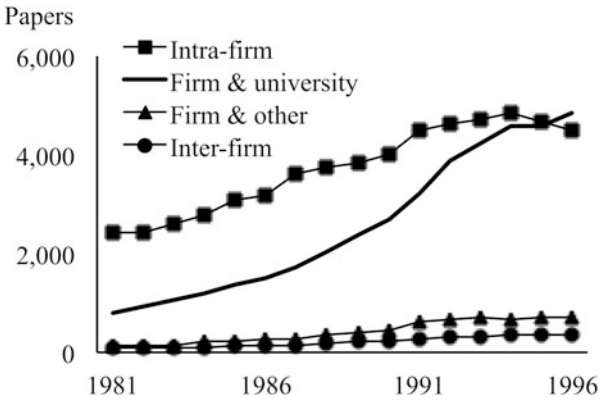

Fig. 2.3 Japan industry-authored papers, by mode of linkage. Intra-firm papers: by author(s) within a single firm. Inter-firm papers: by authors in different firms. Firm and university papers: by authors from both industry and university sectors. Firm and other: by authors in the industry sector and organizations in the "other" category (primarily national laboratories, public corporations and non-university hospitals). (Source: original data, also in Pechter and Kakinuma (1999 MIT), Pechter and Kakinuma (1999), Pechter (2001c))

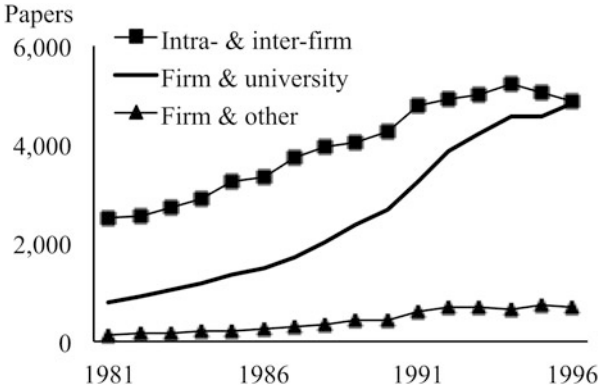

Fig. 2.4 Japan industry-authored papers, by mode of linkage (intra-firm and inter-firm combined). (Source: original data, also in Pechter and Kakinuma (1999 MIT), Pechter and Kakinuma (1999), Pechter (2001c))

Most surprising of all, however, was how closely our findings for the key university–industry coauthorship ratio for Japan matched other studies finding for the US (and also the UK for which we located comparable data). We see this in Fig. 2.6.

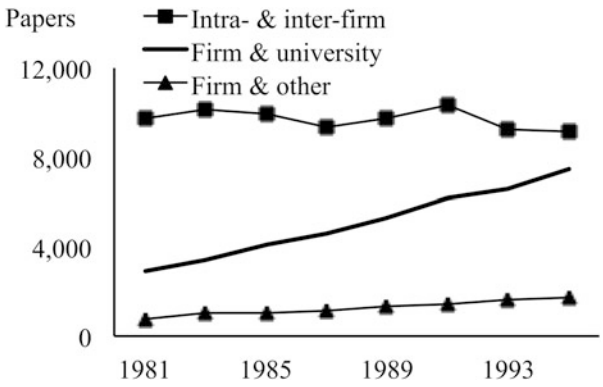

Fig. 2.5 US industry-authored papers, by mode of linkage (intra-firm and inter-firm combined). (Source: National Science Board (1998))

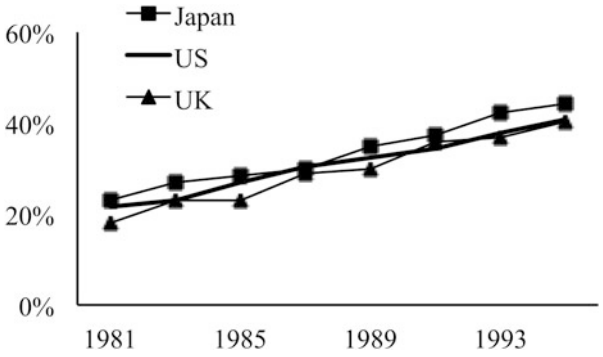

Fig. 2.6 University–industry coauthorship ratios in Japan, the US, and the UK. (Source: original data, also in Pechter (2002c), National Science Board (1998), Hicks and Katz (1997, p. 136))

2.3.6 Skeptical Reaction

Our finding went so much against the conventional wisdom at the time that it generated tremendous skepticism toward our conclusions. For instance, given the widespread acceptance of the prominent role of university research in the US innovation system, there was doubt that other countries—let alone Japan—would have similar coauthorship ratios. So, we found similar studies for the UK, and included that in our findings shown in Fig. 2.6.

We agreed that certain differences between the three studies of Japan, the US and the UK meant that the figures were not exactly comparable (the methodologies were very similar, but these were distinct and separate studies after all). In spite of that, the fact that all three started at comparable levels and grew dramatically over nearly two decades at essentially the same rate indicate that perhaps something more universal than the institutions of national innovation systems might be driving

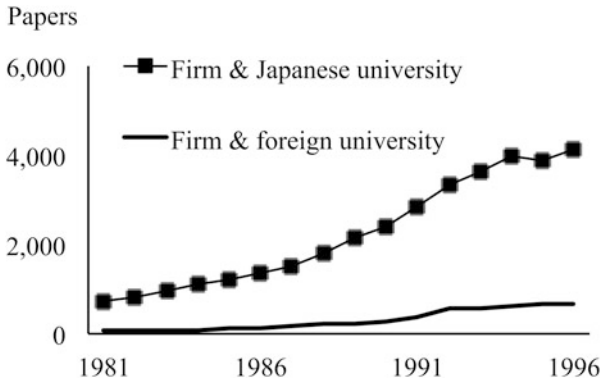

Fig. 2.7 University–industry coauthored papers in Japan shown, for Japan university coauthors only and foreign university coauthors only. (Source: original data, also in Pechter and Kakinuma (1999 MIT), Pechter and Kakinuma (1999), Pechter (2001c))

the change: namely, the patterns of innovation itself in the emerging paradigm of mega-competition and global business.

