Linkage between Public Science and Technology Development of Genetic Engineering: Preliminary study on patents granted to Japan, Korea and Taiwan

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Abstract

The aim of this study is to demonstrate the basics of the research productivity and linkage between public science and technology development in Genetic Engineering Research by taking the patent bibliometrics approach. The research productivity is demonstrated by patent count and the research linkage is examined by tracing the non-patent citations. 1,048 USPTO patents granted to Japan, Korea and Taiwan from 1976 to 2004 in genetic engineering including gene mutation, cell fusion, genetic modification and recombinant DNA and 2,006 referenced patents cited by those 1,048 patents were examined in this study. The author further constructed the linkage foundation between public science and technology development by examining 10,230 non-patent citations.

1. Introduction

It is widely accepted that public science is a driving force behind technology and economic growth both in scientific and economic communities. It is helpful for the researcher from both sides to understand how the knowledge flows between two sectors. For the private sector, it could be used for strategic planning and the linkage of two sides could be a valuable proof in gaining research support when the resources are limited for the public sector. For the past several decades, plenty studies were done to show the research productivities and impact. There are good amount of studies applied the methods adopted from bibliometrics and periodical articles were the common targets for the studies. With the increasing accessibility of patents information, the studies that applied bibliometrics methods on patents become more noticeable in recent years.

The genetic resources become the valuable assess of the biotech century for the possible academic and commercial developments. Not only the public sector, but also the private sectors devote significant resources into this field. The development of Genetic Engineering technologies is one of areas highly driven by the public science. In this study, the author tried to demonstrate the basics of the research productivity and impact in genetic engineering by taking the patent bibliometrics approach. The linkage between patent and scientific research paper was examined by tracing the non-patent citations. 1,048 USPTO patents in genetic engineering including gene mutation, cell fusion, genetic modification and recombinant DNA that granted to Japan, Korea and Taiwan from 1976 to 2004 were included in the patent set for productivity analysis. 2,006 referenced patents cited by those patents were examined for revealing research impact. The author further constructed the linkage between public science and technology development by analyzing 10,230 non-patent citations. The results did not only show the productivity and research impact of genetic engineering research done in

Japan, Korea and Taiwan but also reported the preliminary results of the study of the linkage between public science and technology development in this research domain.

2. DATA AND RESEARCH METHODS

The data source used in this study is USPTO Patent database, one of the most exhaustive patent sources. The patents analyzed in this study were selected by the International Patent Classification (IPC) numbers and assignee country was added to the criteria to identify the Genetic Engineering patents granted to Japan, Korea and Taiwan. The patents with the following primary IPC numbers were defined as genetic engineering patents. The groups and subgroups included "Mutation or genetic engineering" (C12N 15/00), "Preparation of peptides or proteins" (C12P 21/00, C07H 21/00, C07K 14/00) and "Measuring or testing processes involving nucleic acids" (C12Q 1/68). The U.S. Patent Classification (USPC) Numbers were also considered during the patent search to guarantee the completeness of the dataset. The USPC numbers relate to the genetic engineering, such as subclasses 435/440 and 435/69.1 were added to search strategies. For setting apart the patents granted to Japan, Korea and Taiwan, the assignee country was added to the strategies.

The notion of patent bibliometrics is borrowed from bibliometrics. "Patent Count" was used for productivity analysis and with issued year the annual patent growth could be drawn. To reveal the distribution of the patents among assignees, Bradford's model was used to identify the core assignees that hold a substantial portion of the genetic engineering techniques. "Citation Count" was used for impact and linkage analysis. Times cited of patent and non-patent citations were used as a measurement of the research impact. Further investigation was also done with the highly cited non-patent resources.

Several terms were used in this study.

