The Information visualization analysis of the study in International S&T Policy

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Abstract

Document co-citation patterns of papers (1987-2006), which are retrieved by topic word “Science Policy OR R&D Policy OR Research Policy” from the SSCI and SCI databases, are visualized through a number of co-citation maps by information visualization tool, CiteSpace ,and detected by document co-citation clusters, which identified by EM clustering method. The maps show an overall evolution process of S&T Policy and three research fronts or hot points in the field of S&T Policy currently. The research fronts or hot points in the field of the international S&T Policy provide the decision support for the making of our country’s S&T policy.

1. Introduction

According to the U.S. scientific philosopher of K.S. Kuhn’s point of view, the development of science is realized by a sudden outbreak of the scientific revolution or the realization of the scientific paradigm of the conversion, science is constantly from conventional science to the crisis, to the scientific revolution and then to the new norm - The establishment of a new construction of conventional scientific process (T. S. Kuhn,1962). Scientific papers and publications is an important vector of human knowledge, they reflect the rapid growth of human knowledge of the constant development. And the application of citation between scientific literature describes the inner rela tionship between the development of the science. Citation in the scientific literature to a large extent explained the starting point and intellectual bases of the scientific research, was also reflected in the citation with the impact of the study. The more frequency of the paper is cited, the more innovative shows that the paper is stronger on follow-up study on the impact greater. In addition, the endure of paper named as the half-life is also a measure of scientific development as an important indicator. By analyzing the growth of literature, cited half-life and co-citation can know the specific scientific developments in the field of evolution. A broad "science and technology policy(S&T policy)" means the guiding principles and rules that in order to develop the science and technology and the relationship between them of a country or region, and even a department in a certain period of history and strategic objectives. On contrast, the narrow "S&T policy" refers only to the national level of science and technology policy, does not include regional or department science and technology policy. So the science and technology policy research and observation is carried out mostly at the macro level. This paper attempts to show the international science and technology policy’s research fronts by using visualization software named CiteSpace based on the theory of scientometrics and information visualization. We draw the map of network in international science and technology policy research run by CiteSpace. According to the analysis of net work with a total of Node in the relevant

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property values, We can provide the necessary information support to science and technology policy makers and researchers.

2 Data and Method

This article on the use of the current inter national field of information visualization technology for advanced software - CiteSpace as an analytical tool. The software is developed by Dr. Chaomei Chen who is a expert of information visualization come from the College of Information Science and Techno logy in Drexel USA. CiteSpace can be used for detection and analysis of cutting-edge inter disciplinary research Changes in trends in its research front and knowledge bases between the different studies the relationship between the frontier. Through the literature of infor mation visualization of data, more intuitive to identify the research front of the evolution path disciplines and areas of the knowledge base of the classical literature(Chen C,2004).

We retrieved the data from the United States ISI Web of Science, including SCI and SSCI. Each data record, including documents of the main author, title, abstract and citations. We use the topic word “Science Policy or R & D Policy or Research Policy” published in English and the "Article" type between 1987and 2006 for a total of 885 literature data, which contains a total of 29,355 citations. We set up "Time Scaling" the value of 2, so the 20 years are divided into 10 sessions. Sub-time data processing mainly consider the following two aspects: First, CiteSpace software in the design and operation of the process of using the "sub-rule strategy" principle, the Sub-time data processing software will help improve the speed and accuracy. The second is a data processing sub-disciplines to identify the evolution of prominent turning point in the forefront of the dynamic and subject trend.

3 Result

Run the data by CiteSpace，Select "Reference" co-citation and "Cluster" view, we can get the mapping of the network about the evolution of research fronts of the international science and technology policies (Fig.1), in the pattern, with a total network formed a different color Marked clustering groups, the network contains a total of 294 nodes, the connection 3411, which includes four pivot points.

There are 6 clusters marked by different colors which run by EM clustering algorithm in CiteSpace (Fig. 2). CiteSpace calculated a total of nodes in the network map of the half-life, with frequency and Centricity. EM algorithm then cluster through the priori probability and also the half-life, cited frequency, centricity of different nodes. So we can detect which cluster the nodes belong to by their color.

