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Restructuring the Japanese national research system and its effect on performance

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The Japanese government has been attempting to reform the national research system for the past 20 years. This paper describes the structural changes of the system and its performance based on bibliometric analyses and discusses the effects of S&T policy. The investigation indicates that although Japan gradually increased its production of highly cited publications, its share of low-cited publications is much higher than the former. Detailed analyses reveal that the top eight universities account for half of the highly cited publications in the university sector, while other hundreds of universities have massively increased their low-cited publications since 1990. The development of financial and human resources for research in the 1990s enabled new actors to be involved in scientific research, but the resources were concentrated to a small number of universities, reinforcing the collaboration between these universities and others.

Introduction: Transition in the Science and Technology Policy in Japan

For the past 20 years, the Japanese government has been attempting to reform the national research system. In the mid-1980s, the government began to emphasise the promotion of basic research. This was in response to international criticism that Japanese contribution in R&D should reflect its economic strength more accurately. Moreover, the government itself realised that further economic advancement of Japan

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was impossible in the absence of abundant R&D. In this context, the Council for Science and Technology (CST), in its reports of 1984 and 'General Guideline' in 1986, determined that the promotion of 'creative' science and technology should be the primary concern of the science and technology policy. Following the appearance of the reports (and in some cases, prior to their appearance), new research programmes for national and semi-public research institutes, an international collaboration programme, a university-industry joint research programme and a post-doctoral fellowship were established.

However, in the 1980s, the financial condition was unfavourable, particularly for universities, because of the minus-based national budget. These arose various problems, such as reduction in the expenditure for fundamental infrastructure, dilapidated facilities and a shortage of research assistants. In addition, Japan entered an economic depression in 1990. The research expenditure of private industries, which accounted for 70–80% of the Gross Domestic Expenditure on Research and Development (GERD), took a downturn in the first half of the 1990s. Thus, there was a greater need for governmental support with regard to basic research that begets innovative technological progress.

The Science and Technology Basic Law, which expressly stipulated the government's role in promoting science and technology, was enacted in 1995. In the following year, the First Science and Technology (S&T) Basic Plan was established. This Plan called for increasing the public R&D expenditures to 17 trillion yen for the next five years. Based on the Plan, seven new basic research programmes were established, the support for post-doctoral fellows was reinforced, fixed-term employment of researchers was introduced at certain national research institutes and the guidelines for national R&D evaluation were decided upon. In 2001, the Second S&T Basic Plan was established, which stipulated an expenditure of 24 trillion yen for public R&D for the next five years.

The Japanese government thus continuously reformed its national research system with an enormous public expenditure. However the effects of the reform on the S&T system and performance during these 20 years are not clear: Did these reforms lead to the involvement of new research actors in scientific research? If so, did they produce a significant number of research results with high impact? Did the relationship between various actors change? This paper examines the transition in the Japanese national research system over a period of 20 years by undertaking quantitative analyses of huge number of publications.

Japanese research performance at the macro-level

Share of Japanese publications by citation frequency rank

It has been frequently highlighted that Japan has increased the number of publication and is now ranked as the second largest producers of publication in natural sciences, after the U.S.A. The share of Japanese publications (publications having at least one author with a Japanese institution address) in ISI's *National Science Indicators 1981–2002 (Deluxe version)* increased from 6.0% in 1981 to 9.3% in 2002. However, one criticism has been that the citation impact of Japanese publications has not yet reached the international level. The Relative Citation Index (RCI), which is calculated by dividing the share of citations by the share of publications, has been consistently below 1.[1] This implies that, although Japan has been increasing its number of publications, most have been cited only a few times on an average.

On the other hand, however, Japanese researchers have published many articles in top-level journals, such as *Nature* and *Science,* since the early 80s, and Japanese contribution to knowledge development appears to have increased. Using merely the RCI as an average value does not help in determining whether there has been an increase in the publications with a high citation impact or whether the increase is only seen in medium citation impact publications. Such analysis requires detailed examination of the distribution of publications by their impact.

As an example of detailed analyses of distribution, Butler analysed the Australian universities' share of publications by classifying journals into four quartiles based on their five-year average citation impact.[2] In her analysis, she explained that the introduction of performance-based funding for Australian universities had affected the researchers' behaviour; they tended to select low-citation journals so that they could publish more articles. Although we have basically followed her idea, we measured the actual citation counts of all publications, instead of the journals' average citation impacts, in order to identify the ex-post impacts of publications rather than the researchers' tendency in selecting journals.

The measurement of actual citation counts of all publications requires huge data operations. We used the *Science Citation Index* (Thomson ISI: CD-ROM version) from 1982 to 2003 as a data source and re-structured as follows: First, references of all publications contained in each year's SCI were collected and frequencies of their occurrences were counted after making the following modifications in the data: Notations of first and middle names were restricted to one initial (for example, James-DJ was counted as James-D). Abbreviated journal names were changed to complete names. Research-team names written as authors of reference in publications that were cited more than five times a year, were changed to the names of the first author whenever possible. Second, all publications in CD-ROMs 1982–2003 were matched with the list of references using the first author's name, the first character of a journal, volume and pages. The citation frequencies of all publications in the SCI were counted in this manner for the period of 1982 to 2003.

Publications were then ranked by citation count within the same year of publication, same type of document (article, letter, note and review) and same research field. Approximately 170 research fields (Subject Categories), which are provided to journals by the ISI, were used. For example, a review paper in the *Journal of Biochemistry* in 1996 classified as 'biochemistry & molecular biology' was ranked along with all review papers that were published in 1996 in journals classified as 'biochemistry & molecular biology'. With regard to journals that were classified into more than one research field, publications were fractionally attributed to each field. Publications that appeared in journals classified as 'multidisciplinary', such as *Nature* and *Science,* were re-classified into one or more fields using the reference list of the publications, i.e. research fields of referenced journals were counted and the fields that appeared most frequently were selected as the field(s) of those multidisciplinary publications. Publications without any references remained as 'multidisciplinary'.

Following the measurement and classification, normalised indexes of ranks were calculated by dividing the value of rank by the sum of publications in the same field.[3] For example, the normalised index for the 100th publication among 10,000 is 'top 1%'. On the basis of this measurement, we counted the sum of Japanese publications in the top 10% group and in each quartile, from the top 25%, 25–50%, 50–75% and 75–100%, by field and by year.

Figure 1 shows the share of Japanese publications in the top 10% group and in the four quartiles as the total of all fields. This figure shows that the share of Japan in all groups has increased over the past 20 years. Overall, its share in the top 10% increased from 5.5% in 1982 to 8.7% in 2002. In addition, the share in the top 25% showed a similar increase. These results are indicative of the increase of Japanese contribution to the creation of influential basic research, following the recommendations of the Council for Science and Technology in the 1980s.

