Scientific Linkage of Public Research and Technology Development

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Abstract

In this study, the author demonstrated the linkage between public science research and technology development through non-patent citation analysis to reveal the important knowledge resources from public science research had significant impact on technology development. Genetic engineering technology was the field examined in this study.

6,274 patents that were seen as output of genetic engineering technology development, and cited literatures were included in this study.

It was found that over 90% of the citations were non-patent literatures. From the references list in the patents, it was observed that the technology development in genetic engineering was influenced heavily by the research done in the public sector. Although several assignees from private sector devoted resources into the basic research and showed the impact through the citation linkage between patents and non-patent publications, the works done in the public sector, such as University of California (Berkeley), showed the strength in productivity and research impact.

1 Introduction

It is widely accepted that public science research is a driving force behind technology development and economic growth both in scientific and economic communities. In another hand, the utilizing of public science in the development of high technology is also seen as a presentation of the usefulness of output of public science research. It is helpful to the researcher to understand the dissemination of knowledge gained from public science research to technology development by constructing the linkage between public science and technology development. By the same token, the demonstration of the usefulness of public science is valuable to the decision maker while drafting strategic plan. During the past several decades, plenty studies were done to show the productivity and research impact. There were significant amount of studies applied the methods adopted from bibliometrics and periodical articles were used for analyzing purposes. Patent information becomes more accessible in recent years and more visible in relevant studies. In some cases, journal articles were treated as representations of the results of public science research and patents were seen as the output of technology in others. The publication count for both types of materials was used to show the research productivities, and the citation count was done for the analysis of research impact.

In the early studies, the researches focus on the discussion of if there was any correlation between science and technology (Collins & Wyatt, 1988; Narin & Noma, 1985; Narin & Olivastro, 1992). Empirical studies were carried out later on to enforce the validity of the linkage and the importance to establish the linkage (Anderson, Williams, Seemungal, Narin & Olivastro, 1996; Narin, Hamilton & Olivastro,

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1997). Citation analysis was the most common approach taken to define the correlation between science and technology (Bhattacharya, Kretschmer & Meyer, 2003; Collins & Wyatt, 1988; Meyer, 2000a; Meyer, 2000b; Narin, 1994; Verspagen, 1999). Peer opinion regarding the transformation from science to technology was drawn by conducting interviews (Fagerberg et al., 1994; Rosenberg, 1992).

In this study, the author tried to demonstrate the linkage between public science research and technology development of genetic engineering through non-patent citation analysis to reveal the important entities from science research that had significant impact on the development of genetic engineering technology.

2 Methods

This study took bibliometrics approach; *Patent Count* and *Citation Analysis* were used to show the productivity and research impact. Further analyses were done by employing Bradford's model (Narin & Moll, 1977; Garfield, 1980) to identify the core assignees and non-patent citations cited by the core assignees were examined to reveal the linkage of the public science research and technology development.

3 Data

The data source used in this study was USPTO Patent database. The 6,274 patents analyzed in this study were granted during the period of 1980 to 2004 and selected by the International Patent Classification (IPC) numbers and United States Patent Classification (USPC). The patents, which had the primary IPC numbers of "Mutation or genetic engineering" (C12N 15/00) and USPC numbers listed under the class "Process of mutation, cell fusion, or genetic modification" (435/440), were defined as genetic engineering patents.

The core assignees were identified from by taking the Bradford analysis approach. The top 16 assignees, each was granted at least 50 patents, were located in the core zone of the Bradford's distribution. This study examined 1,412 patents granted to the top 16 assignees. The 4,001 cited patents and 35,447 non-patent literatures referenced by the granted patents were also included in this study.

4 Results

Basic Analysis

There were 6,274 patents were included in this study. Four stages could be identified based on the number of patents granted. With the domestic advantages, 4,562 (72.71%) patents were granted to United States based institutions. Examining the patent technologies described in the data, it was found that the technology of "DNA recombinant" was the major technological area, especially modifying DNA and RNA fragments. During late 1990s and early 2000s, there was a technological shift; more patents were granted in "Introducing genetic material."

16 core assignees were identified from 1,300 assignees by the results of Bradford analysis. Among the productive assignees, two California based institutes, University of California (Berkeley) and INCYTE Pharmaceuticals[2], and SmithKline Beecham[3], were the top three assignees that were granted the most number of patents, 181, 127 and 123. Table 1 lists the numbers of patents granted to the core assignees.

Table 1: Productive Assignees, Top 16 (> 50 granted patents).