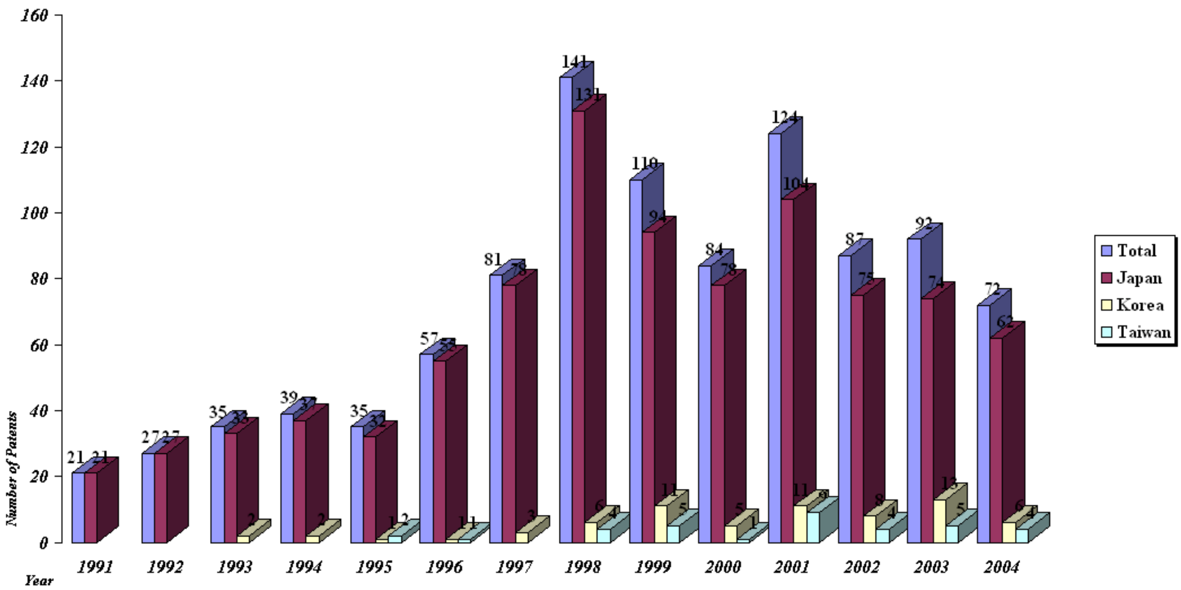
- Patent Count: Count the numbers of the patents granted to different entities, include countries and assignees, during the period of 1976 to 2004. The entities are ranked based on the numbers of patents granted to.
- Bradford's Law: Page headings: Bradford's Law was used to identify the core zone of the assignees that hold significant numbers of patents.
- Citation Count: Count the numbers of patents and non-patent literatures cited by JKT patents. Issued years, types of literatures were included for further analysis.
- Cited Age: Duration from the time of citation issued to the time of cited.

3. RESULTS

3.1. Basic Analysis - Annual Growth

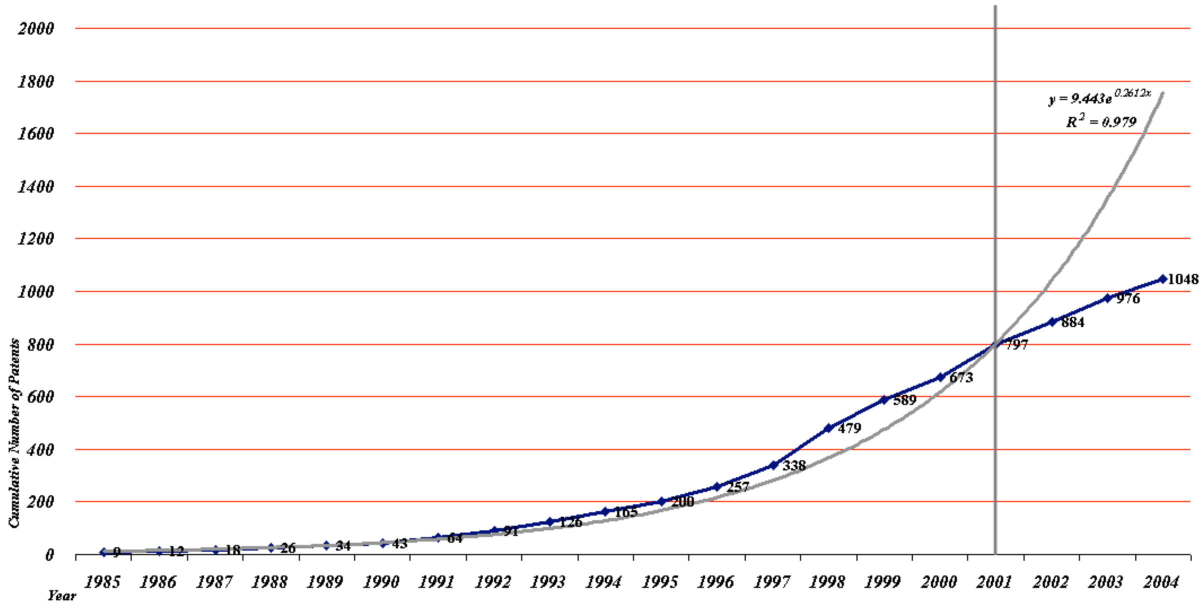
1,048 patents were granted to Japan, Korea and Taiwan during the period of 1976 to 2004. Among these three countries, Japan held the majority of the patents. 944 (90.08%) patents were granted to Japan, 39.33 patents in average annually, but most of the patents were granted after 1991. 1998 was the most productive year for Japan in genetic engineering research, 131 patents were granted that year. Japan also showed innovation capacity in 2001 and 1999, 104 and 94 patents were granted in these two years. Korea and Taiwan were not as productive comparing to Japan, each of these two countries held 69 (6.58%) and 35 (3.34%) patents. Both of Korea and Taiwan were not granted patents early on during the period of 1976 to 2004. It was till 1993 before Korea was granted the first patent and Taiwan was not granted USPTO patent until 1995. Both countries did not demonstrate strong strength in getting patents in any particular year. Figure 1 shows the results of annual patent count from 1991 to 2004 for Japan, Korea and Taiwan.

