Restructuring the Japanese National Research System and its Effect on Performance

Takayuki Hayashi* and Hiroyuki Tomizawa**

*hayashi@niad.ac.jp
NIAD-UE (National Institution for Academic Degrees and University Evaluation), Faculty of University Evaluation and Research, 1-29-1 Gakuen-Nishi-machi, Kodaira-shi, Tokyo 187-8587 (Japan)

**tomizawa@nisteg.go.jp
NISTEP (National Institute of Science and Technology Policy), 2-5-1 Marunouchi, Chiyoda-ku, Tokyo 100-0005(Japan)

Abstract
The Japanese government has been attempting to reform the national research system for the past 20 years. This paper elucidates the structural changes of the system and its performance by highly extensive bibliometric analyses and discusses the effects of S&T policy on it. The results indicate that although Japan gradually increased its production of highly cited publications, its share of low-cited publications was much higher than the former. This tendency of Japan is contrary to that of other advanced countries. 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 radically increased their low-cited publications since 1990. The expansion of financial and human resources for research in the 1990s enabled new actors to be involved in scientific research, but gradually the resources are being concentrated in a small number of universities.

Introduction
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 demands that Japan's contributions in R&D should reflect its economic strength more accurately. Moreover, the government itself realised that further economic advancement was impossible in the absence of abundant R&D. In this context, the Council for Science and Technology, in its 'General Guideline' in 1986, determined that the promotion of 'creative' science and technology should be the primary concern of the science and technology policy.
However, in the 1980s, the financial conditions were 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 expenditures of private industries, which accounted for 70–80% of the 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 Basic Plan was established. This plan called for increasing the public R&D expenditures to 17 trillion yen (about 150 billion US$) for the next five years. Based on the plan, seven new basic research programmes were established and the guidelines for national R&D evaluation were decided upon. In 2001, the Second Basic Plan was established, which stipulated an expenditure of 24 trillion yen (220 billion US$) for public R&D for the next five years.

As just described above, the Japanese government continuously reformed its national research system with the enormous public expenditures. However it is not clear what effects arose on the system and performance in these 20 years: 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? This paper examines the transition of the structure of the Japanese national research system over a period of 20 years by undertaking quantitative analyses of huge number of publications.

Proceedings of ISSI 2005, pages 625–634.
Edited by P. Ingwersen and B. Larsen.

Japanese Research Performance at the Macro-level

Share of Japan's publications by citation frequency rank

It has been frequently highlighted that Japan has increased the number of its publications and is now ranked in the second group among the producers of science publications (excluding the social sciences) next to the U.S. The share of Japan's publications (publications having at least one author with a Japan address) in the *National Science Indicators* increased from 6.6% in 1981 to 10.1% in 2001. However, one criticism has been that the citation impact of Japan's publications has not yet reached international levels. The Relative Citation Index (RCI), which is calculated by dividing the share of citations by the share of publications, has been consistently below 0.9 (NISTEP 2004). This implies that, although Japan has been increasing its number of publications, most have been cited only a few times on an average.

However, on the other hand, Japanese researchers have published many articles in top-level journals such as *Nature* and *Science* since the early 80s, and Japan's contribution to academic 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 in the case of those with a medium citation impact. Such a determination requires detailed analyses of the distribution of publications by their impact.

As an example of detailed analyses of distribution, Butler (2003a) analysed the Australian universities' share of publications by classifying journals into four quartiles based on their five-year average citation impact. 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 journal impact 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 (CD-ROM version)* from 1982 to 2003 as a data source and re-constructed and manipulated it as follows: First, references of all publications contained in each year's *SCI* were collected and frequencies of their occurrences were counted after making some modifications of the fluctuations of notations of authors' initials, of research-team names and of journal names. Next, all publications on each year's CD-ROM were matched with the list of references using the first author's name, first character of the journal's name, volume and pages. The citation frequencies of all publications (not only Japan's publications but all) in *SCI* until 2003 were counted in this manner.