Another criticism was that the process of innovation may indeed be increasing the connection of industry to universities, but to American not Japanese university research (recall that while our dataset was limited to industry authors located in Japan, it included university authors located anywhere). So we performed the analysis shown in Fig. 2.7 as a rebuttal.

It is clear from the figure that university–industry coauthorship was not a result dominated by coauthorship with foreign universities. Consequently, even with the foreign component of Japanese university–industry coauthorship removed, the Japanese coauthorship ratio trend still closely matches that of the US (Pechter, 2000a).

The foreign university component was indeed growing, however. Understanding that this could be a very important trend in the changing nature of global innovation, we also looked at the foreign university component broken down by the G7 regions current at the time. The result is shown in Fig. 2.8.

As clearly seen in the figure, growth in coauthorship with foreign universities is not a story of growing dependence on American university research, which declined relative to other regions (and remained flat in terms of absolute number of coauthored papers in the 1990s).

Another claim leveled at the finding had to do with Japan's bubble economy. This claim said that the rise in university–industry coauthorship in Japan was a fleeting or even cosmetic affect of the bubble economy. It is important to understand that this explanation did not posit a change in the Japanese national innovation system in response to Japan's post-bubble economic transition as the driver of the change in coauthorship. Rather, the explanation posits that rising coauthorship was an unintended result of Japanese business practice under the influence of the

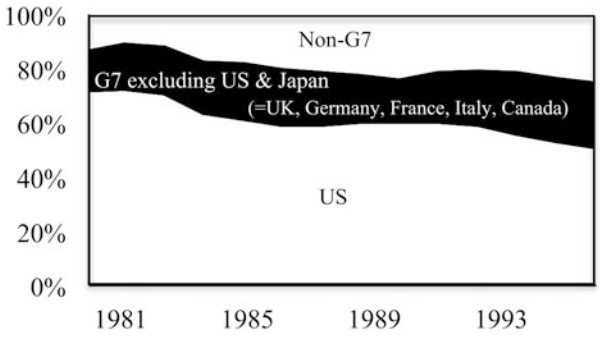

Fig. 2.8 Share of papers with an author in Japanese industry and a university coauthor located outside of Japan, by G7 country. (Source: original data, also in Pechter and Kakinuma (1999 MIT), Pechter and Kakinuma (1999), Pechter (2000a, 2001c))

superfluous economic environment during the bubble, much like the patterns seen in golf course membership turnovers and Japanese outbound tourism over the period.

This is a reasonable doubt to raise, but not a difficult one to answer. Earlier in this essay we discussed that the declining share of the Japanese industry-funded portion in total Japanese university R&D expenditure was erroneously taken as proof of a declining industry interest in university research in Japan, when this could be disproved simply by looking instead from the industry perspective (the increasing share of Japanese industry supported R&D expenditure that was transferred to Japanese university researchers out of total Japanese industry R&D expenditure). In the same spirit we applied a similar lens here and did not find any relationship between the growth of university–industry coauthorship in Japan and the bubble economy phenomenon. Details of this analysis can be found in Pechter (2000a).

The one caveat we made, however, was that at the time of the earlier research, we did not have enough temporal distance from the bubble economy to fully assess its effects. Time was required to gain the perspective to consider this possibility more fully.

The final claim made by critics as the "real" explanation for the rising university–industry coauthorship ratio found by our research was Japan's dissertation doctorate system. In Japan there are two procedures that may be used to obtain a doctorate. One is to enroll in and complete a PhD program in the graduate school of a university, which is generally speaking the same procedure commonly used in the United States. This procedure is known as the course doctorate, which refers to the fact that it is based on course instruction in a graduate program (and like the United States includes the writing of a dissertation). The second procedure is called the dissertation doctorate. Rather than enrolling in a graduate program, the candidate submits to a graduate school a dissertation based on research from their professional career for consideration as worthy of a doctorate. This latter procedure can be traced to the European education models Japan adopted in the late nineteenth century in which doctorates were awarded not for completion of a program but for professional

research contributions to scholarly fields of study. This tradition can still be seen even in the United States in certain fields (e.g., some in the humanities) in which doctorates are awarded far into one's professional career. As such, the dissertation doctorate is not a shortcut to a PhD and has even been shown to be a higher standard than the course doctorate (Kodama & Nishigata, 1991).

Industry researchers, for whom world-class research facilities in the workplace and inflexible employment practices make the option of moving from firm to university less desirable, often use this procedure. While less so now in the twenty-first century, in the past many faculty in certain fields with a strong practical bent such as engineering never pursued doctorates before coming to academia, and these faculty often benefited from the dissertation doctorate system (such as UCI founding Dean of Engineering Saunders, mentioned earlier). The dissertation doctorate was also used more often in the past by faculty members of national universities, for whom civil service status prevents them from enrolling in course doctorate programs concurrently with being employed by their universities, which is why my University of Tokyo PhD was a dissertation doctorate (various changes in the legal status of both national universities and faculty have now reduced these restrictions).

Being unfamiliar, the dissertation doctorate system is seen as problematic and posited as the force behind the high and rising coauthorship ratio in Japan. Of course, compared to the high standards of doctorate systems in the US, Japanese doctorate systems may need to improve their quality control; but this is so for all doctorates, not just dissertation doctorates. If the claim were true, however, it could add a bias to the Japanese coauthorship ratio that would reduce the comparability between the coauthorship measures in Japan and the United States. Suffice it to say that our analysis did not support the dissertation doctorate system as an explanation for the rise in coauthorship ratio, as the number and trend of dissertation doctorates turned out to be uncorrelated with the rise in coauthorship (for details, see Pechter, 2000a).

In summary, the key finding of a large and rising university–industry coauthorship ratio in Japan, and the various additional empirical support for these findings, demonstrated clearly the falsity of the notion that Japanese industry has little interest in the research activities taking place in the Japanese university sector.