However, Figure 1 also shows that the share of the third quartile (50–75% in the citation ranking) was the highest among all quartiles. Further, the share of the fourth quartile, which mostly comprises publications receiving no citations, increased dramatically in the 1990s and reached its peak in 1999. This data shows that Japan produced several low-impact publications, and this trend was reinforced in the 1990s.

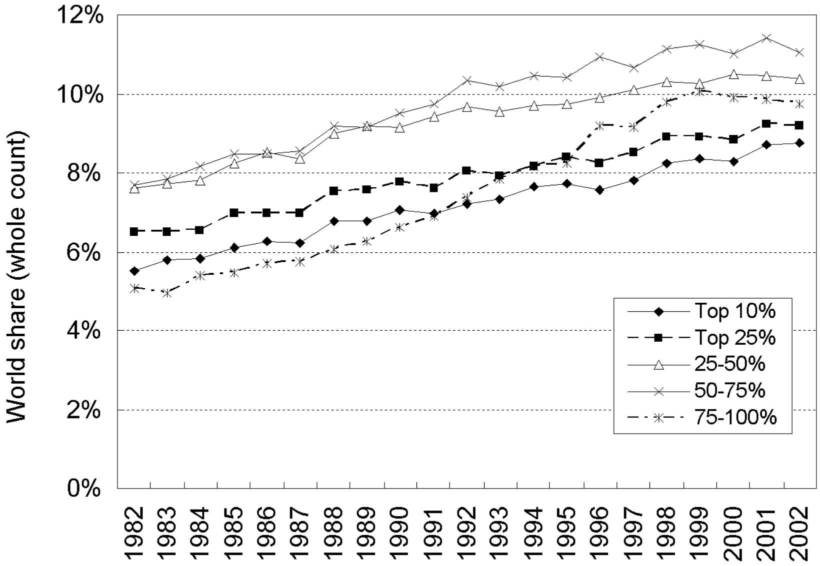

Figure 1. Share of Japanese publications in SCI according to citation ranking

Analyses of different research fields may reveal different characteristics of publications. Figure 2 shows the characteristics of Japanese publication in 20 fields, between 1999 and 2001 on two axes: one represents the share of the top 10% publications and the other represents the rate of the share in the top 10% divided by the share of all publications. In the figure, 168 research fields are merged into 20 fields for clarity. Each of the 168 fields are classified into the most closely-related one of 20 fields according to the *Standard Version of the National Science Indicators* by measuring the number of journals in the cells of a matrix of 168 field × 20 field. The size of the circle of the research field in the figure is related to the number of publications. Three of 20 fields, psychology, social science and multidisciplinary (after our re-classification mentioned above), do not appear in the figure, because they have no or only a small number of publications in the SCI.

The results indicate a better performance in the fields of natural sciences such as materials science, physics and chemistry, than in the fields of life sciences such as clinical medicine and biology which indicate lower index on both axes. Thus, it can be concluded that there are extremely large differences among various research fields, although the share of the top 10% publications is lower than that of all the publications in almost all the fields.

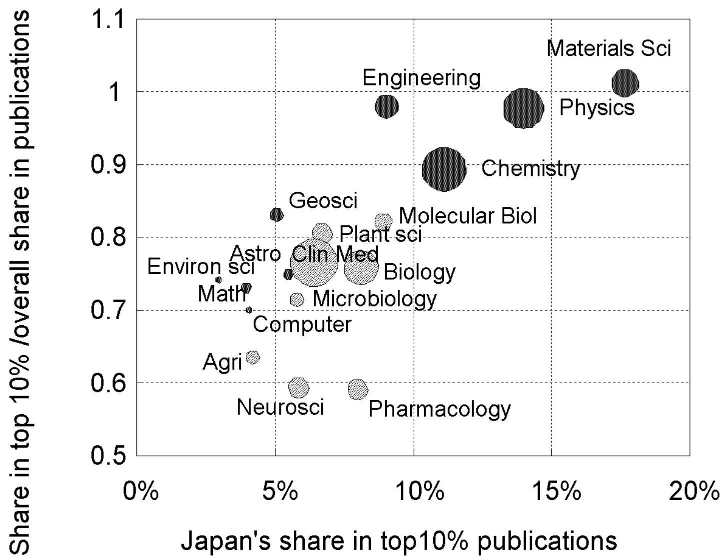

Figure 2. Characteristics for research fields in Japan (1999–2001)
Source: Authors' calculation based on SCI

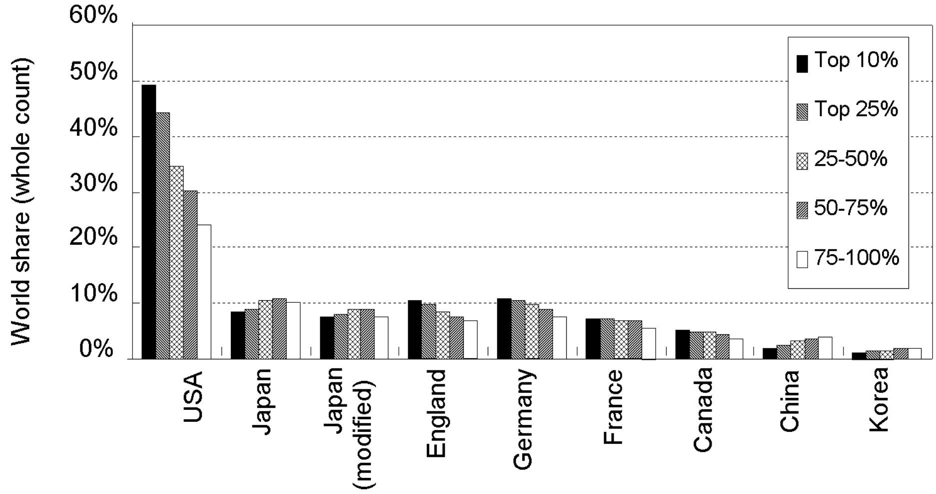

Figure 3. Countries' shares of publication in 2000 by citation ranking
Source: Authors' calculation based on SCI

If this characteristic – the highest share in low-cited publications – was observed in all advanced countries, the production of low-cited publications can be interpreted as part of an essential process of producing an influential publication. As our data enable us to count the publications produced by other countries in the same manner as the Japanese data, we can compare the distributions of publications by citation rank among countries. This type of analysis has not been conducted so far. Figure 3 shows the share of countries in each citation-ranking group in 2000.

The figure shows that the U.S.A.'s share of top 10% publications far exceeds the shares of all quartiles. The more citation publications received, the higher the share of the U.S. publication. This feature is also observed in England, Germany, France and Canada, although the values of the share are far below those of the U.S.A. Japan shows a contrary feature among the advanced countries studied. The more citations publications received, the fewer shares Japan had, with the exception of the last quartile. This tendency is rather similar to that observed in China and South Korea. These results show that Japan still has the characteristic of a 'catching-up' country, despite being the second-highest producer of publications.