Fig. 1: Patent Counts - Annual Statistics.



Examining the growth of the patents and the growth curve demonstrated the logistics growth (Figure 2). It started with slow increasing before 1995 and began to add up rapidly during 1996 to 1999 and turned into linear growth after 2000. The annual productivities were higher than the curve predicted during the period from 1996 to 2001 and annual productivity turned into withdrawn period after 2001.

Fig. 2: The Growth Curve of Issued Patents: 1985-2004.



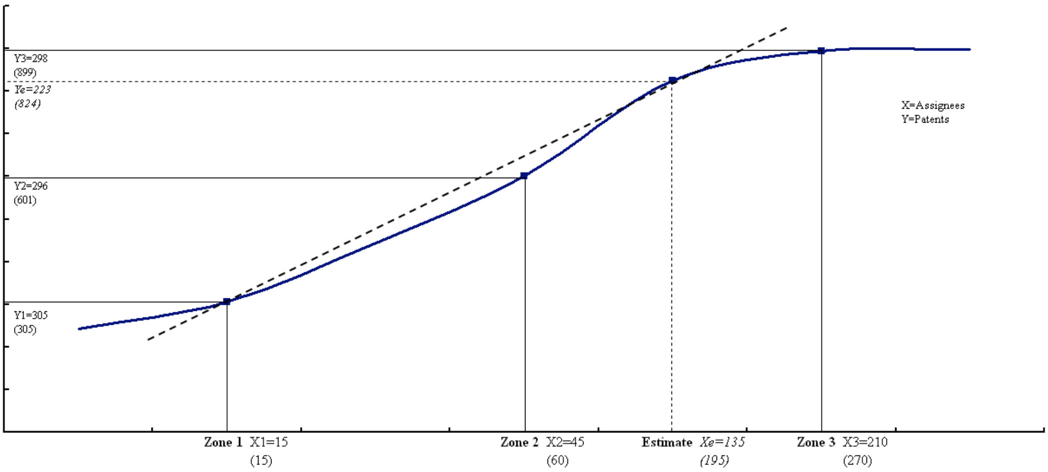
3.2. Basic Analysis - JKT Assignees

270 assignees were identified from patents granted to Japan, Korea and Taiwan. Among them, 235 assignees were Japan based institutions or individual, 26 assignees were Korea based and 9 are from Taiwan. Comparing the numbers of patents owned by the assignees, majority of the assignees owned limited numbers of patents. There were 252 assignees owned less than 10 patents. Among them, 142

(52.40%) assignees owned 1 patent, 50 (18.45%) assignees owned 2 patents and 18 (6.64%) assignees owned 3 patents. The percentage of the assignees owned less than 10 patents is 92.99% and only small portion, 19 (7.01%); of assignees owned more than 10 patents.