Assignee	No	Co	St	Tp
University of California (Berkeley)	181	US	CA	EDU
INCYTE Pharmaceuticals	127	US	CA	COM
SmithKline Beecham Corporation	123	US/ UK	PA	COM
Dept of Health and Human Services, US	99	US	DC	GOV
Pioneer Hi-Bred International, Inc.	98	US	IA	COM
Genentech, Inc.	95	US	CA	COM
Monsanto Company	85	US	MO	COM
The General Hospital Corporation	81	US	MA	COM
Human Genome Sciences	79	US	MD	COM
Chiron Corporation	74	US	CA	COM

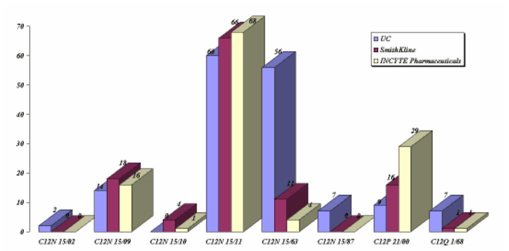
[2] INCYTE Pharmaceuticals was founded in 1991. INCYTE Corporation was moved to Willington, Delaware in 2004 and shifted the research focus to Drug research.

[3] Based at UK, merged with Glaxo to form GlaxoSmithKline in 2001. Patents were granted to US Branch.

Assignee	No	Co	St	Tp
Harvard University	68	US	MA	EDU
The Johns Hopkins University	60	US	MD	EDU
Eli Lilly and Company	58	US	IN	COM
Merck & Co., Inc.	56	US	NJ	COM
The University of Texas (Austin, TX)	53	US	TX	EDU
Genetics Institute, Inc.	53	US	MA	COM

With the advantage of being near by University of California (Berkeley), the leading institution in genetic engineering research, it was found that several institutes from private sector, which were based at the bay area, also showed productive strength in the research.

Besides granted patents in "Modifying DNA or RNA fragments," the top three assignees specialized in various sub-domains of genetics engineering research. University of California (Berkeley) was granted significant amount of patents in "Introducing genetic materials", SmithKline showed gaining in "General process of DNA recombinant", and INCYTE Pharmaceuticals was granted more patents in "Preparation of protein and enzyme". Figure 1 shows technical focus of these three assignees.



C12N/15/11 Modified DNA or RNA Fragments
C12N 15/63 Introduction of foreign genetic material using vectors
C12P 21/00 Preparation of Protein

Figure 1: Technical Focus of Top Three Productive Assignees

Science Linkage Analysis

The cited references listed in the patent front page showed that genetic engineering research was highly dependent on prior art, especially the researches done in public sector. Not only patents were cited, there were significant amount of non-patent literatures contributed to technology development. Examining the patents granted to the top productive assignees, there were 4,001 patents and 35,447 non-patent literatures were cited by 1,412 patents. Each patent had 30.84 references in average, one tenth of the cited references were patents and others were non-patent literatures. Variation of the citation behaviour was observed among the productive assignees. The patents granted to General Hospital (Boston), Harvard University and Chiron cited more references, 50 references in average. The ones granted to University California (Berkeley) and Genetic Institutes cited less reference, 15 references in average. It could imply the assignees in former group focus on the value added works and the ones in latter group were more adventure in genetic engineering research. Review the ratio of cited patents and non-patent literatures, all assignees cited more non-patent literatures than cited patents without exception. More than 90% of citations listed in the patents granted to INCYTE Pharmaceuticals, General Hospital (Boston), Harvard University, Human Genome, John Hopkins University and Genetic Institute were non-patent literatures. Even some of the assignees did cite more patents; the percentage of cited patents was still less than 20% of the total citations. Figure 2 shows the distribution of the cited patents and non-patents literatures.

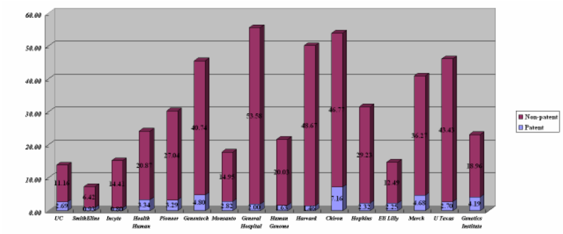


Figure 2: Distribution of Patents and Non-Patent Citations of Top 16 productive Assignees

Examining the types of non-patent citations, information extracted from monographs, proceeding papers, samples from Gene Bank and journal articles were the foundations of genetic engineering technologies. If the journal articles were seen as tokens of the output of basic science research and the patents were taken as presentations of results of technology developments, it could be addressed that genetic engineering research depends heavily on the research of basic science. It was found that journal article took major part of non-patent citations. There were 28,693 (89%) non-patent citations were journal articles. Couple things should be aware of that there were patents listed in the section of non-patent literatures and material types of 110 citations could not be identified due to the lack of information. Figure 3 presents the types of non-patents citations and the distribution of the number of citations in each material type.