Possibilities of biases?

Before investigating the reason for the low impact of Japanese publications, we should first consider the possibilities of biases in the database and data processing. In 1999, the Science and Technology Agency (STA) surveyed Japanese researchers with regard to their views on the reason for the low citation rate of Japanese publications in the SCI.[4]

The most frequent answer (48%, multiple answers) was that the SCI database includes some Japanese-language publications with only abstract written in English. As foreign researchers rarely cite publications written in Japanese, this would decrease the average number of citations. However, the number of Japanese-language publications was 1,266 in SCI 2000, which accounted for only 2% of the total publications produced by Japanese authors.

The next most frequent answer (44%) was that Japanese researchers do not possess sufficient proficiency in writing English. With respect to another question in the survey, 61% of the respondents answered that writing publications in English was difficult. However, today, research communities in many fields have become international and publications in international journals tend to be more valued than those published in domestic journals. Furthermore, in response to international criticism, the Japanese government offers financial support to some Japanese academic societies whereby they can publish their own English-language journals and disseminate Japan's basic research results internationally. As a result, the SCI in 2000 included 11,342 publications in 88 English-language journals published by Japanese academic societies and research institutes, which accounted for 18.2% of Japan's overall publications. In some of these journals, almost all authors were Japanese, and citations by foreign researchers were rare. This might be one reason why the number of Japanese publications in English-language journals in the SCI increased while the citation rate remained low.

Figure 3 also shows the case wherein all publications in the English-language journals published by Japanese academic societies and research institutes are omitted ('Japan (modified)' in the figure). The share of low-cited publications became lower, particularly in the fourth quartile where 36.7% of the publications was produced by Japanese academic societies. Based on this result, we can argue that the distribution could be improved by the technical modification of the dataset, but the propensity that the share in the third quartile is the highest does not change.

The linguistic problem causes another bias in the citation behaviour of Japanese researchers. Japanese publications (written in English) cite fewer documents as compared to the publications of other advanced countries. In 2001, the average number of references in Japanese publications was 24.8, while it was 34.1 in the U.S.A., 30.5 in England, 32.0 in Germany and 30.9 in France. One of the reasons for this might be attributed to the fact that reading publications not written in the mother tongue requires greater effort. Even in the case where citations to author's own publications (author self-citations) are excluded, there is still a greater probability that authors cite documents written by national authors rather than those by foreigners. Thus, the small number of references in Japanese publication results in the low citation rate of the country's own publications.

Table 1 shows that 230,291 of Japanese publications during 2000–2003 (internationally co-authored publications were fractionally counted) cited 298,163 publications in the SCI in 2000 (citations by internationally co-authored publications were also counted fractionally). Thus, one publication during 2000–20003 cited 1.29 publications in average in 2000, of which 0.40 were author self-citations,[*] 0.19 domestic citations (citation to Japanese publications other than one's own), and 0.70 foreign citations (citation to non-Japanese publications). The frequency of author self-citation is rather similar as compared to that in the other advanced countries. However, the numbers of both domestic and foreign citations are low in Japan, although they are not the lowest. The U.S.A. records the lowest value of foreign citation, but it is compensated by the high value of domestic citation owing to the enormous size of the American domestic academic activity. France's lowest value in domestic citation is compensated by high foreign citation. Japan, by contrast, records low values in both categories.

[*] Author self-citations were identified if the authors of the cited publications included at least one name identical to that of one of the authors of citing publications. Indeed, it may include some errors caused due to the existence of a different person with the same family name and initial of the first name, but the probability of citation by different persons with the same name can be expected to be very low.

Table 1. Comparison of citation frequency and probability of domestic citation

	Publication in 2000–2003 (A)	Citation to 2000 from 2000–2003 (B)	Citation frequency				Probability of domestic citation	Probability of foreign citation
			(B/A)	Author self-citation	Domestic citation	Foreign citation		
Japan	230,291	298,163	1.29	0.40	0.19	0.70	3.0	1.3
US	722,394	1,444,154	2.00	0.46	0.93	0.61	4.6	1.4
England	151,981	260,853	1.72	0.40	0.23	1.08	4.6	1.9
France	123,994	204,819	1.65	0.41	0.16	1.08	4.0	1.9
Germany	169,766	309,149	1.82	0.47	0.24	1.11	4.4	2.0
Japan (simulation)	230,291	386,864	1.68	0.40	0.28	1.00	4.4	1.8

(Authors' calculation based on SCI)

If we omit the effect of countries' size by calculating the probability index, Japan's characteristics will become clearer. The probability of domestic citations in Japan is calculated by dividing 0.19 by the total number of Japanese publications in 2000 (62,427) and multiplied by 1,000,000. As shown in Table 1, the probability is 3.0. Japan's probability of foreign citation, measured in a similar manner (0.70 divided by the total number of non-Japanese publications in 2000 and multiplied by million), is 1.3. In the other four advanced countries, the average value of the probability of domestic citation is 4.4 and that of foreign citation is 1.8, which are higher than those of Japan.

If Japanese publications cite domestic and foreign publications with the same frequency as the average rate of other advanced countries, we could expect that the citation rate of Japanese publication will increase. Calculations revealed that domestic and foreign citation frequencies increased from 0.19 to 0.28 and from 0.70 to 1.00, respectively. This simulation shows that the RCI of Japan increased from 0.93 to 0.97 in 2000.

These results signify that the linguistic problem is one of the major causes for the low citation of Japanese publications and that technical modification in counting could improve the rate. However, even after the modifications the result does not change dramatically; the RCI is lower than 1, and the highest share is in the third quartile. Thus, the characteristics of Japanese publications may be affected by linguistic biases, but the results seem to provide a good picture of the activities and quality of Japanese research. This observation collaborates with the third most frequent answer (34%) in the STA survey, that Japanese research lack originality and novelty.

Change of research actors

Transition in the shares of sectors

If the bibliometric analyses reflect Japanese research performance and quality, why have these characteristics emerged in Japan? As explained in the first section, some science and technology policy initiatives were put into practice during the period investigated, and each initiative may have affected particular sectors. The structure of research actors in Japan might have changed, which in turn would affect the macro-level characteristics of Japan. Thus, we will conduct more detailed investigation by examining the actors that produced publications.

With regard to this analysis, first, all authors' affiliations were classified into several sectors as in Refs 5–7. In this study, Japanese research organisations were classified into the following sectors: universities (including higher education institutes such as polytechnics and junior colleges), national research institutes, semi-public research institutes, regional governmental research institutes, hospitals (excluding university hospitals), industries, public-interest corporations and others. The governmental reforms implemented since 2001 modified the sector classification; for example, almost all national research institutes became Independent Administrative Institutions (IAIs) in 2001, and some semi-public research institutes became IAIs in 2003 and 2004. However, as this present analysis uses the classification before 2001, the classification is not affected by the most recent reform.

