A Comparative Study of Linkage Indexes: Co-assignee, Reciprocal Citation, Patent Coupling and Co-patent

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Abstract

Four indexes including co-assignees, reciprocal citation, patent coupling and co-patent were examined in this study to reveal the meanings of the correlations generated via different citation linkages. This study includes 6,274 genetic engineering patents, and 16 primary assignees identified by Bradford model analysis as the base for correlation analysis. The results show that there are four cluster types, including technological affiliated, technological competitor correlated, commercial collaborated and technological isolated.

Keywords: Linkage Indexes; Co-assignees; Reciprocal Citation; Patent Coupling; Co-patent; Citation Linkage

1. Background

The work done by Narin in 1994 established the use of patent bibliometrics approach (Narin, 1994), and this method has been applied to various studies for revealing the research productivity and impact since. Patent counting was heavily used in identification of productive entities, which include countries, assignees and inventors (Banerjee, Gupta, & Garg, 2000; Garg & Padhi, 1998; Lo, 2004; Narin, 1994, 1995), and the results of citation counts were seen as indicators for showing the research impact (Albert & Plaza, 2004; Jaffe, Fogarty, & Banks, 1997; Lo & Huang, 2005; Moed, 2000). Through the density of direct citing, the scholars were able to describe the technical association between science research and technology development (Carpenter, Copper, & Narin, 1980; Collins & Wyatt, 1988; Lo, 2006; Viannen, Moed, & Raan, 1990). As the technology developments become multidisciplinary, the demand of mechanisms for enclosing the research correlation became more vital.

To establish relationships among documents, co-citation, links cited documents through later documents (Bellardo, 1980; Cawkell, 1976; Marshakova, 1979; Small, 1973) and bibliographic coupling, citing same source documents (Kessler, 1963, 1965),

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were applied besides direct referencing to earlier documents. The idea of co-citation was mentioned in the works done by Small, Cawkell and Bellardo (Osareh, 1996). In Small's study, literature network was constructed through the co-citation relationship. The subject similarity of literatures was increased as the times co-cited increased (Small, 1973). Narin applied citation analysis technique in patent citation analysis in his work named "Patent Bibliometrics" (1994), the results showed the similarity of citation analysis and patent citation analysis. Co-citation from bibliometrics analysis was also applied in patent analysis to show the correlation of patents by counting times of co-cited. Coward and Franklin (1989) used co-citation analysis to identify subject areas with strong technology and science link. Applied the techniques of co-citation, Milman (1994) used co-citation analysis of patent citations to monitor the relationship between R & D. Patent coupling was originated from bibliographic coupling method (Lo, 2008), which was proposed by Kessler from Fano's idea (Kessler, 1963), onto patent analysis. The hypothesis was that two patents related to each other if they shared the same cited references. The relevance intensified as the number of shared references increased.

In this study, four linkage indexes including co-assignee, reciprocal citation, patent coupling and co-patent were applied to establish the correlation network of technological development. Genetic engineering was chosen for the technology area and the correlation network was built based on the patents granted to the primary research organizations identified by the results of *Bradford Model Analysis* (Garfield, 1980; Narin & Moll, 1977) on assignees that were granted genetic engineering patents during the period of 1976 to 2004.

2. Research Problems

The aim of this study is to compare the usefulness of four linkage indexes, co-assignee, reciprocal citation, patent coupling and co-patent by constructing the correlation clusters among the primary organizations of genetic engineering research by taking bibliometrics approach. The author examined the patents granted to the primary organizations in genetic engineering research and the cited patents and citing patents were reviewed to construct the correlation clusters and the attributes of the clusters. 16 primary assignees were identified and 120 assignee pairs were formed for, and four indexes were calculated for each pair. *Correlation Analysis, Clustering* and *Multiple-Dimension Scaling* were applied to construct the clusters based on the indexes. The comparison of the four indexes and issues of adopting the indexes were discussed in this study for future studies' references.

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- Constructing the correlation clusters of the primary organizations of genetic engineering research
- Identifying the attributes of correlation clusters
- Comparing the usages of four linkage indexes and discussing issues of adopting the indexes

3. Methodologies

This study took patent bibliometrics approach. Based on authorship and citation analysis, four bibliometrics mechanisms, including co-assignees, reciprocal citation, patent coupling and co-patent, were adopted in this study. The data source used was USPTO Patent database and genetic engineering was the technology area reviewed in this study. The genetic engineering patents were screened out by the classification number search. Both International Patent Classification (IPC) and United States Patent Classification (USPC) were used in this study. 6,274 patents granted in genetic engineering were identified by USPTO during the period of 1976 to 2004 and 1,300 assignees were recognized. Among the 1,300 assignees, 16 assignees were screened out as primary organizations that had important contribution to the development of genetic engineering research by the result of patent counting on the patents granted and *Bradford model analysis*. The 16 primary assignees formed 120 correlation pairs and four indexes, including co-assignee, reciprocal citation, patent coupling and co-patent, were calculated for each pair. *Correlation Analysis* and *Clustering* were done to identify the technological clusters and the results were displayed visually by using *Multi-dimensional Scaling* techniques. To highlight identified clusters, the marks for clusters were added manually.