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 (using approximately 170 research fields, which are provided to journals by the ISI). With regard to journals that were classified into more than one research field, publications were fractionally counted in each field. Publications that were carried 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; that is, research fields of referenced journals were counted and the ones appearing most frequently were selected. 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 (c.f. Shubert and Braun 1996). 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 Japan's publications in the top 10% and in each quartile as top 25%, 25–50%, 50–75% and 75–100% according to each research field.

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

However, Fig. 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.

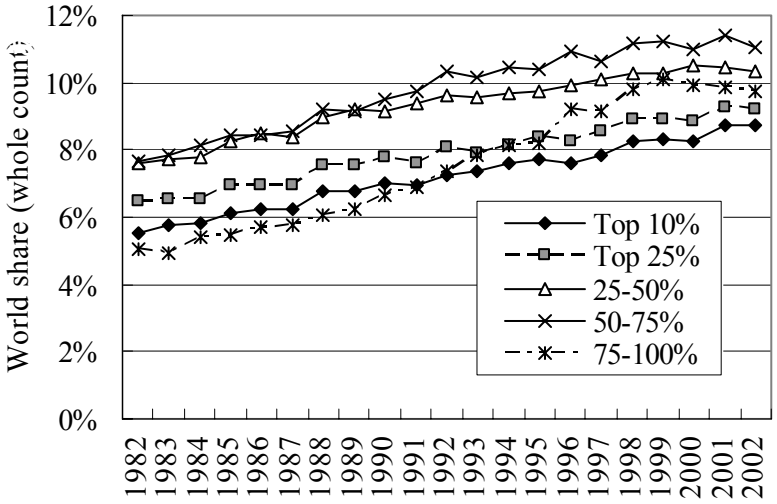

Fig.1: Share of Japan's publications in *SCI* according to citation ranking.

Comparison among countries

If this characteristic—highest share in low-cited publications—was typically observed in all advanced countries, it would be expected that the production of many low-cited publications is an essential part of the process of producing an influential publication, and therefore, we would not be disappointed with the above result. Our re-constructed database makes it possible to count the publications produced by other countries by citation rank in the same manner as Japan's case and to compare the distributions of publications by citation rank among countries. Figure 2 shows the shares for some other countries in 2000 according to each citation-ranking group.

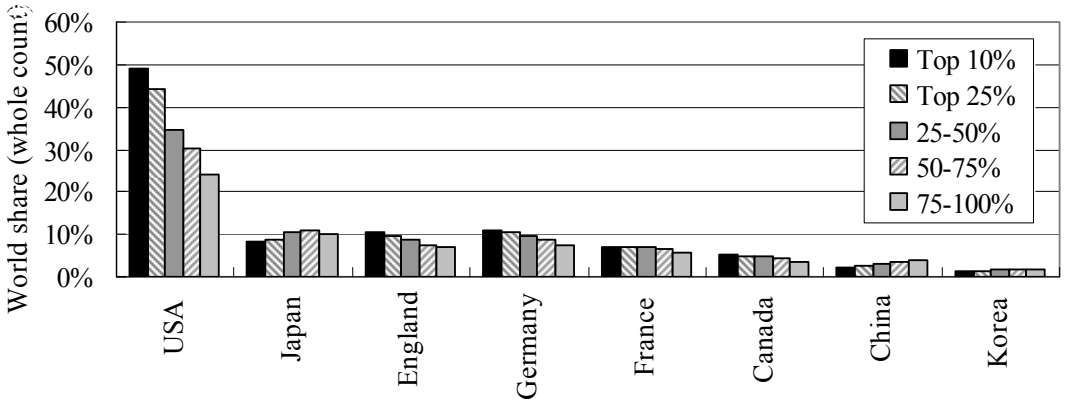

Fig. 2: Countries' shares of publication in 2000 by citation ranking

The figure shows that U.S.' share of top 10% publications far exceeds the shares of all the other quartiles. The more citations publications received, the higher the share the U.S. had. This tendency is also observed with regard to England, Germany, France and Canada, although the values of the share are far below those of the U.S. The tendency with regard to Japan is contrary to that with respect to these advanced countries. The more citations publications received, the fewer shares Japan had, with the exception of the last quartile. This tendency is rather similar to the tendencies observed in the case of China and South Korea.