First, all affiliations in Japan were automatically classified into sectors by use of keywords such as 'UNIV', 'COLL', 'HOSP', 'CORP', 'LTD' etc. Second, a list of English abbreviated names of Japanese research organisations was created using the two directories of Japanese research organisation: the *Nationwide List of Research Institutes in Japan*[8] and the *JST's Directory Database of Research and Development Activities* ('ReaD'). Then the affiliation data and the research organization list were compared. With regard to unmatched data with errors in addresses, we attempted to manually identify their sectors only in cases where they appeared more than ten times in a year. Some could not be classified, but the percentage of unclassified addresses was less than 0.1% among all Japanese addresses.

Figure 4 shows the shares of sectors' publications in the SCI by fractional counting of co-authorship (the contribution by authors of foreign countries co-authoring with Japanese authors is shown at the top of the bars). It can be observed that the university sector increased its world share from 4.9% in 1982 to 6.8% in 1999. Although its share in all Japanese publications decreased from 77% in 1982 to 73% in 1991, due to the increase of other sectors' publication, it slightly increased to 74% in 2002. By whole counting, its world share consistently increased from 5.3% to 8.5% in 20 years. Approximately 80% of the entire Japanese publications included at least one university in the authors' affiliation during 1982–1995 and the value increased to 85% in 2003. These results indicate that the share of Japanese university sector publication has been growing, and the relative importance of the university sector in knowledge production has been extremely high. This trend has been reinforced since the mid-1990s.

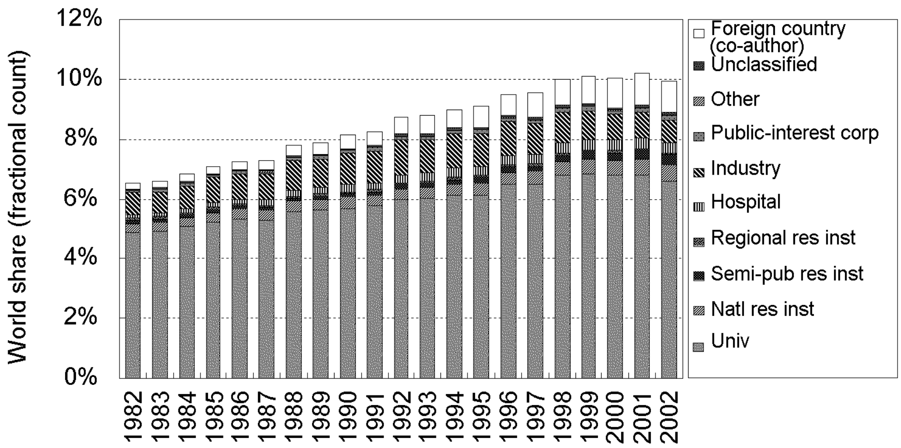

Figure 4. Shares by sector
Source: Authors' calculation based on SCI

During the same period, other sectors have also increased publications. A noteworthy feature is that the semi-public research institutes sector has increased its share to the largest extent. Although its share is small, the semi-public research institute sector doubled its publications within seven years from the latter half of the 1990s when the First S&T Basic Plan was established. Three institutes belonging to this sector – (RIKEN, Japan Science and Technology Corporation (JST) and Japan Atomic Energy Research Institutes) – account for 90% of the sector's publications and the JST is the greatest contributor to this vigorous increase. JST functions more as a funding agency than a research institute, and it periodically groups researchers in its programmes. They employ researchers from several sectors (universities, national research institutes, private companies etc.) and post-doctoral fellows on a part-time basis, a fixed term contract, loans or fellowships. Based on the First S&T Basic Plan, seven new basic research programmes have been launched, one of which is JST's CREST (Core Research for Evolution Science and Technology) programme. Development of S&T activities increased the publications by JST. RIKEN, another semi public research institute, has also developed its research activities and established several new research centres in various research fields such as bio-homeostasis, materials, synchrotron radiation, seismology, brain science and genetics. JST and RIKEN have become the most productive organisations in terms of publication in Japan, following approximately ten universities.

As a result of policy to enhance basic research, the national research institutes also increased publications from the 1980s onwards. After the First Basic Plan, which called for a higher public research budget, the rate of increase became slightly higher. Other sectors such as hospitals and public-interest corporations also consistently increased their world share. However the number of industries' publication peaked during 1992–1996 and decreased thereafter. The industrial sector gradually discontinued conducting basic research in its own central research laboratories, and this trend was accelerated by the economic depression of the 1990s. In the fields of physics and chemistry, wherein industries had previously produced more publications than in any other research field, the drop in the number of publications was substantial – a decrease of 0.62 times in physics and 0.71 times in chemistry within a span of 10 years.*

Classifying the publications according to the citation ranking (as in the previous section) reveals that all major sectors, with the exception of semi-public research institutes and public-interest corporations, had the greatest share in the third or fourth quartile. This trend is consistent with the macro-level characteristics of Japan. While semi-public research institutes radically increased their publications, they had the highest share in the top 10% group, which is identical to the macro-level trend of other advanced countries such as the U.S.A. and England. The reason why the semi-public research institutes can produce such high-impact results might be explained as follows: certain semi-public research institutes that produce publications are engaged in internationally high-level basic research rather than regional services, technological development or educational and clinical activities as conducted by other sectors. They also have more flexible organisational management system than the other governmental research institutes. For example, they can temporally employ high-level researchers from several sectors. These factors, combined with the prioritised distribution of public R&D expenditures to them, might have affected their publication performance.

Changes within the university sector

Since the university sector accounts for 80% of Japanese publication, the macro-level characteristic of Japanese publication in Figure 1 strongly reflects the university sector's performance. Thus, we should analyse university sector in greater detail. As of 2002, Japan had 99 national universities, 75 public (prefectural and municipal) universities, 512 private universities, 541 junior colleges, 62 polytechnics and 15 inter-

* Detailed results according to sectors and research fields can be seen in the authors' report NISTEP (2005).[9]

university research institutes. Figure 5 shows the world shares of the 30 most productive universities. It reveals that the national universities are the principal producers of publication, and that the eight national universities have considerably higher share of publication than other universities. These eight universities are the seven former imperial universities (University of Tokyo, Kyoto, Osaka, Tohoku, Kyushu, Hokkaido and Nagoya) and Tokyo Institute of Technology,