Co-assignees index

Co-assignees index presents collaboration between assignees of each pair by the density of co-ownership of patents. The formula used is, $CoAIij=Pij\div(Pi+Pj- Pij)$.

CoAIij is the co-assignees index for assignees I and J. Pi is the number of patents granted to assignee I. Pj is the number of patent granted to assignee J, and Pij is the number of patents owned by I and J.

Reciprocal citation index

Reciprocal citation index shows the impact of technologies hold by assignees to paired assignees. The index for each pair is calculated as, $RCIij=(CPij+CPji)\div(CPi+CPj-(CPij+CPji))$.

RCIij is the reciprocal citation index of assignees I and J. CPij is the number of patents granted to assignee J cited by assignees I. CPji is the number of patents granted to assignee I

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cited by assignee J. CPi is the number of patent citations of assignee I, and CPj is the number of patent citations of assignee J.

Patent coupling index

Patent coupling index demonstrates the strength of patent coupling of assignee pair based on the number of referenced patents the two assignees had in common. The index is calculated with the fomula, *PCIij=PCij÷ (PCi+PCj- PCij).*

PCIij is the patent coupling index of assignees I and J. PCi is the number of patent citations of assignee I. Pj is the number of patent citations of assignee J, and PCij is the number of shared patent citations of assignees I and J.

Co-patent index

Co-patent index reveals the correlation of assignees by the strength of co-patent, times of co-cited patents of these paired assignees. The index is calculated with the fomula, *CoPIij=CIij ÷(CIi+CIj- CIij).*

CoPIij is the co-patent index of assignees I and, CIi is the times cited of assignee I. CIj is the times cited of assignee J, and CIij is the times co-cited of assignees I and J.

4. Findings

Basic Analysis

There were 16 primary assignees identified from 1,300 assignees, which were granted 6,247 patents, through *Bradford Model Analysis*. Among those productive assignees, University of California (Berkeley), INCYTE Pharmaceuticals (note 1) and SmithKline Beecham (note 2), were the top three assignees that were granted the most number of patents, with 181, 127 and 123 patents respectively. Table 1 lists the 16 primary assignees and the numbers of patents granted during the period of 1976 to 2004. It was observed that not only University of California (Berkeley) was the leading institution in genetic engineering research, but several entities from private sector based in Bay area, such as INCYTE Pharmaceuticals, Genentech and Chiron, also showed productive strength in genetic engineering research.

Examining the primary International Patent Classification Numbers (IPC) of the 1,390 patents granted to the primary assignees, it was found that significant amount of patents involved with Recombinant DNA technologies. Among the 1,390 patents, there were 1,045 (75.18%) patents dealing with the techniques of DNA recombination, including general process of DNA recombination, process of isolation, modifying DNA fragments and introducing

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

Assignee	No of Patents	Country	State	Type of Assignee
University of California (Berkeley)	181	US	CA	EDU
INCYTE Pharmaceuticals, Inc.	127	US	CA	COM
SmithKline Beecham Corporation	123	US	PA	COM
Dept of Health and Human Services	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
General Hospital Corporation (Boston)	81	US	MA	COM
Human Genome Sciences, Inc.	79	US	MD	COM
Chiron Corporation	74	US	CA	COM
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)	53	US	TX	EDU
Genetics Institute, Inc.	53	US	MA	COM

foreign genetic materials. Comparing to the DNA recombinant techniques, there was only very limited number of patents (two patents) granted that involved with the cell fusion and mutation by non-insertion foreign genetic materials methods. Comparing the patents granted to the top three assignees, it showed that the three assignees were granted patents in "Modifying DNA or RNA fragments," but with specialties in various genetic engineering technologies. University of California (Berkeley) was granted substantial number of patents in "Introducing genetic materials" (56 patents), INCYTE Pharmaceuticals was granted more patents in "Preparation of protein and enzyme" by applying recombinant techniques (29 patents), and SmithKline Beecham Corporation were granted more patents in "General process of DNA recombinant" (18 patents) comparing to other sub-domains. Figure 1 shows the distribution of the technologies.