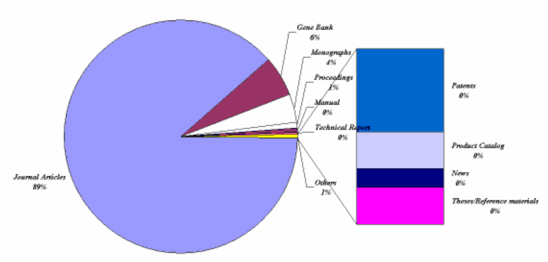


Figure 3: Material Types of Non-Patent Citations

Reviewing the sources of the cited journal articles, 1,521 journal titles were identified. Among them, *Proceedings of National Academic Science* were cited more than other titles, it was cited 2,929 times. Next to *Proceedings of National Academic Science*, *Nature*, *Science*, *Journal of Biological Chemistry* and *Cell* were also highly cited. Table 2 lists the top 10 highly cited journals and the times cited of each title.

Table 2: Top 10 highly cited journals by Top Productive Assignees

Journal Title	Times Cited
Proceedings of the National Academy for Science	2,929
Nature	1,923
Science	1,919
Journal of Biological Chemistry	1,794
Cell	1,489
Journal of Virology	762
Nucleic Acids Research	621
EMBO Journal	604
Molecular and Cellular Biology	579
Gene	503

Origin of Genetic Engineering Researches

Further exam on first authors' affiliation was done for sample cited journal articles. One tenth of cited journal articles, 2,830 articles, were checked and author information of 2,720 sampled articles could be allocated and obtained during the period of the study. Researches done in the United States were the core sources of the research impact. Among the 2,720 authors of articles cited examined, there were 1,867 (68.64%) authors were from United States based organizations. Comparing to the geographic distribution of assignees of cited patents, research impact of research institutes based outside the United States increased, such as the institutions based in Great Britain, Japan, Germany and France. Mapping the authors and affiliations, 2,720 authors were from 794 institutions. Among them, authors from Harvard University were cited most, 121 times in total. The authors affiliated with National Institute of Health and Genentech were also highly cited. Mapping the affiliations of citing patents and cited journal articles, institutional self-citation was quite common; it was observed in the patents granted to Genentech. Similar citing behaviour was also seen with the patents granted to John Hopkins University. Table 3 lists the top ten affiliations of the authors of cited journal articles.

Table 3: Top Ten Author Affiliations of Non-Patent Citations

Organization	Count
Harvard Medical School	121
National Institutes of Health	69
Genentech, Inc.	67
Johns Hopkins University	54
Massachusetts General Hospital	50
Stanford University School of Medicine	46
University of California, Berkeley	42
University of California, San Diego	41
Washington University School of Medicine	35
Massachusetts Institute of Technology	31

Referencing cycles

The average citation age was 9.8, the mode age was 8 and the median age was 9. Although the result from relative study indicated that biotechnology might be one of the domains that there was no time lag or shorter time lag from public science to technological development and market value (Narin, 1994), the results showed in this study indicated that citation ages of 1,227 non-patent citations were over 20 by the time they were cited by the patents included in this study

5 Discussion

The citation pattern and science linkage confirmed the impact of public science on the technology development in genetic engineering research. From the references list on the front page of patents, it was obvious that the technology development in genetic engineering was influenced heavily by the research done in the public sector. Over 90% of the citations were non-patent literatures and over 89% of non-patent citations were journal articles. United States still holds the domestic advantages, not only the patents were granted to the United States based institutions, the sources of research impact were also reflected to the works done by the United States based organizations. Although several assignees from private sector devoted resources into the basic science and showed the impact through the citation linkage between patents and non-patent publications, the basic science works done in the public sector, such as Harvard University, John Hopkins University and University of California, certainly demonstrated the strength not only in the productivity but also in research impact. The information resources that heavily used in the public science research were also highly depended in the technology developments.

Highly public science dependent

Comparing the distribution of cited patents and cited journal articles listed on the front page of patents granted to productive assignees, it was found that the number of cited journal articles were exceeded the number of cited patents by significant margin. The difference indicated the link between technology development and public research of genetic engineering research and the link also represented the dependence.

Country preference

Examining the sample citations of patents granted to the productive assignees, it was found that the outcomes of genetic engineering research performed by the United States based institutions dominant the developments. Over 67% of the journal articles citations were written by the authors that affiliated with United States based institutions.

Institutional preference

Further examining the institutional types of the authors' affiliations, the results showed that the patents granted to Universities tended to cited more works done by the authors were also affiliated with universities. As for the private sector, the influence of public science was also shown, but the distribution of sources of research impact was more balance between public sector and private sector. It was also observed that the assignees from public sector had higher self-citation rate.

From the results of this study, there is no doubts that the development of genetic engineering research were highly dependent on prior art, especially the link to public science research. Continuing enquiries on citation behaviour could further reveal how the knowledge-transfer taken place.

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