2.3.7 Unpursued Implications of Earlier Research

Our interpretation of these research findings at the time was that the widely held assumption of a disconnect in the innovation nexus between the university and industry sectors was incorrect. However, we did not conclude that this meant there was no problem with the Japanese university–industry nexus. At that time, Japan was well into its first *lost decade* of economic stagnation following the collapse of the economic bubble, and policy adjustments in the institutional relationships governing the nexus were needed. Any such adjustments, we argued, should be based on the empirical evidence, and not on assumptions.

In one of the studies that came out of this research (Pechter, 2002a), we posited that the problem in need of improvement was not the lack of university–industry linkages, but the lack of flexibility in these linkages. We cited the importance not only of efficient link formation, but also of the efficient severing of links as an imperative in the resource reallocation needed in support of innovation. In today's common parlance, we would refer to this as a need for disruption of the status quo as a prerequisite for innovation. At the time, however, the term "disruption" was not widely used (Clayton Christensen had just popularized it as an innovation term in his 1997 book *The Innovator's Dilemma* Christensen (1997)), and we ventured to use the unorthodox term "dis-organization" as a direct reference to the need to disrupt (to change the organizing forces in) the existing organizational structure. This key issue required further study.

We also noted that although the university–industry coauthorship ratio started out strong, grew strongly over the period of study, and was comparable to that in the US and UK—and was a robust finding in the face of all empirical scrutiny leveled against the finding—the data did indicate the possibility of a leveling off. If so, the leveling could herald of a coming decline in the coauthorship trend. This concern is seen most clearly in the last years of the time trend in the figure University–Industry Coauthorship Ratio in Japan, 1981–1996 (Fig. 2.1). Only time would tell, as additional years data became available.

This concern pointed to the future agenda for this research: **To study the trajectory of the university–industry nexus displayed in the university–industry coauthorship ratio in Japan, as it evolved in the latter half of the 1990s and moved into the twenty-first century.**

However, by that time I had been on the faculty of the University of Tokyo for about a decade, and I was driven by a desire to get back to the impetus for coming to Japan in the first place: To experience the practice of innovation in Japanese industry. By the early 2000s, the impact of Japan's burgeoning soft power was starting to emerge, a trend that would be dubbed "Japan's Gross National Cool" by Douglas McGray in 2002 (McGray, 2002), and later be adopted under the moniker "Cool Japan" by the Government of Japan. The global influence of Japan-originated media content including anime and video games, and the Japan-related content emanating from Hollywood and elsewhere in the form of titles such as *The Last Samurai, Memoirs of a Geisha, Kill Bill,* and *Lost in Translation* presaged what would gain traction as the Japan and Japan-relevant *content industries*. While these were fundamentally different from the science-based innovation of concern in my university–industry nexus research, I saw these emerging areas of economic activity as very much central to innovation. In fact, as the pursuit of profits based on the fruits of creative output—and using no small amount of technology in doing so—I saw these *creative* (or *cultural* or *Cool Japan*) industries at the time as very much innovation-based, and was drawn to the business sector to engage with them. So I left academia by the mid-2000s, and spent the next decade or so working with Japanese animation, film, television, entertainment, mobile, and internet media content, as well as fashion and advertising. For this reason, I never did follow up on the research agenda identified by my university–industry innovation nexus research:

specifically, the question of how the university–industry coauthorship ratio would evolve from there. **Would it continue to grow, or had we been witnessing the beginning of a decline in the linkage? Or were we simply incorrect to begin with, as many claimed?**

With this current essay, I am now able to consider this question, and provide an answer.

2.4 Post-1996 University–Industry Coauthorship Linkage in Japan

With the passage of time, I am now able to pick up where I left off two decades ago, and finally answer the question posed in the previous section: **Was our key finding of a strong and increasing university–industry coauthorship trend real—and did it persevere?**

A fuller account of the unfolding university–industry coauthorship linkage will require more in-depth primary source analysis, which means acquiring and processing a new dataset for the years since 1996. This is a huge and expensive undertaking. So for this initial survey, I will rely on some valuable key secondary source data, which we are fortunate to have thanks to the open model of scientific research publication.

2.4.1 Research Study of Interest, 1981–2004

The discussion of the university–industry innovation nexus within the functioning of national innovation systems has continued to be a subject of interest to researchers and policymakers in the two decades since I left off my own research, with three additional developments.

First, although the role of government (specifically, government-run research centers) has often been included in the analysis as it should be given its influence on innovation, the tools for managing such complex systems has advanced, making this much more effective. This was already happening in the 1990s when the Triple Helix Model of the knowledge-based economy (universities, industry, and government) was being developed by researchers such as Henry Etzkowitz and Loet Leydesdorff (for example, Etzkowitz & Leydesdorff, 1995, 2000). Since then, the approach has been broadened to utilize ideas from information theory to analyze mutual information in three dimensions as an indicator of Triple Helix relations at the systems level (Leydesdorff, 2003, 2006; Leydesdorff & Fritsch, 2006; Leydesdorff et al., 2006); and to consider more complex systems including additional sectors such as civil society institutions (Quadruple Helix), and the natural environment (Quintuple Helix) (Carayannis & Campbell, 2009, 2010; Leydesdorff, 2012).

Second, the globalization of innovation systems has taken a more central position in various studies, and the internationalization of both research and development has meant that more trans-national linkages have emerged, and in particular increased international collaboration via university–industry coauthored publications (for example, Igami et al., 2016).

Third, the relative position of nations has evolved. Japan's prolonged economic stagnation has reduced its position as China's tremendous economic growth has spurred on an active research portfolio. Such changes have been accompanied by variations in the position of nations, as major key research areas including AI and bio-medical technology have started producing results.