Correlation analysis

The 16 primary assignees identified from the results of *Bradford Model Analysis* formed 120 correlation pairs. Four linkage indexes

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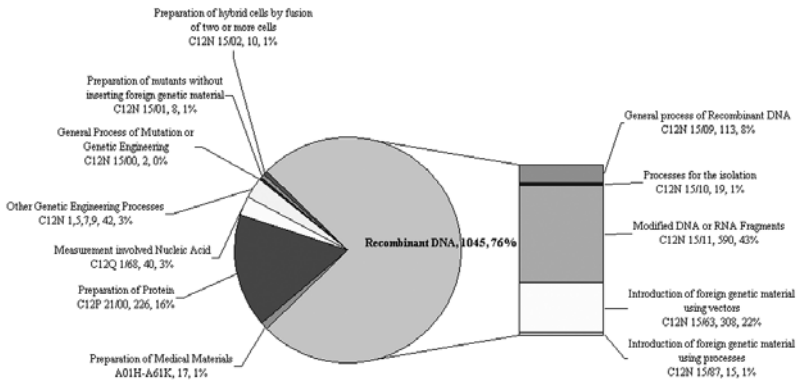


Figure 1. Distribution of Technologies

including co-assignees, reciprocal citation, patent coupling and co-patent were calculated for each pair. *Correlation Analysis*, *Clustering* and *Multi-dimensional Scaling* were further done to identify the clusters.

- Co-assignees index

Among the four linkage indexes, co-assignee index had very limited implication of showing the correlation among the primary assignees. There were 11 pairs of assignees co-owned patents. University of California (Berkeley), which co-owned 7 patents with other 5 primary assignees, was the assignee that collaborated with the most number of primary assignees. Reviewing the co-assignee index, the results showed that University of California (Berkeley) established greater research network in genetic engineering research comparing to other academic institutions among the assignees included in this study. General Hospital (Boston) and Harvard University co-owned 10 patents, making them the co-assignee pair with the most number of co-owned patents. This might due to the geographic impact on collaboration. The low co-assignee index indicated the institutional independent R&D strategy. There was no significant evidence to support the collaboration among primary assignees. Table 2 lists the pairs with co-owned patents.

- Reciprocal citation index

Among 120 pairs, there were 92 pairs of assignees that had direct citation linkage. University of California (Berkeley) was reciprocal citation correlated with other 15 assignees and also presented a cumulative reciprocal citation index (RCI), sum of RCIij, at 0.2235, which was the second highest. Besides its high production in genetic engineering

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Table 2. Assignee Pairs with Co-owned Patents

Co-assignee Pair	No. of Co-owned Patents
General Hospital (Boston) - Harvard University	10
University of California (Berkeley) - Genentech	3
SmithKline Beecham - Human Genome Sciences	2
University of California (Berkeley) - Pioneer Hi-Bred	1
University of California (Berkeley) - General Hospital (Boston)	1
University of California (Berkeley) - Chiron	1
University of California (Berkeley) - Harvard University	1
Dept. Health and Human Services - General Hospital (Boston)	1
Dept. Health and Human Services - John Hopkins University	1
Human Genome Sciences - Harvard University	1
Chiron - Genetics Institute	1

research, University of California (Berkeley) also showed great impact on the works done in other primary organizations by the times cited for patents and number of citing primary assignees. Genentech was the assignee that got the highest cumulative RCI at 0.2674, which was reciprocal citation correlated with other 10 assignees. Common citation behaviour observed among all the primary assignees showed that they were all highly self-cited. The self-citation index (note 3) was 0.0876 in average, 40.61% of cumulative RCI. The high self-cited rate implied the continuing development strategy of the primary assignees. SmithKline Beecham, Pioneer Hi-Bred, Monsanto and Eli-Lilly all had higher self-citation index at 0.0783, 0.0653, 0.1302 and 0.2188 respectively, comparing to RCI with other primary assignees. Differing from University of California (Berkeley) and Genentech, which were technological dependent on other primary assignees, INCYTE Pharmaceuticals, SmithKline Beecham, Pioneer Hi-Bred, Monsanto and Eli Lilly were less reciprocal citation correlated to other primary assignees. Rather than citing works done by other primary assignees, those assignees had much higher self-cited indexes. The weak linkage could be interpreted as those assignees were technological independent from other primary assignees

The RCI of each pair showed that Dept. of Health and Human Services, together with Chiron, was the pair with highest RCI at 0.052758 based on 44 direct citations, 4.57 times of average RCI value, which implied technology dependent between these two

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assignees. Genentech and Genetics Institute also presented high RCI at 0.0519, based on 38 direct citations. University of California (Berkeley) and Genetics Institute were also technologically dependent with RCI at 0.044655, based on 33 direct citations. University of California (Berkeley) had greater research impact on Genetics Institute. Table 3 shows the RCI of the top 10 RCI pairs. Among the RCI pairs, Academic and Research institutions dominated in the pairs, demonstrating higher research impact on the other pair member.