Figure 3 shows the trends of distributions in four countries. There are varieties of trends; U.S. has decreased its shares, while England kept its share and France increased slightly. Radical increase by 5% as observed in Japan's fourth quartile is only seen in China in this decade.

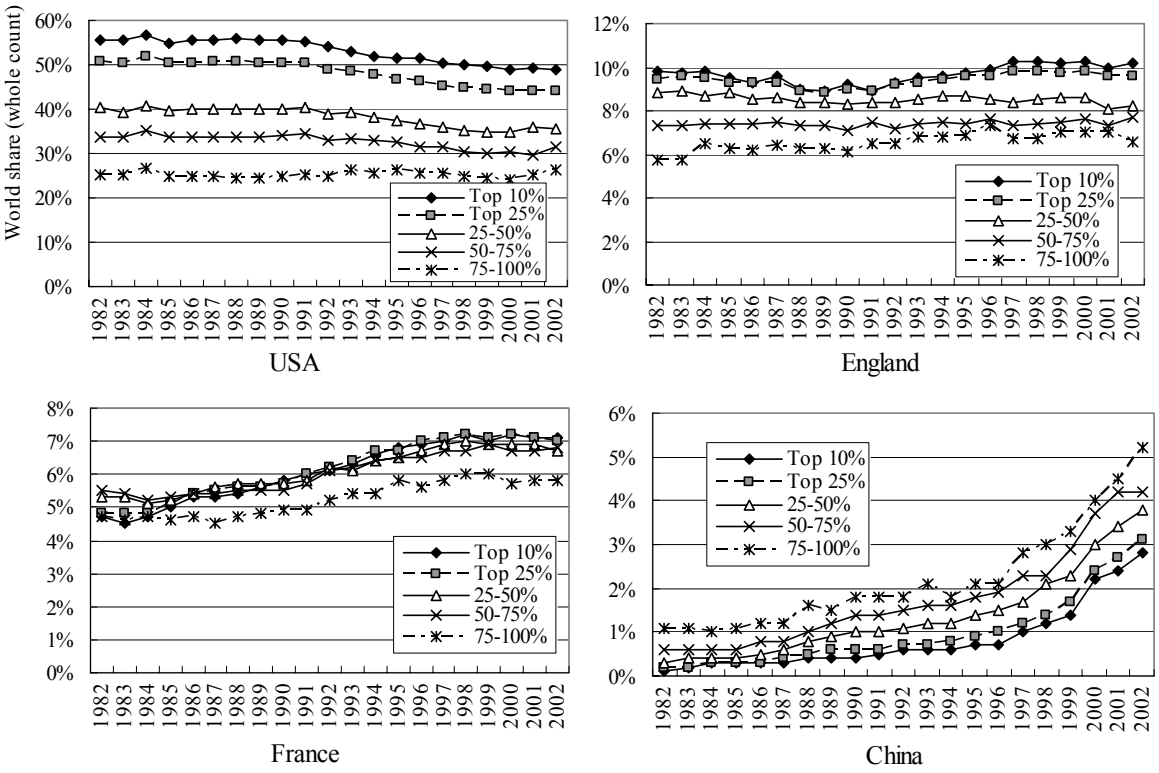

Fig. 3: Trends of shares in four courtiers

These results show that Japan still has the tendency of a 'catching-up' country, despite being one of the second-highest producers of publications.