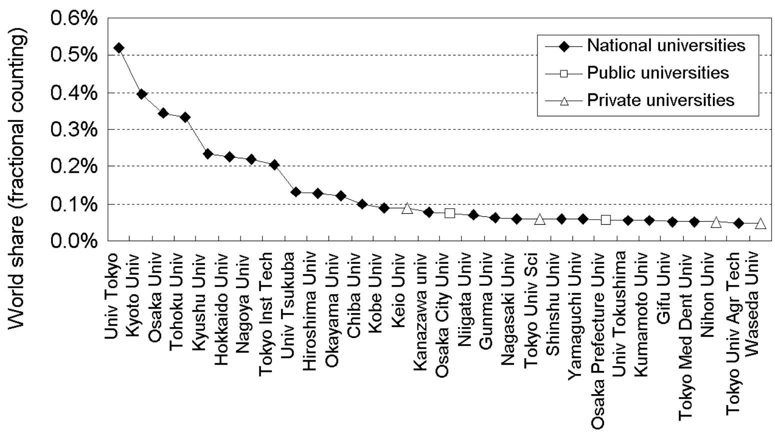

Figure 5. Shares of universities (2001)
Source: Authors' calculation based on SCI

Figure 6 shows the share of each university category, in which the eight most productive national universities are shown separately from the other national universities. As shown in the figure, the 99 national universities accounted for approximately 70% of the university sector's publications by fractional counting, and the top eight national universities accounted for 36.7% of the sector's publications in 2001. The sum of world shares of eight universities has consistently been 2.2–2.5%, while the actual number of publications has increased by 1.6 times. Other national universities (excluding eight universities), public and private universities have increased their world shares, and in absolute term the publications multiplied by 2.3, 2.5 and 2.3, respectively. These results indicate that the increase in the world share of universities' publications in 20 years has primarily been the result of the expansion of research activities of universities that were not ranked high in the hierarchy.

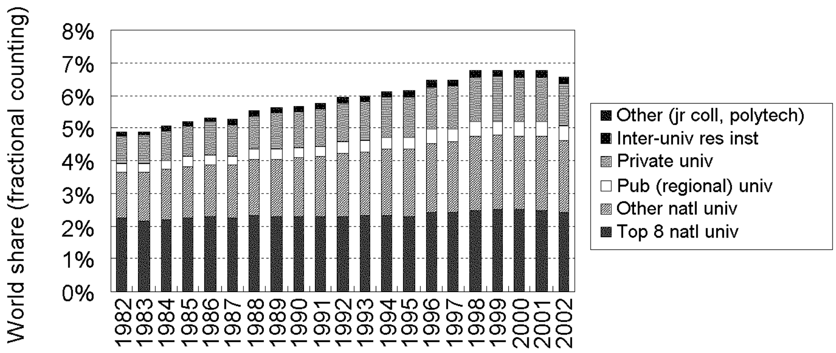

Figure 6. Shares of universities for all publications
Source: Authors' calculation based on SCI

However, restricting the discussion to the top 10% publications, we find that the eight universities accounted for 50.4% of the university sector's publications in 2001 by fractional counting (Figure 7). In the case of whole counting, at least one of the eight universities appeared in 58.0% of universities' publications and 47.9% of Japanese total publications. Their world share was 2.3–2.6%, which was almost the same as in the case of the total number of publications shown in Figure 6. Although universities other than the top eight produced the other half of the sector's publications, the world shares are much smaller than their share in all publications.

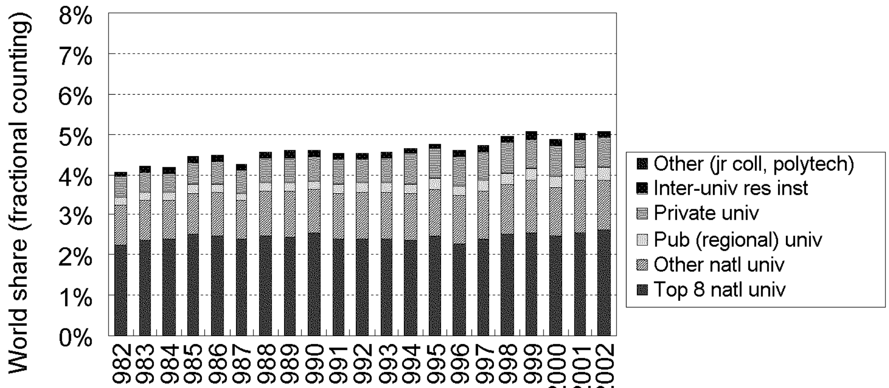

Figure 7. Shares of universities for top 10% publications
Source: Authors' calculation based on SCI

In the fourth quartile, where Japan greatly increased the share in the 1990s, the top eight universities had a lower share than in other quartiles with a slight increase of their share to 2%. However, the share of other universities significantly increased and it attained the highest level in the latter part of the 1990s (Figure 8).

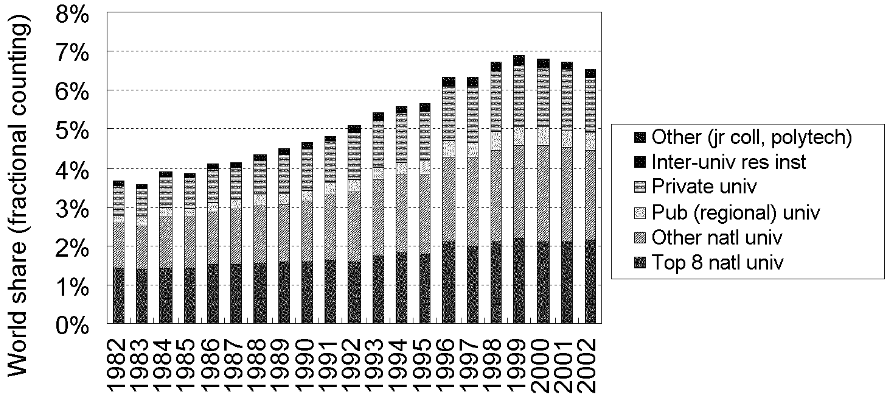

Figure 8. Shares of universities for 75–100% publications
Source: Authors' calculation based on SCI

Structural characteristics and relationships with the S&T policy

Expansion of research activities and concentration of excellence

In the above analyses, we simultaneously observed two opposing characteristics in the Japanese research system: decentralization of research activities and concentration of excellence. Decentralization implies that new actors became involved in research activity and increased their publications. In particular, various universities that were not ranked high in the hierarchy began to publish in international journals.

The degree of concentration can be indicated by the Herfindahl index, which is one of the indicators frequently used in structural analyses on industry. The index is defined as:

$$H = \Sigma S_i^2 \times 10000$$

where S_i is the share of actor 'i'. In other words, the index H is the sum of the squares of the shares of actors. The Herfindahl index is one of the indicators for concentration that reflects both the number of actors (absolute concentration) and the degree of relative concentration within actors.[10]

In Figure 9 shows that in all publications produced by the university sector (including junior colleges and polytechnics), H decreased during the 1980s to the mid-1990s. From around 1996 onwards, it remained almost constant at approximately 230. Additionally, in the top 10% publications, H decreased until 1995 and remained constant at approximately 430. These results imply that Japan's university sector decentralised in the 1980s and the first half of the 1990s by involving various university actors in research activities, and this trend ended in the mid-1990s.