Correlation Analysis, *Clustering* and *Multi-dimensional Scaling* were further done to identify clusters among the primary assignees, in which 4 reciprocal citation clusters were drawn (Figure 2). After examining the characteristics of the assignees in each cluster, it was found that the clusters showed various attributes. University of California (Berkeley), Dept. of Health and Human Services and Harvard University hold the leading technologies that had impact on the researches done in Genentech and Genetics Institute. John Hopkins University, INCYTE Pharmaceuticals were more technologically advanced in their clusters. The pair of Pioneer Hi-Bred International and Monsanto was more like collaborative cluster comparing to others.

- Patent coupling index

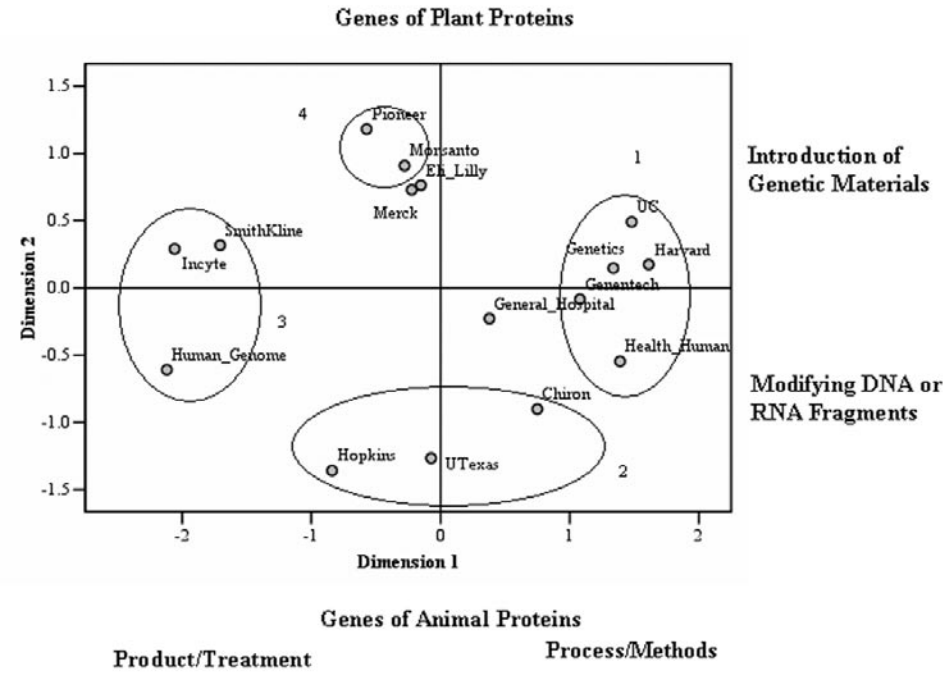
Patent coupling index showed greater correlation density of the primary assignees. It revealed the technological correlations that were not shown in co-assignees index and Reciprocal

Table 3. Assignee Pairs, Reciprocal pairs and Index, Top 10

Reciprocal Pair	RCI
Dept. of Health and Human Services- Chiron	0.052758
Genentech - Genetics Institute	0.051913
University of California (Berkeley) - Genetics Institute	0.044655
INCYTE Pharmaceuticals - Human Genome Sciences	0.034653
John Hopkins University - University of Texas (Austin)	0.032727
University of California (Berkeley) - Chiron	0.026217
University of California (Berkeley) - General Hospital (Boston)	0.024902
University of California (Berkeley) - Dept. of Health and Human Services	0.024772
Dept. of Health and Human Services - Genentech	0.023499
Human Genome Sciences - John Hopkins University	0.023346

Note: Assignees underlined had greater research impact in the pair.

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1 UC - University of California (Berkeley), Genentech, Genetics Institute, Dept. of Health and Human Services, Harvard University
2 John Hopkins University, University of Texas (Austin), Chiron
3 INCYTE Pharmaceuticals, SmithKline Beecham, Human Genome Sciences
4 Pioneer Hi-Bred, Monsanto
General Hospital (Boston)
Eli Lilly
Merck

Figure 2. Reciprocal citation clusters

citation index. There were 99 pairs being coupling correlated. Genentech and General Hospital (Boston) were coupling correlated to all the other primary assignees. University of California (Berkeley), Department of Health and Human Services (US), Chiron and University of Texas were coupling correlated to other 14 primary assignees. Only Pioneer and Eli Lilly were coupling correlated to less than 10 primary assignees. General Hospital (Boston) had strongest Coupling Strength at 0.897866, and the pair of Genentech and Genetics Institute had highest Coupling Index at 0.336806. Comparing the Patent Coupling Citation Index (PCI) of each pair, Genentech and Genetics Institute made the pair with

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highest PCI at 0.336806, based on 194 shared citations, 9.44 times of average PCI value which implied the similarities of technological development or collaboration between these two assignees. Harvard University and General Hospital (Boston) were also with high PCI at 0.230519, based on 71 shared citations. Pioneer Hi-Bred International and Monsanto were also technologically correlated, with PCI at 0.209091 based on 92 shared citations. Table 4 lists the PCI of the top 10 PCI pairs.