For the narrow purposes of this essay, however, we are interested in studies that have used comparable methodology to our original study, but extend beyond our earlier dataset's end date. **Namely, analysis of coauthorship data drawn from the bibliometric database of scientific publication going beyond the 1996 end date of our own study.**

Being that we are now in the decade of the 2020s, ideally we would like to find data sets that extend to the mid or even late 2010s if we were lucky enough to find such published data (keeping in mind that in the early 2000s the most recent accessible dataset went up to 1996). Currently, however, the best candidate dataset is from the Triple Helix work done by Leydesdorff and various colleagues, extending the coverage of the dataset up to 2004 (Leydesdorff & Sun, 2009). While this is short of our hoped-for ideal of extending through the mid-2010s, it does extend the window by 8 years. This is enough to see whether, as the tail end of our own research suggested, the trend of strong and growing connection of industry to Japanese academic research might be leveling off and perhaps even starting to decline. As this new dataset also starts in 1981, it provides a double-check of our own findings.

The research methodology of Leydesdorff and Sun is similar to that used in our earlier research. This is perhaps not so surprising, since there is widespread acceptance now of bibliometric analysis techniques based on citation index databases such as the former Institute of Scientific Information's (ISI) Science Citation Index and related databases for social sciences and arts & humanities etc.—now all under the umbrella of the Web of Science Core Collection maintained by Clarivate Analytics (former Intellectual Property and Science business of Thomson Reuters).

Moreover, Leydesdorff based much of his work on a Japanese dataset developed by a group of his collaborators in Japan, among them Negishi, Nishizawa, Watanabe and Sun (Sun et al. 2006, 2007). The Japanese research group worked to categorize all publications with at least one author address in Japan during the 1981–2004 period in the Science Citation Index, the Social Science Index, and the Arts & Humanities Index.[3]

[3] The methodological similarity to my own earlier research is not entirely coincidental, as my earlier work on coauthorship data would not have been possible with my close collaborator at the time, Sumio Kakinuma, who worked at National Center for Science Information Systems (NACSIS), the progenitor of National Institute of Informatics (NII). Professor Masamitsu Negishi

Table 2.1 Papers in Pechter & Kakinuma and Leydesdorff & Sun Datasets

Study	Pechter & Kakinuma (1981–1996)	Leydesdorff & Sun (1981–2004)
Number of papers—All Japan authors		
1981–1996 total	About 800,000	703,720
1981–2004 total	NA	1,277,030
Number of papers—Japan industry authors		
1981–1996 total	110,588	120,410
1981–2004 total	NA	205,634

Source: Pechter and Kakinuma (1999 MIT), Leydesdorff and Sun (2009)

The Japanese research group of Leydesdorff's dataset identified all publications in the three ISI databases that had at least one author address in Japan during the 1981–2004 period, and categorized authors into university, industry, government, or combinations of these three sectors, and also categorized the non-Japan authors addresses as foreign (but did not distinguish between types of foreign addresses, such as foreign university or foreign company, etc.). Note that by design of the dataset, foreign authors only were included in the dataset if they coauthored with an author in Japan.

This dataset consisted of 1,453,888 papers with at least one author address in Japan in the three ISI databases during 1981–2004. After performing standardization work to unify organizational name variations, and translation inconsistencies, organizational name changes and mergers and acquisitions etc. (Sun et al., 2007), the resulting final subset for the study contained 1,277,030 papers (87.8% of the original subset before standardization).

While this 1981–2004 dataset is quite similar in methodology to our earlier 1981–1996 dataset, there are differences of note:

- The two studies used different standardization processes to classify papers into university, industry, and other sectors.
- The 1981–2004 data contains only articles but uses all three ISI citation databases combined (the Science Citation Index, the Social Science Citation Index, and the Arts & Humanities Index), while the 1981–1996 used articles, notes, or proceedings papers, but excludes papers in journals classified as economics and business, education, law, psychology/psychiatry, and social sciences-general .

The resulting total number of papers in the two datasets is shown Table 2.1.

Because of the differences in the datasets, direct number-to-number comparisons must be made with these differences in mind. However, for such broad datasets occurring over a many years, component ratios (such as university–industry coauthorship ratio) and time trends do carry meaning.

also had some indirect involvement via his connection to Professor Kodama, to whose University of Tokyo laboratory I belonged.

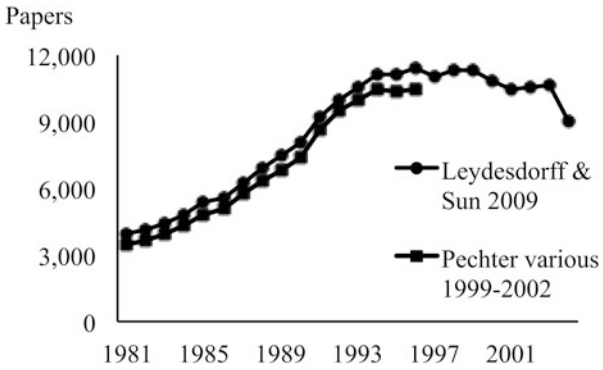

Fig. 2.9 Papers with an author from industry in Japan. (Source: original data, also in Pechter and Kakinuma (1999 MIT) and Pechter (2001c), reworking of data in Leydesdorff and Sun (2009))

2.4.2 Main Findings of the 1981–2004 Dataset

With the similarity and differences between the Leydesdorff dataset and our earlier dataset elucidated in the previous section, the first matter of interest is to compare the time series data for size (number of papers) of the industry papers between the two sets. We see that in Fig. 2.9.

As is clearly visible in the figure, the two datasets track each other quite closely. This is perhaps not surprising for the reasons of similarity explained in the previous section, but it is welcome confirmation of the earlier results. Our earlier dataset appears to undercount the industry papers relative to the newer dataset. Possible reasons for this include:

- The exclusion in the 1981–1996 dataset of non-science fields while the 1981–2004 dataset includes research from all fields.
- Techniques used to standardize records in terms of precise addresses for university and industry evolved (the latter study made further efforts to refine the process of accounting for institutional name variations and translation discrepancies when determining affiliations of authors) (Sun et al., 2007).

It is worth noting, however, that for the common years of 1981–1996, the industry paper count of our research was 110,588 and for the later research was 120,410, for a total coverage of 92% that improved over time.