Applied the Bradford's Law to analyze the distribution of productivity among assignees and 16 core assignees are identified. The assignees were sorted descending by the numbers of patents granted and divided the 270 assignees into three groups. The number of patents granted to the assignees in each zone was from 295 to 305. It was found 15 assignees in the core zone and the estimate number of assignees in the third zone was off. According the original Bradford's Law equation, the estimate number of assignees was 135 and the number of patents is 824. The adjustment could be made to the original equation, *1:ak:1.5_ak2*, 'a' equals to 15 and 'k' equals to 3. Figure 4 shows the results of the Bradford's Law analysis.

Fig. 3: Distribution of Productivity – Bradford's Law Analysis.



3.3. Citation Analyses

Three types of cited references listed in the patent literatures, USPTO patents, foreign patents and non-patents. The cited references present the sources of research impact on the genetic engineering research done in Japan, Korea and Taiwan. The cited patents presents the influence from the technology development and the non-patent citations were seen as the evidences of the linkage between public science and technology development. The citation count done in this study covered the patent and non-patent citations, detailed analysis was done for non-patent literatures.

3.3.1 Patent Citation Count

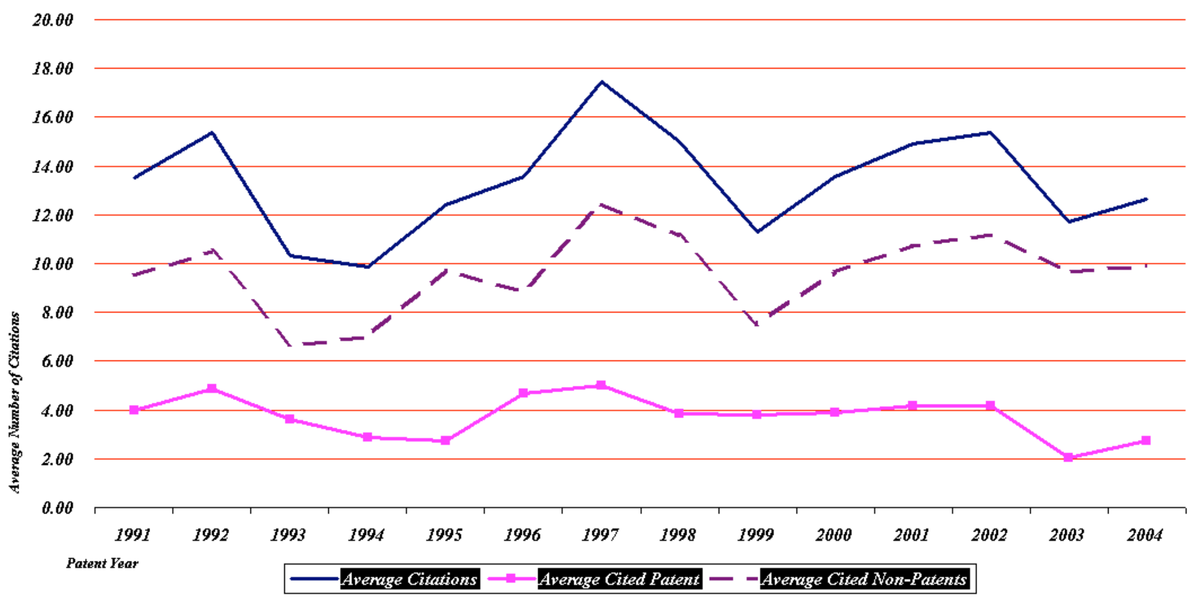
1,048 JKT patents cited 4,945 U.S. patents; each patent cited 4.72 patents in average. 188 out of 944 patents (20%) granted to Japan did not cite patents and other 756 patents cited 3,640 patents that it was 3.86 patents in average. 21 out of 69 patents (30.4%) granted to Korea did not cite any patents and other 48 patents cited 161 patents, which was 2.33 patents in average. As for the patents granted to Taiwan, 9 out 35 patents (22.9%) did not cited patents and other 27 patents cited 109 patents and 3.11 patents in average. The patents granted to Japan, Korea and Taiwan cited 1,819, 106 and 81 USPTO patents. Most of the cited USPTO patents were held by the U.S. based institutions. It implied that U.S. held the primary Genetic Engineering technologies that were with high research impact on the research done in JKT. Besides U.S. based institutions, the institutions based in the same county had the secondary research impact. Although JKT patents also cited patents granted to other countries, the research impact was limited based on the number of cited patents. The average citation age was 6.46.