Correlation Analysis, *Clustering* and *Multi-dimensional Scaling* were further done to identify clusters. 5 clusters and 2 isolated assignees were identified in the analysis results. One of the clusters included University of California (Berkeley), Dept. of Health and Human Services, Harvard University, General Hospital (Boston) and the cluster of John Hopkins and University of Texas (Austin) were identified as "Modifying genes encoding animal proteins" groups. The cluster of Genentech, Genetics Institute and Chiron also focused on the modifying genes techniques, but specialized more in the research of disorder of cell growth and repair methods. INCYTE Pharmaceuticals, Human Genome Sciences and SmithKline Beecham were in the drug research cluster, and Pioneer Hi-Bred and Monsanto focused on the research in hybrid seeds. Figure 3 demonstrates the results of clustering analysis.

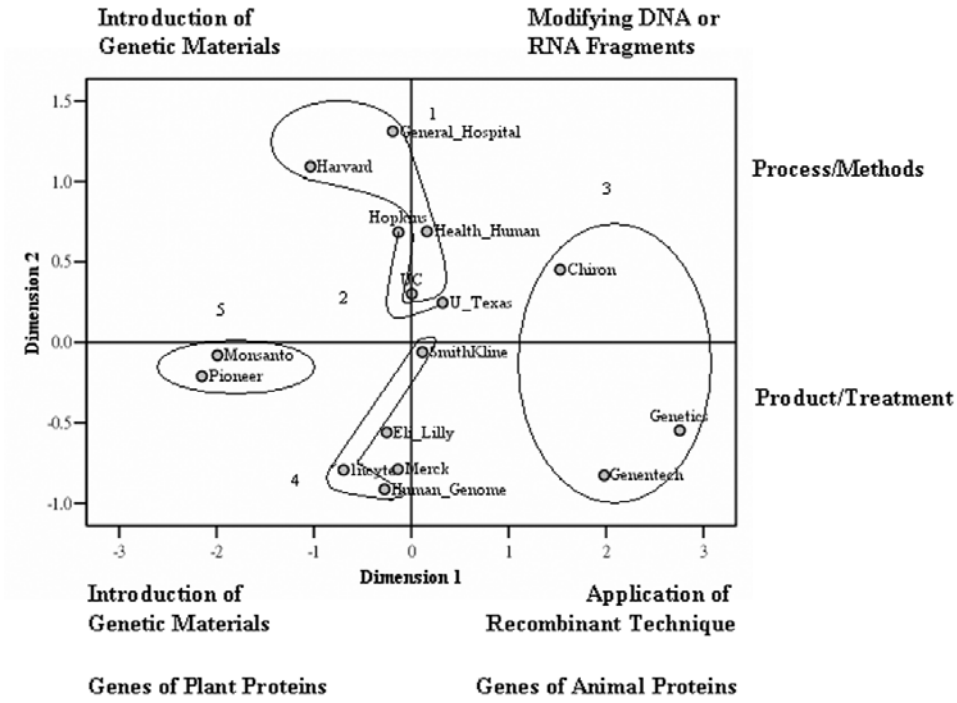
- Co-patent index

Among the primary assignee pairs, 97-pair assignees were co-patent related. University of California (Berkeley) and General Hospital (Boston) were co-cited with other 15 primary assignees. Genentech, Harvard University,

Table 4. Assignee Pairs, Patent Coupling pairs and Index, Top 10

Patent Coupling Pair	PCI
Genentech - Genetics Institute	0.336806
Harvard University - General Hospital (Boston)	0.230519
Pioneer Hi-Bred International - Monsanto	0.209091
Chiron - Genetics Institute	0.203343
University of California (Berkeley) - Chiron	0.129897
General Hospital (Boston) - Chiron	0.097990
Dept. of Health and Human Services - Chiron	0.097500
University of California (Berkeley) - General Hospital (Boston)	0.096774
Dept. of Health and Human Services - General Hospital (Boston)	0.078394
General Hospital (Boston) - U. of Texas (Austin)	0.065000

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1 UC - University of California (Berkeley), Dept. of Health and Human Services, Harvard University, General Hospital (Boston)
2 John Hopkins University, University of Texas (Austin)
3 Genentech, Genetics Institute, Chiron
4 INCYTE Pharmaceuticals, Human Genome Sciences, SmithKline Beecham
5 Pioneer Hi-Bred, Monsanto
Eli Lilly
Merck