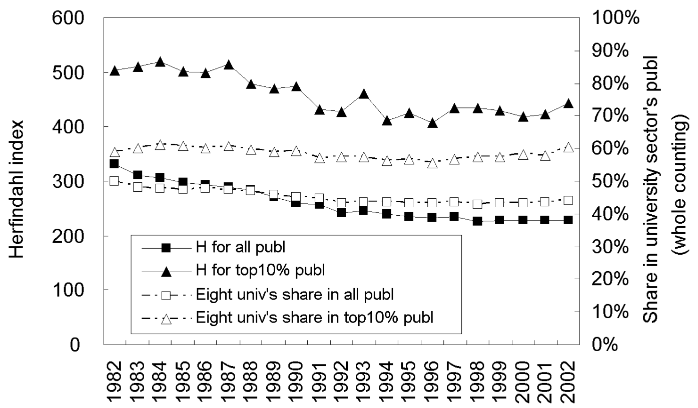

Figure 9. Degree of concentration and share of top universities
Source: Authors' calculation based on SCI

While the share of the top eight universities among the university sector's publications decreased from 46% to 37% by fractional counting of co-authorship, it did not change radically in the case of the top 10% publications, with a slight decrease from 55% in 1982 to 52% in 2002. Further, as revealed by whole counting as shown in Figure 9, the share of publications in which at least one of the top eight universities appears in the authors' affiliation increased slightly from the latter half of 1990s.

Thus, a summary of these observations and those in the preceding section is as follows:

1) University publications increased in the 1980s. A radical increase in low-cited publications by universities that were not included in the top-ranking category was perceived since 1991, and it peaked in 1999.

2) Decentralisation that began in the 1980s ceased in 1996, and the publication share of top universities increased from then onwards.

Why did these trends arise? The reason partly lies in the change of human and financial resources for research.

First, the number of universities increased 1.5 times, and the faculties within the university sector increased 1.4 times, particularly in private and public universities. This might have contributed to the decentralisation in the 1980s. However, only 39% of the faculties belong to national universities, and only 13% belong to the top eight national universities. Thus, the number of faculties in itself is insufficient to explain the fact that more than 70% of the publications were written by national universities.

Another reason for the change may be the number of doctoral students which substantially increased after 1991. This is also the period during which the fourth quartile publications began to increase. The number of doctoral students increased from 28,354 in 1990 to 65,525 in 2001 (Figure 10). This was due to the higher education policy implemented around 1990. The University Council, which was established in 1987 as an advisory council for the Monbusho (Ministry of Education), published a report in 1991 that recommended the increase of graduate schools.[11] This report mentioned the importance of graduate schools in both boosting the level of academic research in Japan and developing researchers and professional workers. It recommended doubling the number of graduate students over 10 years. This led to the establishment of new graduate schools at many universities. In addition, prior to and following this recommendation, certain top universities changed faculties' status from undergraduate departments to graduate schools. This led to an increase of the capacity of graduate students, which is regulated by the Ministry based on the number of faculties affiliated to graduate schools.

The increase of graduate students might have enhanced research activity at several universities and could partly explain the increase in the number of publications since 1991. However, despite the increase of students in absolute term, approximately 70% of the doctoral students belong to national universities after 1995. This figure was 60% in the mid-1980s. Furthermore, approximately 35% belonged to the top eight universities during the 20 years examined. The increase of students at the top universities implies that a greater concentration of brilliant students to these top universities was possible because they offered a better environment for education and research. This trend could have widened the differences in performance among universities.

On the other hand, financial resources also became concentrated into a small number of universities. The University Council's reports around 1990 mentioned the importance of an internationally high-level 'centre of excellence (COE)', and graduate schools were expected to strive for it. The COE policy, in general, requires the prioritised distribution of resources. In Japan, the primary portion of block grants for the research activities of national universities had been distributed by a formula based on the number of faculties, regardless of performance. This part of block grants was equally calculated for all national universities. However, its unit price did not increase in nominal terms in the 1980s; that is, it decreased in real terms.[12]

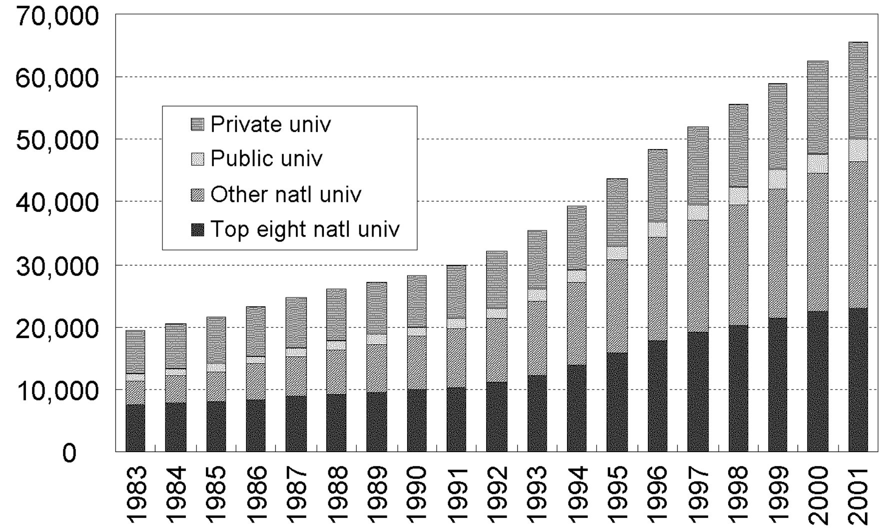

Figure 10. Number of doctoral students
Source: School Basic Survey (Monbusho) and *University List* (JUAA)

After the University Council made its recommendations, new items such as 'special funds for the promotion of the advancement of education and research' and 'prioritised funds for advanced equipment for graduate schools' were established in the block grant. These new funds were distributed to universities that can produce excellent research and educational results or those that undertook new challenges. This implies that even the block grants were gradually concentrated to a small number of universities.

Moreover, competitive R&D project funds which are distributed based on reviews of proposals were also concentrated to these universities. In Japan, the Grant-in-Aid for Scientific Research by the Monbusho has been the biggest programme for academic research. As shown in Figure 11, this fund developed in the 1990s. In addition, seven basic research programmes and other competitive programmes were established after the First Basic Plan. Thus, the system of university funding changed from a quasi-monopoly of Grant-in-Aid to multi-funding sources.[13] However, despite the radical increase of funds, the top eight universities were awarded 49% of the entire funds distributed to universities by the Grant-in-Aid in 2001. In regard to the entire public competitive R&D funds distributed to universities, of which the Grant-in-Aid accounts for approximately half, the top eight universities were awarded 52%.[14] Thus, the financial resources have also concentrated to a small number of universities since 1996.