For the university–industry coauthored papers we see an even closer result, as shown in Fig. 2.10.

For the common years of 1981–1996, the university–industry coauthored paper count (which includes papers that must have at least one Japan industry author, at least one university author either inside or outside of Japan, and could also have additional authors from non-industry and non-university sectors, primarily

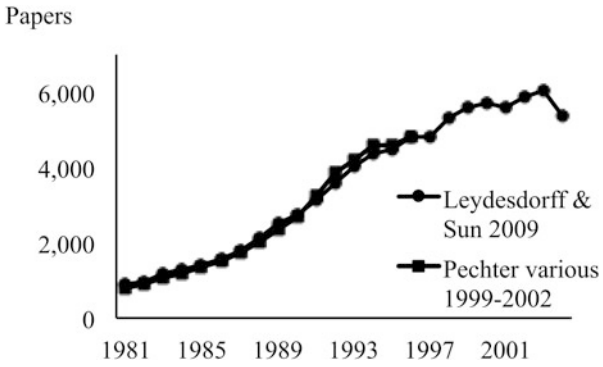

Fig. 2.10 Coauthored papers with an author from industry in Japan and a university author located anywhere. (Source: original data, also in Pechter and Kakinuma (1999 MIT) and Pechter (2001c), reworking of data in Leydesdorff and Sun (2009))

government research institutes) of our research was 40,903 and for the later research was 40,856, for a total coverage of virtually 100%.

With these welcome confirmations of our earlier research via the closeness of datasets, we are finally able to see how close our earlier results correspond to the latter results in terms of coauthorship ratio from the industry perspective.

It is important to note that looking from the perspective of industry was the intentional starting point of our earlier research. The reason is:

1. Given the conventional wisdom that Japanese university research of little interest to Japanese industry (widely accepted in Japan as well as overseas), it was first priority to examine the university–industry nexus from the point of view of industry.
2. The narrowing down of the required dataset and subsequent database management resources required were much more manageable for a small research project like ours if we started with the dataset of all Japanese industry-authored papers rather than all Japan-authored papers.
3. Given the nature of the science-oriented and/or public nature of university research, we do not expect industry support of research to be the major driving mode of research in the university sector. This supposition is borne out by the 1981–2004 dataset, for which the university–industry coauthorship ratio from the university perspective is calculable (in other words, the ratio of university–industry coauthored papers to all university papers in Japan), and indeed this ratio is generally less than 20% of the ratio from the industry perspective.

With this as preamble, comparison of the two datasets' industry perspectives on university–industry coauthorship (in other words, the ratio of university–industry coauthored papers to all industry papers in Japan) is shown in Fig. 2.11.

Inspecting first the 1981–1996 period common to both studies, the data agree well. While there is some slight divergence between our old data and the new data

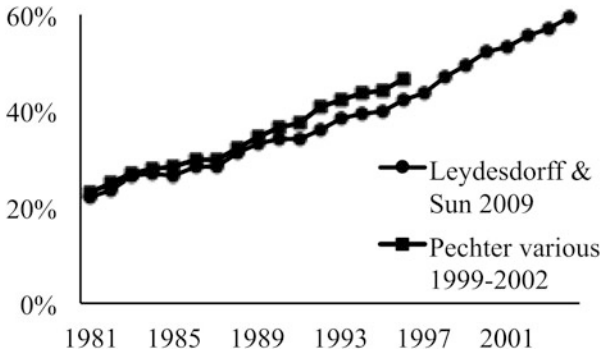

Fig. 2.11 University–industry coauthorship ratio for industry authors in Japan and university authors anywhere. (Source: original data, also in Pechter and Kakinuma (1999 MIT) and Pechter (2001c), reworking of data in Leydesdorff and Sun (2009))

(due to slight over counting of the old university–industry coauthorship data relative to the new data toward the end of the earlier study, as well as the under counting of the industry data relative to the new data toward the end of the earlier study as well), the time trends are remarkably similar.

This agreement is not surprising, as we already knew the both the ratio's numerator and denominator were similar between the two studies. The key point of interest is what happened next, in the period after the end of the 1981–1996 dataset study: **The university–industry coauthorship ratio continued to grow throughout the rest of the latter study period.**

In fact, the new trendline of the rise in the coauthorship ratio matches the earlier trendline, with both having a correlation of 99% to time (in other words, linear growth with time explains 98% of the change due to the *R*-squared, linear regression's coefficient of determination, equaling the square of the correlation in the case of two variables), and both the former trendline and the latter trendline has the same slope (increase rate of coauthorship ratio over time).

In the next two figures, we also see close agreement between the 1981–1996 dataset and the 1981–2004 dataset on the university–industry coauthorship ratio disaggregated into Japanese industry coauthorship with domestic Japanese universities and with foreign universities (Figs. 2.12 and 2.13).

Although we will discuss below that the increasing globalization in innovation systems may be leading to substantive changes in the patterns of domestic research interaction across the world, it is clear from the above two figures that trends of our earlier study have held steady beyond the 1996.

The sentence in the boldface type above is the number one result we have been wondering about for the past 20 years in response to our concern: **Did our finding of a significant and steadily increasing university–industry coauthorship ratio hold up; or did it change as a result of the dynamics of either Japan's national innovation system or emerging global patterns of innovation; or was our**

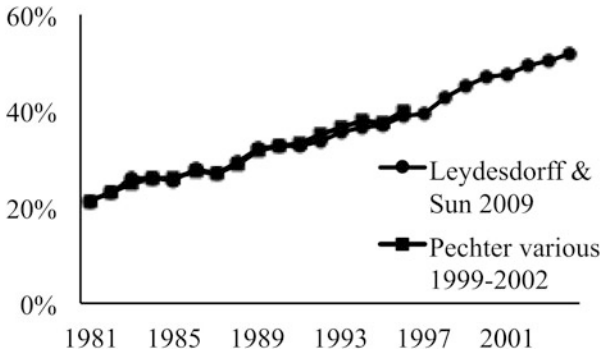

Fig. 2.12 University–industry coauthorship ratio for industry authors in Japan and university authors in Japan. (Source: original data, also in Pechter and Kakinuma (1999 MIT) and Pechter (2001c), reworking of data in Leydesdorff and Sun (2009))