Figure 3. Patent coupling clusters

University of Texas and Genetics Institute were co-cited with other 14 primary assignees. Among the primary assignees, Monsanto had the highest co-patent strength at 0.4217. General Hospital (Boston) and Genentech also had high co-patent strength, with strength index at 0.3974 and 0.3907 respectively. Among the 97 co-patent pairs, the pair of Pioneer Hi-Bred and Monsanto was the most co-cited one, co-cited by 201 later issued patents and the co-patent index was 0.2092. Besides highly co-cited with Pioneer Hi-Bred, Monsanto was also highly related to Eli-Lilly comparing to other assignees. With co-patent index at 0.1003, these two assignees were co-cited 116 times. The pair of General Hospital (Boston) and Harvard

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University, another highly related pair, was co-cited 121 times, with co-patent index at 0.1167, 5.84 times of average co-patent index. Another pair composed of General Hospital (Boston), together with Genetics Institute, a Cambridge, Massachusetts based company, was co-cited 107 times and the co-citation index was 0.0989.

Comparing the CoPI of each pair, Pioneer Hi-Bred International and Monsanto made the pair with highest CoPI at 0.209157, by which they were co-cited for 201 times, indicating the similarity of technological development and the impact on the latter development of these two assignees. Harvard University and General Hospital (Boston), co-cited for 201 times, were also with high CoPI at 0.116683. Monsanto and Eli-Lilly made up another pair that was highly technologically correlated, whose CoPI was 0.100259 with 116 times co-cited. Table 5 lists the CoPI of the top 10 CoPI pairs.

Correlation Analysis, *Clustering* and *Multi-dimensional Scaling* were further done to identify clusters. 5 group clusters and three isolated entities were identified through the analysis. The works done by University of California (Berkeley), Genentech and John Hopkins University in early 1990s showed greater impact on later development in modifying genes of animal protein. The works related to modifying animal protein and preparation of vectors for introducing genetic materials by INCYTE Pharmaceuticals and University of Texas had impact on later development. Harvard University, Genentech and Genetics Institute showed higher impact on research of measurement/sequencing

Table 5. Assignee Pairs, Co-Patent pairs and Index, Top 10

Co-Patent Pair	CoPI
Pioneer Hi-Bred International - Monsanto	0.209157
Harvard University - General Hospital (Boston)	0.116683
Monsanto - Eli Lilly	0.100259
General Hospital (Boston) - Genetics Institute	0.098891
University of California (Berkeley) - Genentech	0.094518
SmithKline Beecham - Human Genome Sciences	0.083810
Genentech - John Hopkins University	0.059928
Human Genome Sciences - Genetics Institute	0.046693
Genentech - General Hospital (Boston)	0.037838
Harvard University - Pioneer Hi-Bred International	0.036327

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techniques. SmithKline Beecham and Human Genome Sciences contributed in the research of isolation of composition, while Pioneer Hi-Bred, Monsanto and Eli-Lilly showed influence on research of modifying plant protein. Figure 4 is a visual presentation of the co-patent clusters.

5. Discussion and Conclusions

Discussion

The results showed that there was no strong evidence to indicate the correlations among primary assignees by co-ownership analysis, except for the pair of Harvard University and General Hospital (Boston). With the advantage of geographic preference, Harvard University and General Hospital (Boston) are affiliated in genetic engineering research. Reciprocal Citation and Patent Coupling present the sources of prior art of genetic engineering research and there was resemblance existing in the clusters revealed by these two methods, which might indicate the possible competition or collaboration in the development of genetic engineering research. Several technological groups could be traced and the groups include counterparts with the similar technology focus, such as (1) University of California (Berkeley) and Dept. of Health and Human Services (US); (2) Genentech and Genetics Institute; (3) John Hopkins University and University of Texas (Austin); (4) INCYTE Pharmaceuticals, Human Genome Sciences and SmithKline Beecham; (5) Pioneer Hi-Bred and Monsanto. Comparing the assignees' profiles with the clusters identified by linkages of Reciprocal Citation and Patent Coupling, four types of clusters could be observed, which are technological affiliated, technological competitor correlated, commercial collaborated and technological isolated.

(1) University of California (Berkeley) and Dept. of Health and Human Services (US)

University of California (Berkeley) and Dept. of Health and Human Services (US) were technological competitor correlated. Both of these two assignees focus on researches in "Modifying DNA or RNA of animal proteins" and "Introduction of foreign genetic materials using vectors," but no evidence was found to indicate the possible collaboration through patent analysis.