Meso-level analyses of sectors and the structure of concentration

Transition in the shares of sectors

If the bibliometric analyses reflect Japan's research, performance and quality, why have these characteristics emerged in Japan? As explained in the introduction section, there have been some initiatives with regard to the S&T policy within the period, and each of them is related to particular sectors. Therefore, the structure of research actors in Japan might have changed, which in turn would affect the macro-level characteristics of Japan. Thus, in what follows, we conduct more detailed analyses by dividing the actors that produced the results.

With regard to this analysis, first, all authors' affiliations were classified into several sectors as in Katz et al. (1995), Godin and Gingras (2000) and Hayashi (2003). In this study, Japanese research organisations were classified into the following sectors: universities (including 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. In the process, first, all affiliations were temporally classified automatically by keywords such as 'UNIV', 'COLL', 'HOSP', 'CORP', 'LTD' etc. Next, the affiliation data was matched with a list of the English abbreviated names of research organisations in Japan, that was constructed using *the Nationwide List of Research Institutes in Japan* (MEXT 2003) and the JST's *Directory Database of Research and Development Activities* ('ReaD'). 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 identified, but the percentage of unclassified addresses was less than 0.1% among all Japan addresses.

Figure 4 shows the shares of sectors' publications in the *SCI* by fractional counting of co-authorship (Thus, 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 Japan's publications decreased from 77% in 1982 to 73% in 1991 for the increase of other sectors' publication, it slightly increased then to 74%

in 2002. In the case of whole counting, approximately 80% of Japan's 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 publications by Japan's university sector have been growing, and the relative importance of the university sector in knowledge production has been extremely high and has been increasing since the mid-1990s.

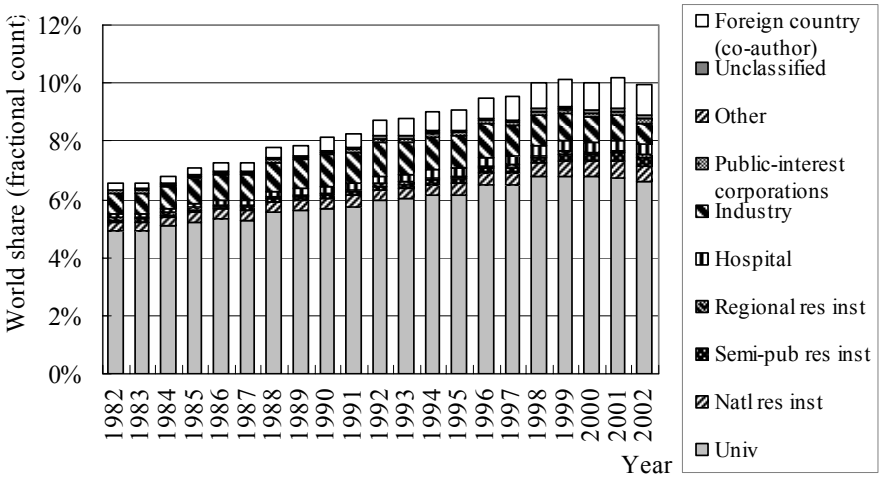

Fig.4: Shares by sector

On the other hand, other sectors have also expanded their 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 its publications, and particularly JST made the greatest contribution to the radical increase. JST functions more as a funding agency than a research institute. However, it periodically puts together research groups in its programmes by hiring researchers from several sectors and post-doctoral fellows on a part-time basis, or for a fixed term. 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. This expansion of activities increased the publications by JST. RIKEN, another semi public research institute, has also expanded its research activities, establishing several new research centres in various research fields. Thus, JST and RIKEN have become the most productive organisations in Japan, following approximately ten universities.

As a result of the policy shift to basic research, the national research institutes also expanded their 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. Excluding industry, other sectors such as hospitals and public-interest corporations, consistently increased their world share. However the number of industries' publications peaked during 1992–1996 and decreased thereafter. The industrial sector gradually discontinued conducting basic research in its own central research laboratories, and this was accelerated by the economic depression of the 1990s. In the fields of physics and chemistry, wherein the industry had previously produced more publications than all other research fields, the drop in the number of publications was substantial—a decrease of 0.62 times and 0.71 times respectively within a span of 10 years.