The average citation age of cited patents referenced by Japan patents was 6.86, mainly was from 2 to 7 years. A few cited patents were over 20 years old. The average citation ages of cited patents referenced by Korea and Taiwan were 6.60 and 5.91, mainly was from 3 to 7 years old.

3.3.2 Non-Patent Citations

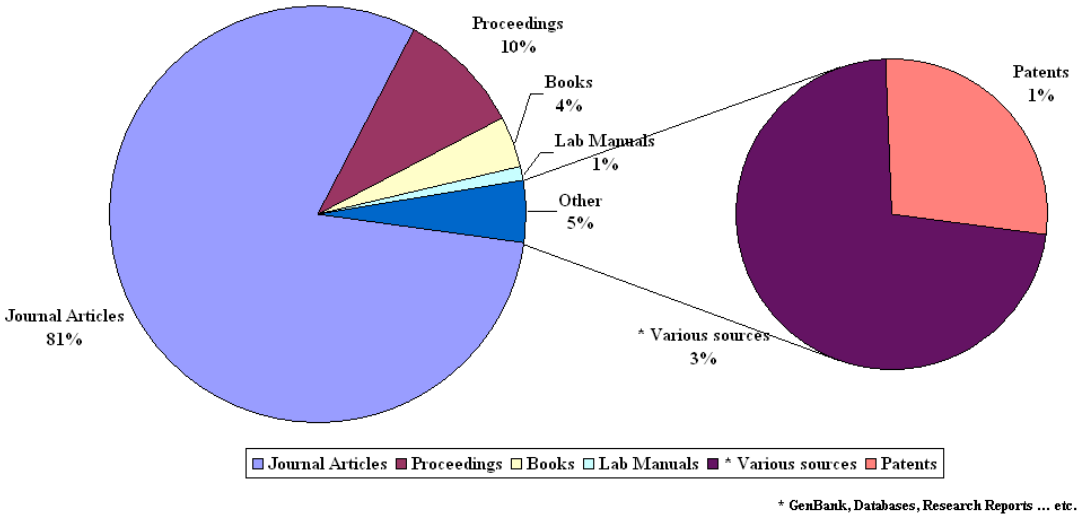
10,230 Non-patent literatures cited by JKT patents, double the number of cited patents. Patents granted to JKT cited 9.54 (J), 8.74(K) and 17.69(T) non-patent citations in average. No particular pattern from the viewpoint of years, except the patents that granted to Japan after 1995 did cite more non-patent literatures in average, but no significant increase. A few patents granted to Korea and Taiwan heavily cited non-patent literatures. In General, the patents reviewed in this study cited more non-patent literature than patents. It presented an indicator of the linkage between public science and technology development. Figure 4 shows the average citations of patents and non-patents referenced by JKT patents issued from 1991 to 2004.

Fig. 4: Average Number of Citations - Patent vs. Non-Patent; from 1991 to 2004.



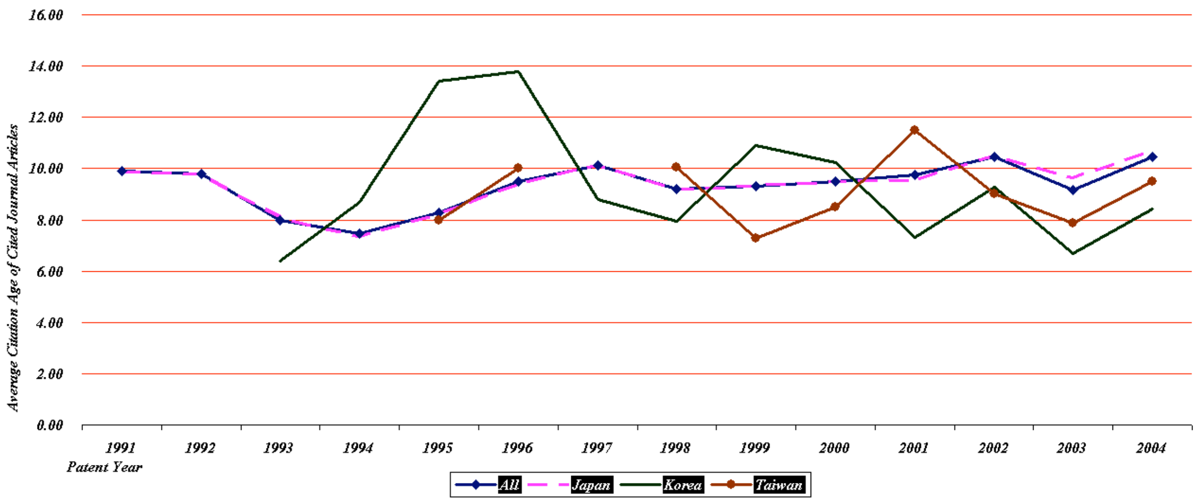
Based on the characteristics of non-patent citations, several material types could be identified that include journal articles, proceeding articles, monographs, lab manual, etc. Journal articles tool major portion of non-patent citations and proceeding articles were also highly cited by JKT patents. Over 80% (8,244) of the non-patent citations were journal articles and close to 10% (971) were conference papers. Similar distribution was shown when examined the cited non-patent literatures of the patents granted to JKT separately. It was found that 1% of the non-patent citations were actually patents or patent related documents. 3% of the non-patent citations were the deposits of genetic materials, DNA sequence information from *GenBank* and unpublished research reports. Figure 5 shows the portions of various materials types.