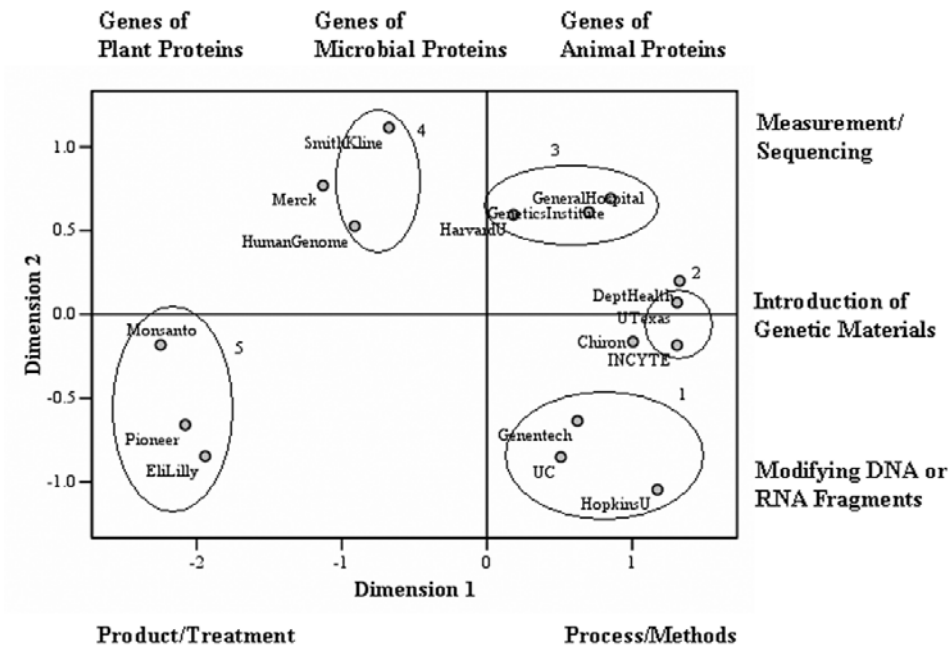
(2) Genentech and Genetics Institute

Genentech and Genetics Institute were technological competitor correlated. Both of these two assignees focus on researches in "Modifying DNA or RNA of animal proteins", specialized in the research of disorder of cell growth and repair (blood).

(3) John Hopkins University and University of Texas (Austin)

John Hopkins University and University of Texas (Austin) were technological competitor

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2 INCYTE Pharmaceuticals, University of Texas (Austin)
3 General Hospital (Boston), Harvard University, Genetics Institute
4 SmithKline Beecham, Human Genome Sciences
5 Pioneer Hi-Bred, Monsanto, Eli-Lilly
Chiron, Merck

Figure 4. Co-patent clusters

correlated. Both of these two assignees focus on researches in "Modifying DNA or RNA of animal proteins."

(4) INCYTE Pharmaceuticals, SmithKline Beecham, Human Genome Sciences

Pharmaceutical companies, focusing on the developing of drug products. Smith Kline Beecham and Human Genome Sciences are the leading commercial partners for the co-development and commercialization of LymphoStat-B. INCYTE Pharmaceuticals, together with SmithKline Beecham or Human Genome Sciences, become technological competitive pairs.

(5) Pioneer Hi-Bred, Monsanto

Both assignees invest more effort than others in hybrid seeds, such as corn. Pioneer Hi-bred, a seed producer, is a subsidiary of DuPont that established collaboration and joint venture with Monsanto.

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The results of Co-Patent analysis also showed the technological correlation, but with different meaning comparing to the observation from the results of Reciprocal Citation and Patent Coupling. The correlation existing in the identified clusters was more like a representation of both the similarity between important technologies held by the assignees and the transformation of key technologies.

Conclusion

This study applied four indexes, including co-assignees, reciprocal citation, patent coupling, and co-patent, for correlation analysis. The results show that co-assignee index does not provide strong evidence to support the correlation analysis comparing to the other three indexes. For the analysis purposes, reciprocal citation index gave more insights on the density of research impact among assignees. After further examination of the results from reciprocal citation and patent coupling analysis, the outputs present the technological correlation while the research and development works are carried out. Co-patent index also presents the technological correlation, but provides more information on the similarity between key technologies held by the assignees in the same cluster which only reflects partial technological aspects. Besides the similarity between technologies, several issues might influence the depth of linkage among assignees, geographic and institution attributes. The institutions based in Bay area of California US, including University of California (Berkeley) and Genentech, and those based in Boston, Massachusetts, including Harvard University, General Hospital (Boston) and Genetics Institute, are technologically and geographically correlated. Besides, affiliation and subsidiary also enhance the knowledge transfer. Pioneer Hi-Bred and Monsanto were highly correlated probably because Pioneer Hi-Bred is a subsidiary to DuPont that has join venture with Monsanto.