Classifying the publications according to the citation ranking as in the previous section revealed that all major sectors, with the exception of semi-public research institutes and public-interest corporations, had attained a peak 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%, which is identical to the macro-level trend of other advanced countries such as the U.S. and England.

Changes within the university sector

Since the university sector accounts for 80% of Japan's publications, the macro-level characteristic of Japan's publications in Fig. 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-university research institutes.

Figure 5 shows the share of each university category, in which the eight most productive national universities are shown separately from the national university. As shown in the figure, the 99 national universities accounted for approximately 70% of the university sector's publications by fractional counting, and only 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. On the other hand, other national universities (excluding eight universities), public and private universities have increased their world shares, and the actual numbers of publications have become 2.3, 2.5 and 2.3 times, 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.

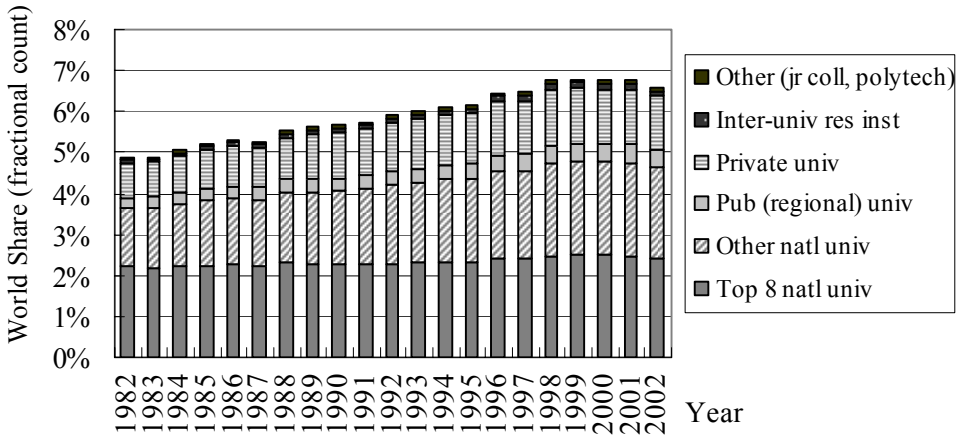

Fig. 5: Shares of universities for all publications

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 (Fig.6). In the case of whole counting, at least one of the eight universities appeared in 58.0% of universities' publications and 47.9% of Japan's 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 Fig.5. On the other hand, 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.

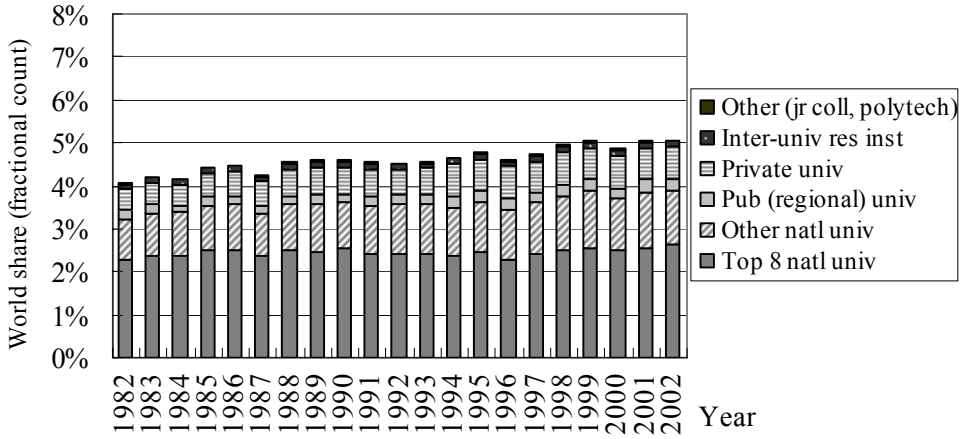

Fig. 6: Shares of universities for top 10% publications

On the contrary, in the fourth quartile, wherein Japan radically increased its share in the 1990s, the top eight universities had a lower share than in other quartiles and slightly increased their share to 2%. However, the share for other universities dramatically increased and considerably peaked in the latter part of the 1990s (Fig. 7).