We selected the top 5 Time-cited articles in each cluster through the result of EM algorithm. We can get the further analysis of the literature each cluster in the network..

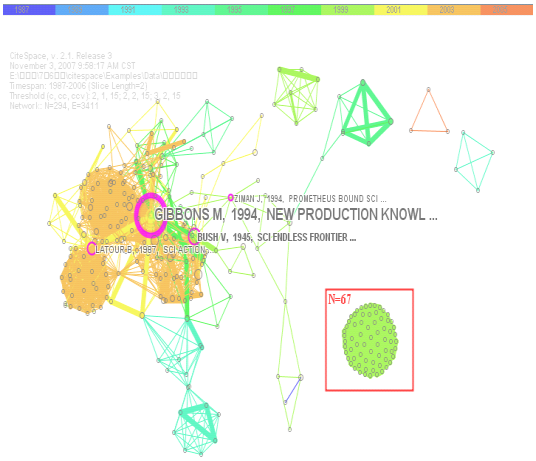

Fig. 1 Mapping of the network of documents co-citation of international S&T policy

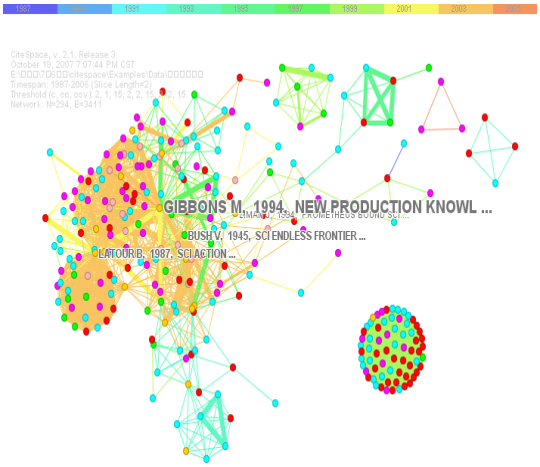

Fig. 2 Mapping of the EM clusters

Tab. 1 Top 5 of time-cited of each clusters

From the result of the EM cluster, there are 69 nodes in cluster 1 which have the 23 percent of the whole nodes in the network. The average published year of the literature is 1985, the average half life is 13.8 years and have a relative high average cited frequency and centricity. Analyze from the average published year, the literature in cluster 1 are the research fronts in 1980s of international S&T policy. The relationship between the progress of science and technology and economics theory, scientific activities Eval uation, scientific research and technology foresight intellectual property issues are the main research fronts of S&T policy during this period.

AU	PY	HL	CE	CL
CARPENTER-MP	1981	19	0	cluster1
DOSI-G	1988	15	0.02	cluster1
ROSENBERG-N	1982	21	0.01	cluster1
NELKIN-D	1984	10	0	cluster1
MARTIN-BR	1983	5	0.01	cluster1
BUSH-V	1945	53	0.19	cluster2
HAGSTROM-WO	1965	29	0	cluster2
POLANYI-M	1962	32	0.06	cluster2
POLANYI-M	1966	38	0.02	cluster2
KUHN-TS	1970	33	0.01	cluster2
LUUKKONEN-T	1992	4	0.09	cluster3
LEYDESDORFF-L	1994	2	0.06	cluster3
WYNNE-B	1992	12	0.04	cluster3
JASANOFF-S	1990	11	0.04	cluster3
MOED-HF	1989	7	0.02	cluster3
MCMILLAN-GS	2000	3	0.03	cluster4
SALTER-AJ	2001	3	0.03	cluster4
GIERYN-T	1999	4	0.01	cluster4
GUSTON-DH	1999	2	0.04	cluster4
NOWOTNY-H	2001	3	0.04	cluster4
*OECD	1999	4	0	cluster5
COOKE-P	2002	2	0	cluster5
KAPLINSKY-N	2002	2	0	cluster5
TIJSSEN-RJW	2002	1	0	cluster5
GLANZEL-W	2004	2	0	cluster5
GIBBONS-M	1994	3	0.47	cluster6
PAVITT-K	1984	19	0.01	cluster6
LUNDVALL-BA	1992	11	0.01	cluster6
ZIMAN-J	1994	6	0.14	cluster6
DASGUPTA-P	1994	9	0	cluster6

In these, G. Dosi's " Technical change and economic theory " published in 1988's and the United Kingdom N. Rosenberg's "Inside the Black Box: Technology and Economics " are both listed, which are the important works on scientific and technological progress and mutual economic relationship. D. Nelkin in his book" Science as Intellectual Property: Who Controls Research?" discusses the related controversial issues on the control of scientific research, such as the issues of scientific secrets and ownership , the interests of scientists, the rights of citizens which should be told and legitimate security that the government and administrative bodies need and other issues(D. Nelkin, 1984).