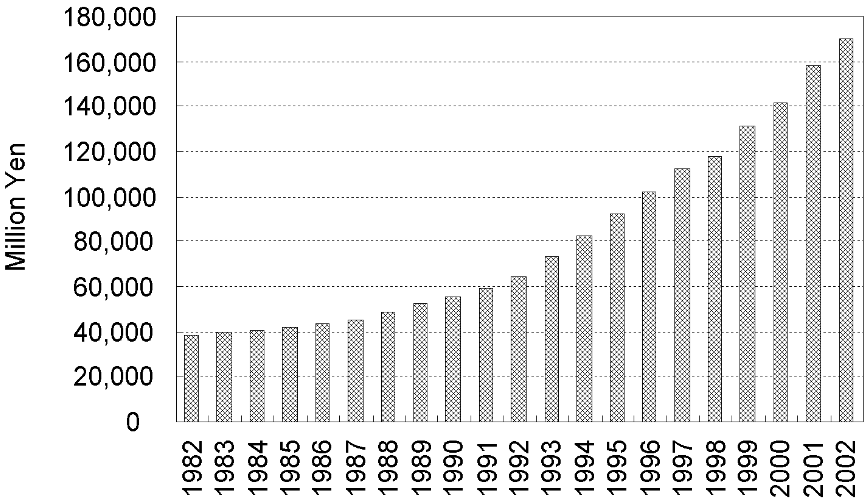

Figure 11. Grant-in-Aid for scientif research (budget)
Source: White paper of Monbusho and MEXT

Table 2. Correlation coefficients between publications and inputs

Variables	1	2	3	4	5
1. All publications / faculty					
2. Top 10% publications / faculty	0.83**				
3. Doctoral course student / faculty	0.56**	0.71**			
4. JSPS post-doctoral fellow / faculty	0.69**	0.64**	0.42**		
5. R&D expenditure except for labor costs / faculty	0.28*	0.47**	0.43**	0.46**	
6. R&D funds received / faculty	0.74**	0.90**	0.75**	0.56**	0.53**

* $p<0.05$ ** $p<0.01$
Case: 75 national universities (all date are restricted to natural sciences excluding social sciences and humanities)
Source: Publications – authors calculation based on SCI (2001)
Students, R&D expenditure and funds – *Report on the Survey of Research and Development* (2000)
JSPS post-doctoral fellow – The survey of graduate schools by MEXT (2000).

Table 2 shows Pearson's correlation coefficients between the number of publications (both all and top10% publications) per faculty and four variables of resources per faculty for 75 national universities which have doctoral courses in natural sciences. Four variables are the number of doctoral course students, the post doctoral fellows funded by JSPS, R&D expenditure (excluding labour costs), and R&D funds received (mainly project grants awarded by the government) and these values are restricted to natural sciences excluding social sciences and humanities. The result reveals that the R&D funds, post-doctoral fellows and doctoral students significantly correlate with the number of all publications per faculty ($r = 0.74$, 0.69 and 0.56

respectively; $p<0.01$). Further, R&D funds and doctoral students have stronger correlations with the number of top 10% publications ($r = 0.90$ and 0.71; $p<0.01$) than with that of all publications. Considering that the number of post-doctoral fellows was small in Japan, this result implies that the concentration of two resources indeed contributes to enhance high impact research.

In addition to the increase in resources, we can view the situation in a different context. The report of the University Council in 1991 introduced 'the self monitoring and evaluation' system into universities. Following this, almost all universities conducted self-monitoring to some extent. In the Australian case analysed by Butler, the introduction of performance-based funding led the faculties to select low-citation journals in order to publish more.[2,15] Although Japanese 'self-monitoring and evaluation' system was merely a self-evaluation which is not linked with funding, a survey on the implementation of self-monitoring and evaluation in 1999 revealed that 90.2% of universities included research publication list of all faculties in their self-monitoring and evaluation report, while 82.2% considered the list as a significant measure to be used in their self-evaluation process.[16] Thus, the new evaluation system might have implicitly increased the pressure on faculties to publish more, as observed in the case of Australia. In the following decade, more evaluation systems such as the R&D project evaluation based on national guidelines in 1997 and the establishment of an independent organisation (NIAD-UE) to evaluate universities were institutionalised and the pressure to publish increased even more.

These factors might have affected the universities' research activities. In addition to the cultural change in the research community to publish in international journals rather than domestic ones, the equally distributed block grant promoted decentralisation in the 1980s, as shown by the decrease of the Herfindahl index. Also after 1990, the increase in the number of doctoral students and the introduction of evaluation affected the rate of increase of low-cited publications, but the human and financial resources gradually concentrated in a small number of universities that were traditionally ranked at the top of the hierarchy. Following the Basic Plan in 1996, although R&D project funds radically expanded, half of these funds were distributed among eight universities. As the initial effect of the new evaluation system gradually stabilized, the productivity of low-cited publications decreased, the Herfindahl index became constant and the share of eight top universities slightly increased, particularly with regard to their share of high-impact publications.

Networks between and within sectors

Based on the abovementioned results, can we say that further concentration of human and financial resources in a small number of universities can increase high-impact publications? Merely providing an affirmative answer would be misleading because the increase of research actors and concentration of resources are simultaneously promoting a third characteristic, i.e. networking between and within sectors.

As to the eight top universities, co-authorships with other universities and other sectors have increased. In 1991, percent of co-authored publications as of the entire eight universities' publication (N = 15,432) was 46.2%, that is, more than half of university publications were produced by a single university. In 2001, the rate of co-authorship became 61.8% of 23,892 publications. Within the top 10% publications, the rate of co-authorship was slightly higher, at 68.1% in 2001. Within this 68.1%, 12.5% were co-authored among eight universities, 27.1% with other universities, 14.8% with semi-public research institutes, 8.7% with industry, 7.7% with national research institutes and 29.1% with foreign countries. These observations imply that the top eight universities produced more than half of their high impact publications by co-authoring with others. Thus, if there is an excess of concentration of resources to only a small number of universities, to the point that other universities will face difficulties to continue their research, there is a risk of disintegrating the existing collaboration network that can produce high-impact results.

With respect to the other universities and sectors, the significance of entering into a partnership with a university that is counted among the top eight has also increased as shown in Table 3. With regard to other universities' publications, the rate of co-authorship with the top eight increased from 15.6% in 1991 to 18.5% in 2001. With regard to the top 10% publications, the rate was 27.2% in 2001, which implies that more than one-fourth of their high-impact publications had a co-author from at least one of the eight universities.