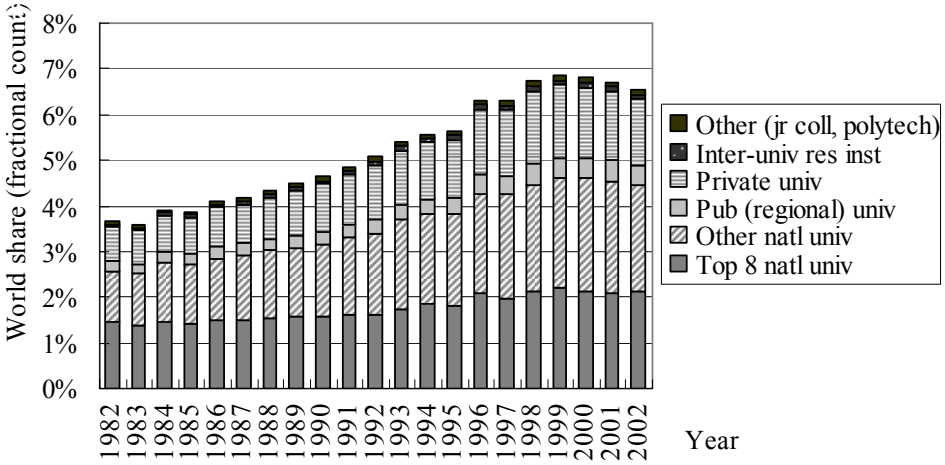

Fig.7: Shares of universities for 75-100% publications

Expansion of research activities and concentration of excellence

In the above analyses, we simultaneously observe two opposing characteristics in the Japanese research system: decentralization of research activities and concentration of excellence. 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:

$$H=\Sigma Si^2 *10000$$

where Si 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 and the degree of relative concentration within actors (Yoshikane 2000).

In Fig. 8, with regard to all the 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.

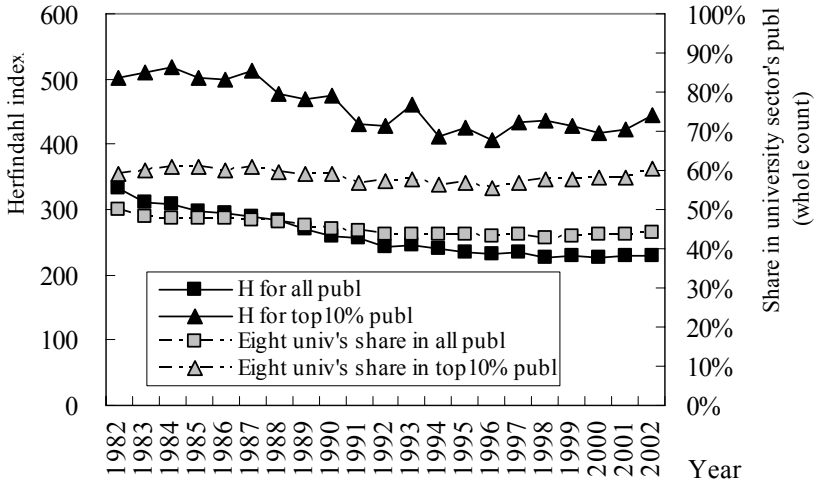

Fig. 8: Degree of concentration and share of top universities.

On the other hand, 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 onwards.

Relationships with the policy

A summary of this and the preceding section is as follows:

1) University publications increased from the 1980s with a radical increase in low-cited publications by universities that were not included in the top-ranking category since 1991, and they peaked in 1999.
2) Decentralisation that began in the 1980s ceased in 1996, and the 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.