It is worth mentioning that, B. R. Martin's "Assessing basic research: Some partial indicators of scientific progress in radio astronomy" is listed in these , and Martin is the first scholar to put forward the concept of "Technology Foresight". In 1983, the British University of Sussex, SPRU, John Irvine and Martin are commissioned by the British government to study the future of scientific investigation in the government departments, funding bodies, companies and technical advice organizations based on the science and technology, in order to confirm the methods used in the activities of the long-term priority areas. The study covers France, Germany, the United States and Japan four countries. And the results were published in 1984 as the caption "science in the foreseeable: the selection of a winner". From 1987 to 1988, commissioned by the Government of the Netherlands, two scholars did further research in this direction in accordance with the latest development and extended the countries to eight, an increase of Australia, Canada, Norway and Sweden. The study report was published by the Netherlands Ministry of Education and Science publication with the caption "research foresight: creating the future", and published as a book with the title "research foresight: the priority areas set up". In these two studies, they put forward the concept of "foresight" different from the (technical) prediction. What they initially put forward was "research foresight" which ensure the strategic basic research, and later it expanded to "Technology Foresight" included GM technology area (CL Fan, 2004). The Technology Foresight that Martin made and advocated has an important valuable to the formulation and decision-making of science and technology policy.

There are 23 nodes in cluster 2 which have the

8 percents of the whole nodes in the network. The average published year of the literature is 1967, the average half life is 32.5 years and have a relative high average cited frequency and centricity. Its long half-life represents long article endurance. The documents in C2 are the basic and classic articles of science and technology policy. Among them, the first five nodes literatures of the highest cited frequency are monographs, including Wanneil Bush's scientific research report "Scientific Research: the Endless Frontier." The linear model of basic and applied research which Bush has proposed for in scientific research is important theoretical basis related to scientific research and science and technology policy-making. The two famous book" The Tacit Dimension "and "The Republic of science: Its Political and Economic Theory" published in 1962 and 1967 by European excellent physicist and philosopher Michael Po1anyi in the 20th century are both listed in these. As early as in the 1940s, Polanyi has advocated, a scientist can be regarded as a businessman in a free market looking for maximize profits as an actor. He also tried to use the "invisible hand" mechanism to explain the scientific community organizations. Polanyi deemed, an scientist was independent, and he made choices, did researches freely based on their own judgments ;at the same time, scientists as members of organizations also relied on and cooperated with each other, and the actions among them were coordinated. The "invisible hand" played an important role in this coordination process. " the greatest degree coordination between independent scientific researches brought about by the process of self-regulation, reminds people of the self-regulation reached by producers and consumers in the operation of the market…… there is an 'invisible hand' leading the coordination in the creative activities to achieve the maximization of scientific development" (F Ouyang, 2007). Here, Polanyi borrowed Smith's "invisible hand" to explain scientific activities; its main purpose is to promote scientific freedom, decline projects to science. W. Hagstrom in 1965 published a book" The Scientific Community". The Teamwork which he put forward is large scale cooperative research structure that has a division of labor and a grading system, and such cooperation has " Reciprocal Inter dependence ", that is there is highly relevant in the work shared by the participates of the research projects, the results need to feedback in time, and the acts of individual partners will have a direct and rapid impact on the group of other people. In cluster Ⅱ,the cited scientific literature out of previous five also includes the United States philosopher Kuhn's book " The Structure of Scientific Revolutions ". The result of Academic Google search is, it was cited a total of 14,602 times (November 7, 2007 Retrieval). The concept of the scientific paradigm in the Kuhn's book, is still the hot issues in the research.