Co-assignee, reciprocal citation, patent coupling and co-patent approaches have been used to construct the research network and the correlation among the entities in the network. This study examined the meaning of the linkage indexes gained by taking different approaches and the results show different prospects of relationship among the entities. With this finding, the meaning of the correlation generated by different methods should be interpreted with qualifiers to specify the correlative meanings. Further studies in different subject domains can be carried out to identify the possible new meanings of linkage indexes.

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Note

Note 1 INCYTE Pharmaceuticals was founded in 1991. INCYTE Corporation was moved to Willington, Delaware in 2004 and shifted the research focus to Drug research.

Note 2 SmithKline, based in UK, merged with Glaxo to form GlaxoSmithKline in 2001. Patents were granted to US Branch office.

Note 3 Self-citation index, $RCIii=(CPii)\div(CPi\times 2-(CPii))$, CPii is the number of patents granted to assignee I cited by assignees I, CPi is the number of patent citations of assignee I.

References

Albert, A., & Plaza, L. M. (2004). The transfer of knowledge from the Spanish public R & D system to the productive sectors in the field of biotechnology. *Scientometrics, 59*(1), 3-14.

Banerjee, P., Gupta, B. M., & Garg, K. C. (2000). Patent statistics as indicators of competition: An analysis of patenting in biotechnology. *Scientometrics, 47*(1), 95-116.

Bellardo, T. (1980). The use of co-citations to study science. *Library Research, 2*(3), 231-237.

Carpenter, M. P., Cooper, M., & Narin, F. (1980). Linkage between basic research literature and patents. *Research Management, 23*, 30-35.

Cawkell, A. E. (1976). Understanding science by analyzing its literature. *The Information Scientist, 10*(1), 3-10.

Collins, P., & Wyatt, S. (1988). Citations in patents to the basic research literatures. *Research Policy, 17*, 65-74.

Coward, H. R., & Franklin, J. J. (1989). Identifying the science-technology interface: Matching patent data to a bibliometric model. *Science, Technology, & Human Values, 14*(1), 50-77.

Garfield, F. (1980). Bradford's law and related statistical patterns. *Current Contents, 19*, 5-12.

Garg, K. C., & Padhi, P. (1998). Scientometric study of laser patent literature. *Scientometrics, 43*(3), 443-454.

Jaffe, A. B., Fogarty, M. S., & Banks, B. A. (1997). *Evidence from patents and patent citations on the impact of NASA and other federal labs on commercial innovation* (NBER Working Paper 6044). Cambridge, MA: NBER.

Kessler, M. (1963). Bibliographic coupling between scientific papers. *American Documentation, 14*, 10-25.

Kessler, M. M. (1965). Comparison of the re-

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sults of bibliographic coupling and analytic subject indexing. *American Documentation, 16*(3), 223-233.

Lo, S. C. (2004). A study of the productivity of genetic engineering research from 1991 to 2002 using the patentometrics approach. Paper presented at *International Workshop on Webometrics, Informetrics and Scientometrics & Fifth COLLNET Meeting*, Roorkee, India.

Lo, S. C. (2006). Linkage between public science and technology development of genetic engineering: Preliminary study on patents granted to Japan, Korea and Taiwan. Paper presented at *International Workshop on Webometrics, Informetrics and Scientometrics & Seventh COLLNET Meeting*, Nancy, France.

Lo, S. C. (2008). Patent coupling analysis of primary organizations in genetic engineering. *Scientometrics, 74*(1), 143-151.

Lo, S. C., & Huang, M. S. (2005). Research impact on genetic engineering research: Patent citation analysis. Poster presented at *10th International Conference of the International Society for Scientometrics and Informetrics*, Post Session, Stockholm, Sweden.

Marshakova, I. V. (1979). Citation networks in information science. *Scientometrics, 3*(1), 13-26.

Milman, B. L. (1994). Individual co-citation clusters as nuclei of complete and dynamic informetric models of scientific and technological areas. *Scientometrics, 31*(1), 45-57.

Moed, H. F. (2000). Bibliometric indicators reflect publication and management strategies. *Scientometrics, 47*(2), 323-346.

Narin, F. (1994). Patent bibliometrics. *Scientometrics, 30*(1), 147-155.

Narin, F. (1995). Patents as indicators for the evaluation of industrial research output. *Scientometrics, 34*(3), 489-496.

Narin, F., & Moll, J. K. (1977). Bibliometrics. *Annual Review of Information Science and Technology, 12*, 35-58.

Osareh, F. (1996). Bibliometrics, citation analysis and co-citation analysis: A review of the literature I. *Libri, 46*(3), 149-58.

Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science, 24*(3), 265-269.

Van Viannen, B. G., Moed, H. F., & Van Raan, A. F. J. (1990). An exploration of the science base of recent technology. *Science Policy, 19*, 61-81.

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