On the other hand, the number of doctoral students radically increased after 1991. This is also the period during which the fourth quartile publications began to increase (Fig. 9). 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 Monbusyo (Ministry of Education), published a report in 1991 that recommended the expansion of graduate schools (University Council 1991). 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' affiliations from undergraduate departments to graduate schools. This led to an increase in the capacity for graduate students, as determined by a formula using the number of faculties.

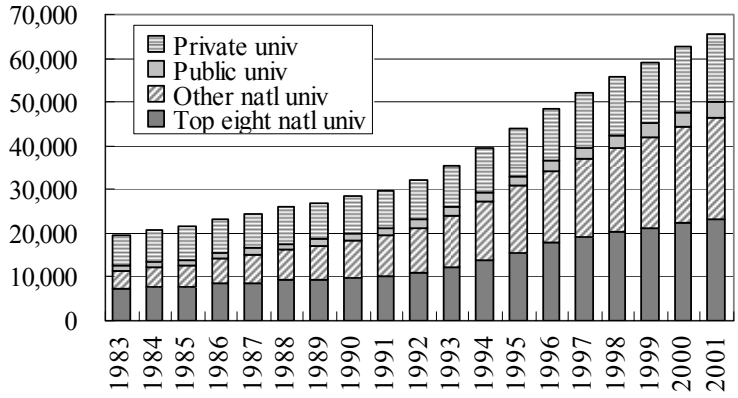

Fig. 9: Number of doctoral students.

The radical expansion in the capacity of graduate students might have activated research at several universities and could partly explain the increase in the number of publications since 1991. However, despite the increase, approximately 70% of the doctoral students belonged to national universities after 1995. This figure was 60% in the mid-1980s. Further, approximately 35% belonged to the top eight universities through the 20 years. The increased capacity for students at the top universities implied that there existed a greater concentration of brilliant students because they offered a better environment for education and research. This could have widened the differences in performance among the universities.

On the other hand, financial resources were also gradually 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. Generally speaking, the COE policy 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. Thus, 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 (Asonuma 2002). On the other hand, after the University Council made its recommendations, certain new items were established in the block grant, such as 'special funds for the promotion of the advancement of education and research' and 'prioritised funds for advanced equipment for graduate schools', which 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 in a small number of universities.

Moreover, R&D project funds, which are competitively distributed based on reviews of proposals, concentrated on 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 Fig. 10, this fund expanded in the 1990s. However, in 2001, despite the radical increase of funds, the top eight universities were awarded 49% of the portion distributed to universities by the Grant-in-Aid and 52% of the portion of all public competitive R&D funds distributed to universities, of which the Grant-in-Aid accounts for approximately half (Cabinet Office 2004). Thus, the financial resources have also concentrated in a small number of universities since 1996.

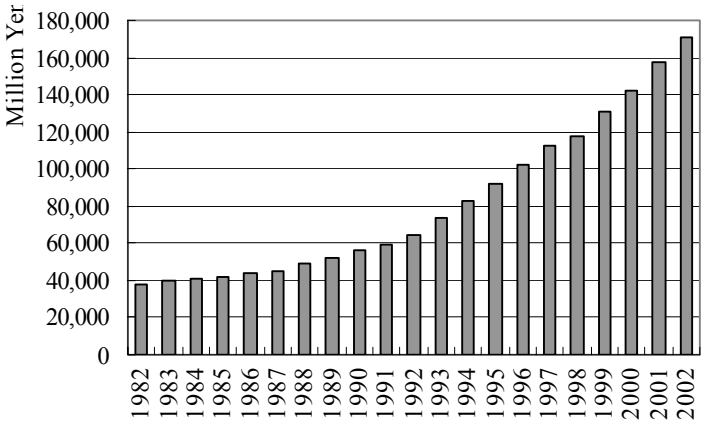

Fig. 10: Grant-in-Aid for Scientific Research (budget).