There are 100 nodes in cluster 3 which have the 34 percents of the whole nodes in the network， and it is the cluster which has the largest number of nodes in the six clusters. Articles in C3 are published in between around 1994, more likely to have high centrality, and with a 5.7 year of citation half life.It is the literature cluster which introduces quantitative research methods on the area of international science and technology policy research, which shows the hot researched on the forefront in the 1990s is analyzing science and technology policies on means of the mathematical model and quantitative analysis of the literature. These researches include the measurement of international scientific coop eration research, economics and evolution of chaos theory, uncertainties research, citation analysis theory. In 1992 T. Luukkonen jointly issued the “Understanding Patterns of International Scientific Collaboration” with O. Persson and G. Sivertsen. They made quantitative research on the model of international scientific cooperation, and they made an objective evaluation of the network of international cooperation and cooperative relations in various areas between the major developed countries (T. Luukkonen, O. Persson, G. Sivertsen, 1992). L. Leydesdorff in 1994's issued the" Evolutionary Economics and Chaos Theory: New Directions in Technology Studies", and he proposed the idea of the introduction of evolution of economic theory and chaos theory on technology research (L. Leydesdorff，P. van den Besselaar, 1994). S. Jasanoff issued the " The Fifth Branch: Science Advisers as Policymakers ". HF Moed through the citation analysis of literature , introduced the research methods of citation analysis.

There are 18 nodes in cluster 3 which have the 6 percents of the whole nodes in the network，and it is the cluster which has the smallest number of nodes in the six clusters. Articles in C3 are published in between around 1998, with a 2.9 year of citation half life, and have a not relative high average cited frequency and centricity. GS McMillan and others’” An analysis of the critical role of public science in innovation: the case of biotechnology” pointed out that public science policy is a driving force behind high-tech and economic growth. The so-called "public science" refers to the scientific research funded by government agencies, academic institutions, charitable organizations and conducted in government research institutions, academic and research institutions and charitable research institutions (G. S. McMillan， F. Narin， D. L. Deeds, 2000)."The economic benefits of publicly funded basic research: a critical review " issued by A. J. Salter in 2001 critically reviewed the economic benefits problems of the public funds in financing Basic research, through econometric research, case studies and literature survey three methods, discussed the model of the government's public funds in basic scientific research in the economic efficiency, re-examine the theory of the government funds in financing basic research , and provide important reference for policy makers to (A. J. Salter，B. R. Martin, 2001). "Cultural Boundaries of Science: Credibility on the Line " issued by T. F. Gieryn in 1999 advocated the "build out of the laboratory." Scientific knowledge was built out of the laboratory, but we could not find the eternal nature of science to the defense for science. He proposed the demarcation of science , science should be defined in specific scenarios in order to get an answer.In these situations, related groups based on their goals, positions and interests shape the image of science, outline the borders of science, build the scientific authority(T. F. Gieryn, 1999). D. H. Guston in the" Stabilizing the Boundary between US Politics and Science: The Role of the Office of Technology" pointed out that the scientific community became the trustees of the public, and whether its work met the requirements of the public, had the respon sibility to accept the review of the public; when scientists made their professional advice in the scientific affairs, the public had the right to review, to investigate whether abusing public trust, whether expense the overall public interest to meet their special interests of its groups; and we needed to establish a "science on the social contract" between the public and the scientific community(D. H. Guston, 1999).

There are 64 nodes in cluster 4 which have the 22 percents of the whole nodes in the network Articles in C4 are published in between around 2000, with a 2.6 year of citation half life, and have a relative high average cited frequency of the nodes. The nodes literatures of the cluster belong to the literatures on the forefront. Through analysis of the literature, we can sum up the three trends of the international science and technology policy research forefront: National and regional innovation system and science and technology policy development, the application of the bolometric analysis in the field of science and technology policy research, and the researches related to scientific cooperation.