Table 3. Rate of co-authorship with universities in 2001

	All publications		Top 10% publications	
	With top eight natl univ (N = 23,892)	With not-top univ (N = 37,527)	With top eight natl univ (N = 2394)	With not-top univ (N = 2384)
Top eight natl univ	9.8%*	29.0%	12.5%*	27.1%
Not-top univ	18.5%	20.9%*	27.2%	23.3%*
Semi-public res inst	47.8%	37.9%	58.0%	35.9%
Natl res inst	23.6%	33.9%	30.3%	32.1%
Industry	23.0%	36.8%	28.3%	30.6%
Regional govern res inst	21.9%	54.9%	27.2%	58.3%
Hospital	25.8%	58.7%	29.1%	55.5%

(Authors calculation based on SCI)
* co-authorship with other universities in the same groups.

Semi-public research institutes co-authored 58.0% of their top 10% publications with the eight universities. As explained before, JST is a special organisation that forms researchers from universities and other sectors. Thus, 71.7% of the entire publications of semi-public research institutes were co-authored with the eight universities. RIKEN also produced 50.5% of their publications with the eight universities. National research institutes produced 27.2% of their publications with the top universities. These networks of public research institutes and universities have two aspects. First, research projects are frequently conducted with faculties of top universities as the project leader, as typically observed in the case of programmes established by the JST. The other aspect is that universities use the public research institutes to conduct advanced research and education beyond their traditional departmental structure. For instance, with the expansion of graduate schools after 1991, the 'Collaborative Graduate Studies Program' was introduced in certain universities, which enabled them to use external researchers from public research institutes as guest professors and supervisors of doctoral students. For example, RIKEN presently cooperates with 21 universities and AIST with 49 universities. Thus, research and education are conducted across the boundary of university and public research institute. Based on these results, we can say on one hand that the top universities are significant partners for some sectors, particularly when conducting high-level basic research. On the other hand, top universities are incapable of producing more than half of the high-impact publications without cooperation.

However, we should note that other universities that are not ranked at the top are never peripheral with respect to other sectors. As shown in Table 3, they construct other type of networks, particularly with regional governmental research institutes and hospitals. These sectors produced a greater number of co-authorships with other universities than with the top universities. It is understandable that medical schools would cooperate with hospitals in the same region, and that regional research institutes would cooperate with neighbouring universities in engineering, agriculture and environment research. As seen not only in Japan but also worldwide, objectives of research activities of universities are diversifying and they require different type of collaboration with heterogeneous actors.[17] The co-authorship analysis indicates that the highly ranked universities and other universities have different roles to play in the knowledge production enterprise. Thus, resources should not be exceedingly concentrated to a handful of universities, and research activities should be financially supported by various means.

Conclusion

This paper analysed the transition of the Japanese research system and its performance over a period of 20 years. Japan is the second largest producer of academic publications, but it still shows the characteristics of a "catching-up country", in which the percent of low-cited publications is high. Such characteristic can be explained by the increase of both the human and the financial resources in the 1990s. The COE policy to establish internationally high-level universities enhanced the concentration of increased resources to the top ranking universities. This concentration resulted in the increase of high-impact publications and the formation of networks among the top eight universities in basic research.

Such concentration is likely to be fostered in the future as the Council for S&T Policy (CSTP) is strongly recommending the increase of competitive research funds rather than the non-competitive earmarks. Furthermore, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) launched the '21st century COE program' in 2001, in which 30 graduate schools by field were funded after a severe selection process. This programme was highly competitive as who receives the fund is not decided ex ante by the traditional hierarchy. However, it cannot be totally fair as there already exists a considerable disparity in the infrastructure and the resources between the top universities and the others. The top universities are therefore in an advantageous position, whereas other universities are required to develop their solid strategy, such as the priority setting in research fields, to boost their research. In April 2004, the status of all national universities changed to Independent Administrative Institute (IAI). This significant reform also requires universities to develop a management system which is highly strategic.

It is not yet clear whether the new system will actually increase the quantity of publications, improve the quality, foster network between institutes or individual scientists. The system of evaluation and funding is still under discussion. The effects of the new policy need to be continuously monitored using the quantitative indicators presented in this study.

References

1. NISTEP, *Science and Technology Indicators: 2004 A Systematic Analysis of Science and Technology Activities in Japan.* 2004.
2. L. BUTLER, Modifying publication practices in response to funding formulas. *Research Evaluation*, 12 (2003) 39–46.
3. A. SCHUBERT, T. BRAUN, Cross-field normalization of scientometrics indicators. *Scientometrics*, 36 (1996) 311–324.
4. SCIENCE AND TECHNOLOGY AGENCY, *Survey on the current states of national research activities in 1999, 2000.* (in Japanese).
5. J. S. KATZ, D. HICKS, M. SHARP, B. R. MARTIN, *The Changing Shape of British Science*. STEEP special report no. 3, 1995.
6. B. GODIN, Y. GINGRAS, The place of university in the system of knowledge production. *Research Policy*, 29 (2000) 273–278.
7. T. HAYASHI, Effect of R&D programmes on the formation of university–industry–government networks: comparative analysis of Japanese R&D programmes. *Research Policy,* 32 (2003) 1421–1442.
8. MEXT, *Nationwide List of Research Institutes in Japan,* LATTICE, 2003.
9. NATIONAL INSTITUTE OF SCIENCE & TECHNOLOGY POLICY (NISTEP), *Study for Evaluating the Achievements of the S&T Basic Plans in Japan: Quantitative and Qualitative Analysis of the Outputs of Research and Development*. NISTEP REPORT No.88, March, 2005. [in Japanese] (to be publish English summary).

10. F. YOSHIKANE, Concentration in bibliometric distributions: the notion of concentration and concentration measures. *Journal of Japan Society of Library and Information Science*, 46 (2000) 18–32 (in Japanese).
11. UNIVERSITY COUNCIL, *Report on Quantitative Expansion of Graduate Schools*, 1991 (in Japanese).
12. A. ASONUMA, Financial reform in Japanese higher education. *Higher Education*, 43 (2002) 109–126.
13. S. KOBAYASHI, Y. OKUBO, Demand articulation, a key factor in the reconfiguration of the present Japanese science and technology system. *Science and Public Policy*, 31 (2004) 55–67.
14. CABINET OFFICE, *Reform of Competitive Research Funding Program for Advanced Science- and Technology-Oriented Nation*. National Printing Bureau, 2004 (in Japanese).
15. L. BUTLER, Explaining Australia's increased share of ISI publications – the effect of a funding formula based on publication counts, *Research Policy,* 32 (2003) 143–155.
16. A. YONEZAWA et al., *University Evaluation – Trends and Tasks*, Review in Higher Education no. 62, 2000 (in Japanese).
17. M. GIBBONS, C. LIMOGES, H. NOWOTNY, S. SCHWARTZMAN, P. SCOTT, M. TROW: *The New Production of Knowledge,* Sage, 1994.