In addition to the increase in resources, we can view the situation in a different context. The reports of the University Council in 1991 introduced 'the self monitoring and evaluation' into universities. In the Australian case analysed by Butler (2003a, b), the introduction of performance-based funding led the faculties to select low-citation journals in order to publish more. Japanese 'self-monitoring and evaluation' was merely self-evaluation and was not linked with funding, but a survey of universities revealed that 90.2% of universities listed research publications in the report, and 82.2% emphasised them in the evaluation process (Yonezawa et al. 2000). Thus, the evaluation might implicitly strengthen the pressure on faculties to publish more, as observed in the case of Australia.

These factors might have affected the universities' research activities. In addition to the cultural change in the tendency of 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 introduction of evaluation gradually matured, the radical expansion of low-cited publications decelerated, the Herfindahl index became constant and the share of those eight universities slightly increased, particularly with regard to their share of high-impact publications.

Conclusion

This paper analysed the transition in the Japanese research system and its performance over a period of 20 years. Japan is one of the second largest producers of academic publications, but it still displays the characteristics of a catching-up country, in which the share of low-cited publications is high. This can be explained by the expansion of research activities due to increasing human and financial resources in the 1990s. Simultaneously, the COE policy to establish internationally high-level universities promoted the prioritised increase of resources in the top universities. This resulted in the increase of their high-impact publications.

In the future, this concentration will be fostered. The Council for S&T Policy is strongly recommending the increase of competitive research funds rather than the non-competitive appropriations. Further, with respect to the higher-education policy, the Ministry of Education, Culture, Sports, Science and Technology launched the '21st century COE program' in 2001, in which 30 graduate schools are competitively selected for funding in each field. Indeed the top universities are in an advantageous position for the good environment for research, but other universities is constructing their strategic decisions, such as a priority setting in research fields, to boost their research. In April 2004, all national universities incorporated and became a type of Independent Administrative Institute. This significant reform also requires strategic management in universities.

It is not yet clear whether the new system is actually increasing the quantity of publications or improving their quality and whether it is promoting networking between institutes or individualism. This is because the system of evaluation and funding is still under discussion. The effect of the new policy should be further checked using the quantitative indicators presented in this study.

References

Asonuma A.(2002), Financial reform in Japanese higher education, *Higher Education*, 43, 109-126

Butler, L.(2003a) Modifing publication practices in response to funding formulas. *Research Evaluation*, 12, 39-46

Butler, L.(2003b). Explaining Australia's increased share of ISI publications – the effect of a funding formula based on publication counts, *Research Policy*, 32, 143-155

Cabinet Office (2004). *Reform of competitive research funding program for advance science- and technology-oriented nation*, National Printing Bureau [in Japanese]

Godin, B and Gingras, Y.(2000). The place of university in the system of knowledge production. *Research Policy*, 29, 273–278.

Hayashi T.(2003). Effect of R&D programmes on the formation of university-industry- government networks: comparative analysis of Japanese R&D programmes. *Research Policy*, 32, 1421–1442

Katz, J.S., Hicks, D., Sharp, M. and Martin, B.R.(1995). *The Changing Shape of British Science. STEEP special report no. 3*

MEXT, Nationwide List of Research Institutes in Japan, LATTICE, 2003

NISTEP(2004). *Science and Technology Indicators: 2004 A Systematic Analysis of Science and Technology Activities in Japan*

NISTEP(2005). 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, [in Japanese] (to be publish English summary)

Shubert, A. and Braun, T.(1996). Cross-field Normalization of Scientomerics Indicators. *Scientometrics*, 36, 311-324

University Council(1991). *Report on Quantitative Expansion of Graduate Schools* [in Japanese]

Yonezawa A. et al.(2000). *University Evaluation – Trends and Tasks, Review in Higher Edcuation no.62* [in Japanese]

Yoshikane, F.(2000). Concentration in bibliometric distributions: the notion of concentration and concentration measures. *Journal of Japan Society of Library and Information Science*, 46, 18-32 [in Japanese]