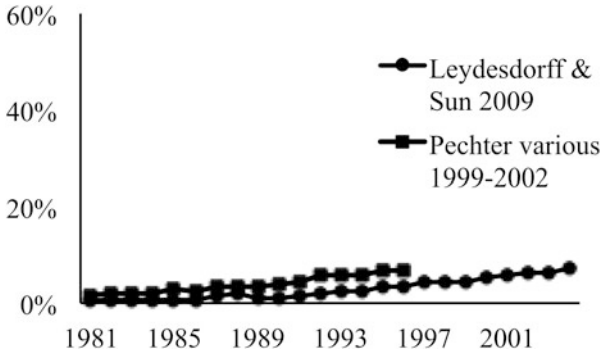

Fig. 2.13 University–industry coauthorship ratio for industry authors in Japan and university authors outside of Japan. (Source: original data, also in Pechter and Kakinuma (1999 MIT) and Pechter (2001c), reworking of data in Leydesdorff and Sun (2009))

finding even perhaps flawed somehow which would be revealed in a failure to be confirmed by later studies?

At last, we now have the answer (of course, since the secondary source dataset was from 10 years ago, we did not have to wait 20 years to find it).

2.4.3 Implications of the New Study on Our Earlier Study

With the welcomed confirmation of our earlier finding, I would like to delve deeper into the confirmation to the extent allowed by the newer dataset, and consider more of the findings of our earlier research. In particular, the newer study contains data that sheds light on some of the issues mentioned above.

We already covered the biggest concern: Was the slight weakening in the growth of the university–industry coauthorship ratio the beginning of the end of the steady upward time trend? The answer is a clear **No**.

The more recent study also sheds light on the matter of dependence on foreign university research. We had concluded 20 years ago that while the connection to foreign university research was growing, it was still small compared to the connection to domestic university research (less than 10% of the total connection). Of course, we expect more domestic research connections than cross-border connections, so the trend in a growing connection with foreign researchers is important. However, the newer data indicates that as of 10 years ago toward the end of this study, the foreign university connection of Japanese industry was still just over 10% of the total university connection.

It is important to keep in mind that one of the most important findings of the bibliometric research conducted in the last two decades is an increase in international coauthorship of research papers (note that coauthorship here refers to trans-national coauthorship by researchers in different countries, and does not necessarily refer to university–industry coauthorship) (for example, Igami et al., 2016).

This trend was also seen in the Leydesdorff and Sun (2009) research. Over the 1981–1996 period of our earlier study, the Leydesdorff and Sun study shows the percentage of all Japanese papers with an overseas coauthor going from 5% to 14% (note that since our original study started with the dataset of industry-authored papers only, a comparable figure does not exist). In the 8 years following the end of our earlier study, the 14% of 1996 continued upward to 22% in 2004. The globalization of national innovations systems is a key agenda item for further research.

2.5 Concluding and Looking Forward

This essay's simple purpose was to empirically assess the metric of university–industry coauthorship in Japan, extending beyond the 1996 endpoint of my earlier study of the same metric. The reason for doing this was because the key finding of my earlier research—a significant and rising university–industry coauthorship ratio in Japan—was so contrarian to the conventional wisdom of the time that it called into question the veracity of our analysis. Time was required for enough additional years' data to accumulate in order to confirm or contradict our finding—and for someone to do the requisite analysis, as I had transitioned from an academic career to a business career and did not do the analysis myself.

The conventional wisdom of the time and still persisting now, is that Japanese public sector and basic research is weak, and therefore Japanese industry is more interested in accessing the open research in other countries such as the US; as a result, Japan is free-riding on the basic research done elsewhere without providing similar access to valuable research in its own innovation system. There is no doubt that basic research in Japan may call for various improvements (for instance, in the

past 10 years Japanese R&D spending growth has lagged (OECD, 2021), Japan has experienced a decline science publications (National Science Board, 2018, Chap. 5; OECD, 2017), and Japan's number of scientific publications with high citations has moved from ninth to tenth in the world, while China surpassed the United States for the first time and ranked first among major countries in scientific publications with high citations (NISTEP, 2021)).

Care must be exercised, however, when interpreting citation counts. For instance, one of the top takeaways from Stanford University's *Artificial Intelligence Index Report 2021* was that although China overtook the US in AI journal citations (after surpassing the United States in the total number of AI journal publications around 2016), "the United States has consistently (and significantly) more AI conference papers (which are also more heavily cited) than China over the last decade" (AI Index Steering Committee, 2021). Important nuances lie below the surface of macro trends.

Although the brash assertions of asymmetric access were based in part on faulty grounds, there may indeed be something to the issue of lack of access to Japan. The problem, however, may be more complex that a simple lack of things worth accessing. For instance, in a recent study, Japan was ranked 196 out of 196 countries in the ratio of inward Foreign Direct Investment to GDP, just behind North Korea. As journalist and highly regarded Japan analyst Richard Katz has pointed out, the cabinet-level council tasked with promoting Foreign Direct Investment (FDI) in Japan acts as if the problem is a lack of companies in Japan that could attract the interest of foreign investors, when in fact such companies are not few. As a result, the council's main policies are aimed at increasing attractiveness rather than at addressing the actual and more complex obstacles (Katz, 2021). The parallels between the problems of Japan's FDI policies and university–industry linkage policies (both which take lack of anything worth accessing as the obstacles to growth) are striking, down to even the imprudent use of metrics (the insufficient treatment of statistics for making international comparisons in both cases) (Ibid).