Fig. 5: Material Types of Non-Patent Citations.



The average cited age was 9.6 and the median age was 8. For the cited journal articles, the average cited age was 9.5 and median was also 8. Most of the cited journal articles were issued during the period of 1986 to 1997. Most of the journal articles cited by Korea owned patents were issued during the period of 1990 to 1995 and the ones cited by Taiwan owned patents published between the years of 1989 to 1995. Figure 6 is a visual display of the distribution of the citation age of journal articles that were cited by the patents granted from 1991 to 2004.

Fig. 6: Distribution of Citation Age of Cited Journal Articles: from 1991 to 2004.



3.4. *Most Cited Journals*

Cited journals articles were published in 991 journals. Close to 90% of journals were cited less than 10 times and only a few journals were highly cited. 58 journals titles (5.85%) were cited more than 20 times. Times of cited of the top 10 journals took one third of the total cited times. Those highly cited journals are in-field journals. Most of the highly cited titles cover the papers with the topics in Biochemistry and Molecular Biology, Genetics Research. Nature and Science that are multidisciplinary titles were also heavily cited. The cited articles from these two titles were subject related. Table 1 gives more details about 33 highly cited journals that were cited at least 50 times. A good portion of those 33 titles are published by the U.S. based publishers; except 8 titles are published by non-U.S. based publishers, 4 are by publishers from Netherlands, such as *Gene*, and *Plant Molecular Biology*; 3 are by the ones from England, such as *Nucleic Acids Research*; and 1 is Japan, *Journal of Biochemistry*. The most cited journal title was *J. Biol. Chem.* (*Journal of Biological Chemistry*) that was cited 554 times. *Nature* and *Science*, these two titles were the top second and third cited journals; they were cited 443 and 401 times. Other highly cited titles include *Nucleic Acids Research*, *Gene* and *Cell* that were cited more than 200 times. One thing worth to note is that certain articles that published during the 70s and 80s still had high research impact after published 20 years. The average cited age of the journals articles are more than 8 years. The average cited age of *J. Mol. Biol. (Journal of Molecular Biology)*, *Methods in Enzymology*, *Virology*, and *Biochimica et Biophysica Acta* was even over 12. Comparing the cited status of those titles provided by Web of Science, all the titles are WOS journals and all those titles were also highly cited by journal articles. Most of the titles are on the top 10 list of highly cited journals by total cites. Comparing the Impact Factor, most of the titles are still the titles with high research impact.

Table 1: Highly Cited Journals.