There are a variety of factors that may be inhibiting Japan's innovation system from more effectively engaging with the global economy and reviving its long-stagnant economy (long-time Japan watcher William Pesek for instance cites "cutting red tape, modernizing labor markets, catalyzing a startup boom, empowering women, boosting productivity and attracting international talent" (Pesek, 2021)). Addressing such issues requires looking beyond simplistic assumptions and grasping the state of the system more realistically. That was the imperative of my earlier research: To start at the most basic level and actually measure the university–industry linkage in research.

This earlier research clearly showed a strong, growing, and internationally comparable university–industry linkage in Japan. And subsequent analysis at the time rebutted conventional wisdom derived counter-explanations such as that the university–industry linkage we measured was a cosmetic result of the bubble economy, a result of dependence on American university research, or a side effect of Japan's dissertation doctorate system. Even so, we were eager for other research groups to validate or contradict our findings. This required us to wait and see. One

more counter-explanation was that our finding was a temporary trend that was about to end. The only way to assess this claim as well was to wait for time to pass and see what happened in the years to come.

With this essay, we finally were able to examine the research record for other research that could check our results. We were pleasantly surprised that the record supported our findings tremendously well, with no detraction from our conclusions. The university–industry linkage as measured by coauthorship of scientific publication was as strong as we said, rose as much as we said, and this trend continued for the additional 8 years that the new study covered (Leydesdorff & Sun, 2009).

While 8 years is a big extension of the endpoint past 1996, 2004 was already 17 years ago. A good next step would be to find more recent secondary analysis of comparable datasets, or to invest the substantial time and money to generate the datasets and conduct primary analysis.

My earlier research also analyzed university–industry innovation nexus in terms of cross-sector R&D expenditure flows and cross-sector contribution to patenting. An extension to this analysis would also be valuable.

Moreover, my original research position was not that the university–industry nexus in the Japanese innovation system was fine and in need of no improvement. My intent was to remove spurious assumptions so that issues in need of attention could be addressed. The hypothesis at the time—which I still believe is relevant today—is that the problem with the Japanese university–industry linkage was not one of disconnect, but rather of not enough flexibility in the connections. The efficient reallocation of resources demanded by innovation requires long-term stable relationships be disrupted (at the time I used the term "dis-organized" (Pechter, 2002a, c)). More work is needed to assess this problem and generate policy recommendations.

For example, we can look at the Leydesdorff and Sun (2009) dataset to which this essay owes its existence. The Leydesdorff group using its own Triple Helix methodology, incorporating Shannon-type mutual information theory, had cautionary results for the Japanese university–industry innovation nexus. They found that increasing internationalization of the innovation system in Japan is changing the nature of linkages between the university, industry, and government research sectors in Japan. In particular, "a major trend is increased internationalization of academic research" resulting in "a relative decline of university–industry relations in Japan."

This said, according to the Stanford AI report, in terms of joint university–industry peer-reviewed AI Japan publications, Japan publishes far less in AI fields than either the US or China (adjusting for size of their economies, Japan and China are similar to each other, and are about 75% of the US). But in terms of the gold standard citation metric of Field-Weighted Citation Impact (Field-Weighted Citation Impact is the ratio of the total citations received divided by the total citations that would be expected based on the average of the subject field, with 1 designating meets expected citation level, and less than 1 or greater than 1 accordingly indicating below- or above-average performance), China and Japan are both about 1.3 while the US is about 2.1 (AI Index Steering Committee, 2021). It would appear that

although Japan lags in absolute amount of university–industry research impact in AI, it is carrying its own weight adjusting for economic size.

More work needs to be done in improving our view of the nature of national and global innovation systems in general, and in assessing the Japanese system in order to support effective policymaking. But for the immediate purpose of this essay, verifying our earlier key result of a strong and increasing university–industry coauthorship linkage—and confirming that it held up over time—is a welcome and long-awaited confirmation. And recognizing some of the key people who made this work possible was also long overdue.

References

AI Index Steering Committee. (2021). *The AI index 2021 annual report*. Human-Centered AI Institute, Stanford University, Stanford.

Branscomb, L. (1999, January 8). Official correspondence to University of Tokyo.

Branscomb, L. M., Kodama, F., & Florida, R. (Eds.). (1999). *Industrializing knowledge: University-industry linkages in Japan and the United States*. MIT Press.

Carayannis, E. G., & Campbell, D. F. J. (2009). 'Mode 3' and 'Quadruple Helix': Toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management, 46*(3), 201–234.

Carayannis, E. G., & Campbell, D. F. J. (2010). Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation, and environment relate to each other? *International Journal of Social Ecology and Sustainable Development, 1*(1), 41–69.

Christensen, C. M. (1997). *The innovator's dilemma: When new technologies cause great firms to fail*. Harvard Business School Press.

Etzkowitz, H., & Leydesdorff, L. (1995). The Triple Helix—University-industry-government relations: A laboratory for knowledge based economic development. *EASST Review, 14*, 14–19.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From national systems and 'mode-2' to a TRIPLE Helix of university-industry-government relations. *Research Policy, 29*(2), 109–123.

Hicks, D., & Katz, S. (1997). A national research network viewed from an industrial perspective. *Revue D'Economie Industrielle, 79*(1), 129–142.

Igami, M., Saka, A., & Sadao, N. (2016). Situation of international collaborations in Japan—Evidence from bibliometric analyses and surveys to authors of scientific papers (in Japanese, Nihon no KokusaiKyoudouKenkyuu no Joukyou – RonbunBunseki to RonbunKyouchosha he no ShitsumonHyouChousa kara no Shisa). *The Journal of Science Policy and Research Management* (in Japanese, Kenkyuu Gijutsu Keikaku), *31*(2), 145–158.

Kakinuma, S, & Pechter, K. (1999). University-industry research collaboration in Japan: Industry dependence on academic research (in Japanese "Nihon Kigyou to Daigaku no Kyoudou Kenkyuu - Daigaku Kenkyuu e no Izon"). *Research Bulletin of the National Center for Science Information Systems* (in Japanese *Gakujutsu Joho Senta- Kiyo), 10*.

Katz, R. (2021, August 2). Japan as 196th. *The Oriental Economist*.

Kodama, F. (1995). *Emerging patterns of innovation: Sources of Japan's technological edge*. Harvard Business Review Press.

Kodama, F., & Nishigata, C. (1991). Structural changes in the Japanese supply/employment systems of engineers: Are we losing or gaining? In D. S. Zinberg (Ed.), *The changing university* (pp. 101–128). Kluwer Academic Publishers.

Leydesdorff, L. (2003). The mutual information of university-industry-government relations: An indicator of the triple helix dynamics. *Scientometrics, 58*(2), 445–467.

Leydesdorff, L. (2006). *The knowledge-based economy: Modeled, measured, simulated*. Universal Publishers.

Leydesdorff, L. (2012). The Triple Helix, Quadruple Helix, . . . , and an N-tuple of helices: Explanatory models for analyzing the knowledge-based economy? *Journal of the Knowledge Economy, 3*(1), 25–35. https://doi.org/10.1007/s13132-13011-10049-13134

Leydesdorff, L., Dolfsma, W., & Van der Panne, G. (2006). Measuring the knowledge base of an economy in terms of triple-helix relations among "technology, organization, and territory". *Research Policy, 35*(2), 181–199.

Leydesdorff, L., & Fritsch, M. (2006). Measuring the knowledge base of regional innovation systems in Germany in terms of a Triple Helix dynamics. *Research Policy, 35*(10), 1538–1553.

Leydesdorff, L., & Sun, Y. (2009). National and international dimensions of the Triple Helix in Japan: University-industry-government versus international co-authorship relations. *Journal of the American Society for Information Science and Technology, 60*(4), 778–788.

McGray, D. (2002, May–June). Japan's gross national cool. *Foreign Policy* (pp. 44–54).

Morgan, J. (2021). The end of the Abe Administration—The end of abenomics? Books on past and present in the Japanese political economy. *Quarterly Journal of Austrian Economics, 24*(1), 167–187.

National Science Board. (1998). *Science & engineering indicators*. National Science Board.

National Science Board. (2018). *Science & engineering indicators*. National Science Board.

NISTEP. (2021). *Japanese science and technology indicators 2021*. Center for S&T Foresight and Indicators, National Institute of Science and Technology Policy (NISTEP), MEXT.

OECD. (2017). The digital transformation (science, technology and industry scoreboard 2017).

OECD. (2021, March). Main science and technology indicators.

Pechter, K. (2000a). Empirical support for significant university-industry linkage in Japan. In *Proceedings of the International Conference on the Management of Innovation and Technology,* IEEE Engineering Management Society, Singapore, November 13–14.

Pechter, K. (2000b). Understanding and communicating needs and solutions: A case of comparative policy analysis. *Social Science Japan, 18*, 27–31.

Pechter, K. (2001a). Japanese innovation reform in the light of past dialogue: Conceptions of convergence as perspectives for comparative system assessment. *Comparing Economic Institutions.* In *Proceedings of the 2001 Conference of the European Association for Evolutionary Political Economy*, Siena, Italy, November 8–11.

Pechter, K. (2001b). Comparative policy analysis under conditions of innovation-driven change: Assessment of the university-industry linkage in Japan and the United States. *Change Management and the New Industrial Revolution.* In *Proceedings of the 2001 IEEE Engineering Management Society International Engineering Management Conference*, Albany, New York, October 7–9.

Pechter, K. (2001c). *System assessment for innovation policy formation: Measuring the university-industry linkage in Japan and the United States* (Unpublished Doctoral Dissertation). The University of Tokyo.

Pechter, K. (2002a). Dis-organizing structure as a policy reform objective: Public-private networks in Japan's innovation system. *Managing Technology for the New Economy.* In *IEEE Engineering Management Society 2002 International Engineering Management Conference*, St. John's College, Cambridge, UK, August 18–20.

Pechter, K. (2002b). Field specialization and sectoral division of research in National Innovation Systems. In Q. Xu, X. Wu, & J. Chen (Eds.), *Management of technology and innovation in the 21st century* (Vol. 2002, pp. 62–67). Zhejiang University Press.

Pechter, K. (2002c). Comparative analysis of inter-sector innovation enterprises: The case of university-industry linkage reform in Japan and the United States, Joint Princeton-Northwestern Junior Scholar's workshop on embedded enterprise in comparative perspective, Princeton University, April 11–14, 2002.

Pechter, K., & Kakinuma, S. (1999). Coauthorship as a measure of university-industry research interaction in Japan. *Technology and Innovation Management.* In *Portland International Conference on Management of Engineering and Technology* (pp. 87–93).

Pechter, K., & Kakinuma, S. (1999 MIT). Coauthorship Linkages between university research and Japanese industry. In L. M. Branscomb et al. (Eds.), Industrializing knowledge: University-industry linkages in Japan and the United States (pp. 102–127). MIT Press.

Pesek, W. (2021, September 6). Japan must look beyond the usual suspects for its next leader—Suga's departure is a golden opportunity to reset the economy, Nikkei Asia.

Sakakibara, S. & Ijichi, T. (2001). The state of the university-industry linkage in Japan and the problem of conflicts of interest (in Japanese "Nihon ni okeru san-Gaku Renkei no Jittai to Rieki Souhan Mondai"). In M. Aoki et al. (Eds.), *University Reform: Issues and Discussion* (in Japanese Daigaku Kaikaku no Kadai to Souten, pp. 369–392). Toyo Keizai Inc.

Sun, Y., Negishi, M., Nishizawa, M., & Watanabe, K. (2006). Research linkage between university and industry in Japan: Comparison based on NCR-J and CJP databases. *Journal of Japan Society of Information and Knowledge, 16*(2), 7–12.

Sun, Y., Negishi, M., & Nishizawa, M. (2007). Co-authorship linkages between universities and industry in Japan. *Research Evaluation, 16*(4), 299–309.

United States-Japan Joint Task Force on Corporate Innovation. (1999). *New strategies for new challenges: Corporate innovation in the United States and Japan*. National Research Council/National Academy Press.