	Title	Times Cited	Sub. Rank	Subject*	IF
1	J. Biol. Chem.	554	1	Biochemistry & Molecular Biology	6.355
2	Nature	443	1	Multidisciplinary Sciences	32.182
3	Science	401	3	Multidisciplinary Sciences	31.853
4	Nucleic Acids Research	319	6	Biochemistry & Molecular Biology	7.260
5	Gene	260	7	Genetics & Heredity	2.705
6	Cell	219	2	Biochemistry & Molecular Biology	28.389
7	J. Bacteriol.	196	1	Microbiology	4.146
8	Biochem. and Bioph. Res. Comm.	184	7	Biochemistry & Molecular Biology	2.904
9	EMBO Journal	168	4	Biochemistry & Molecular Biology	10.492
10	Plant Molecular Biology	122	7	Plant Sciences	3.510
11	Mol. Cell. Biol.	115	5	Biochemistry & Molecular Biology	7.822
12	Analytical Biochemistry	110	13	Biochemistry & Molecular Biology	2.370
13	Febs Letters	109	9	Biochemistry & Molecular Biology	3.843
14	Journal of Immunology	106	1	Immunology	6.486
15	Journal of Virology	103	1	Virology	5.398
16	Biochemistry	101	3	Biochemistry & Molecular Biology	4.008
17	Cancer Research	100	1	Oncology	7.690
18	Bio/Technology (Nature Biotechnology)	102	2	Biotechnology & Applied Microbiology	22.355
19	Mol. Gen. Genet.	87	153	Biochemistry & Molecular Biology	2.371
20	J. Biochem.	81	39	Biochemistry & Molecular Biology	2.292
20	J. Mol. Biol.	81	8	Biochemistry & Molecular Biology	5.542
22	Methods in Enzymology	78	16	Biochemistry & Molecular Biology	1.392
22	Virology	78	2	Virology	3.071
24	Biochimica et Biophysica Acta**	74	N/A	Biochemistry & Molecular Biology	N/A
25	Plant Physiol.	73	1	Plant Sciences	5.881

Title	Times Cited	Sub. Rank	Subject*	IF
26 Eur. J. Biochem.	64	15	Biochemistry & Molecular Biology	3.260
26 Genomics	64	5	Biotechnology & Applied Microbiology	3.840
28 Plant Cell	63	2	Plant Sciences	11.295
29 Nature Genetics	56	1	Genetics & Heredity	24.695
30 J. Exp. Med.	55	2	Immunology	14.588
31 Journal of Clinical Microbiology	54	3	Microbiology	3.439
32 Plant Journal	53	4	Plant Sciences	6.367
33 Journal of Biotechnology	52	26	Biotechnology & Applied Microbiology	2.323

* Number of titles in each subject area: Biochemistry & Molecular Biology 261, Biotechnology & Applied Microbiology 133, Genetics & Heredity 120, Immunology 111, Microbiology 84, Multidisciplinary 45, Onology 123, Plant Science 138, Virology 22

** Biochimica et Biophysica Acta is included in WOS under different subtitles that are not available in the citations.

Besides the journals, there were other sources that also included the works that had significant research impact on the development of Genetic Engineering. Among them, *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* was heavily cited. The papers published in *PNAS* were cited 752 times. *Chemical Abstract*, *Molecular Cloning* (Laboratory Manual) and *GenBank* also provided valuable research foundation for Genetic Engineering research related to those patents.

4. Discussion and Conclusion

In this study, author tried to give a very basic view of the Genetic Engineering research done in Japan, Korea and Taiwan. The linkage with public science was also shown with the counting results of non-patent citations listed on the patent literatures. The preliminary results show that the public science demonstrated high impact on the technology development of Genetic Engineering Research. Based on the number of citations, the results imply that the public science provides solid foundation for the Genetic Engineering Research and tight linkage between the private and public sectors. The influence of some research outcome lasts more than 20 years. The scholarly journals are the valuable sources among various communication channels for research output for technology development. The titles highly cited in the patents have similar significant influence on the public science since they were also heavily cited by other scholarly journals. It is worth to have further study on the literature level to reveal the linkage among public institutions and private organizations.

During the process, several problems were occurred that raised the difficult level of analysis. The first thing is the parsing and coding the non-patent citations. It is a very labor-intensive and time-consuming process. Various formats of non-patent citations were found and it was hard to have programs to parse the citations in systematic ways, especially this study covered the patents issued during the period of 30 years. The inconsistency of format was easily found and it made it was impossible to have systematic methods to hand the records. Incomplete and incorrect information also caused problems. Checking other information resources and synchronizing the information were necessary to ensure the credibility of the results. However, based the preliminary results and the studies did in the past, it is certain that public science does have research impact on the technology development, in particular for Genetic Engineering Research. Further in-depth linkage can be and should be established in the future studies.

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