Since the 1990s, the researches of the national innovation system especially the researches oriented in performance evaluation and policy development of the national innovation system increased significantly, the framework conditions of enhancing the innovation ability had become a global policy-makers focus. In 1994, the Organization for Economic Coop eration and Development (OECD) in approval and funding of the European Union of Science and Technology Policy Committee, implemented the national system of inno vation projects by technological innovation policy working group. In its first phase of its work, formed six thematic reports through the case study, and one of the reports "management of a national innovation system" included in the fifth cluster of nodes in the literature. There is still great distance from the researches of OECD national innovation system to policy objectives, but the researches provide a good example for the national innovation system to search for innovation policy. Britain's Cardiff University P. N. Cooke in 1994's " Knowledge Economies: Clusters, Learning and Cooperative Advantage " conducted a comprehensive theory and empirical research to the regional innovation system. In the book entitled "regional innovation system: the context of globalization regional management role" edited by Cooke, Braczyk, Heidenreich in 1996, Cook made a more detailed statement to the concept of

Regional Innovation, and reckoned that the regional innovation system is a system of regional organizations mainly composed of manufacturing enterprises associated in the geographical division of labor with each other, research institutions and higher education institutions, which support and generate innovation(Hans-Joachim Braczyk, HJ Cooke P, 1996).

Scientific cooperative research is an important direction of the researches in the fields of scientific measurement and science and technology policy, including cooperation of scientific institutions and individual scientists, institutional cooperation even cooperation between the universities and the domestic regional cooperation and regional cooperation among countries such several levels. Robert Tijssen is Leiden University psychology master, Scientometrics doctor, and his major research areas are: R & D performance indicators, the national science and technology network, cooperation between business and university, the bibliometric analysis and so on. The cooperation between individual scientists is conducted mainly through the co-author of the paper form. Thus the research of individual scientific cooperation is analyzed mainly through the measurement between the scientific literature . In recent years, here came the research focus areas of bibliometrics, science metrology and information metrology in the world. Scientific measurement methods will be introduced into the science, and that is the hot spots in the field of international science and technology policy research. Belgium Jurists of scientific measurement W.Glänzel conducted the research of international scientific cooperation and the measurement of scientific literature on means of the citation analysis of the literature, co-cited network analysis methods. The article " The influence of author self-citations on biblio metric macro indicators " published in 2004 in the "Scientometrics" contained in this cluster(W. Glanzel, B. Thijs, 2004).

There are 20 nodes in cluster 6 which have the 7 percents of the whole nodes in the network Articles in C6 are published in between around 1991, with a 9.2 year of citation half life, and have a relative high average cited frequency of the nodes. Especially the average centrality is 0.05, which is the highest of six clusters.

4. Research Conclusions

Through the analysis of co-citation network in the international science and technology policies literatures, using the information visualization's method to comb and demonstrate its structure evolution's vein, explained the discipline background and the inner links of evolution of the knowledge structure in the international scientific policy area research. The theory instructs to practice, and the international science and technology policy research's theory front has the significant guiding sense now to various countries' country science and technology policy's formulation and implementation. At the same time, in our country science and technology policy developing process we're facing many questions, still having the independent innovation ability not strong, the technological progress and the economic society develops unifies, the scientific research seal undertightenedly, but questions and so on difficult and international trail connection, therefore, the international science and technology policy research's theory front and the trend of development which it displays, to consummates our country science and technology policy, has the more important enlightenment function in causing it to serve well in the harmonious society's construction.

4.1 Establishment and consummation national science and technology innovation system.

National innovation system refers to a organization and system network composed of a country's public and the private department, and its major function is through promoting and carrying on the innovation, promoting the economic development and the social progress. Internationally the country through improving the scientific and technological innovation ability to create a strong competitive adva ntage is known as the innovation-oriented country. For developing countries, it is necessary to properly handle the introduction of technology and independent innovation to strengthen independent innovation capability. In China, the "10th Five-Year" Plan was proposed for the first time by building a national innovation system, so we should further strengthen and improve China's scientific and technological innovation system, in order to achieve the grand strategy of "leapfrog development".

4.2 establishment of the science and technology policy system in which science and technology and socio-economic promote each other and coordinately develop.

Have mentioned earlier, our country still had the question of technological progress unify undertightenedly with the socio-economic development, therefore we must initiate the science and technology and the social economy promote mutually, impetus socio-economic development by science's and technology's progress, and support science and technology by social economy's development. On the one hand, we must insist that has the behavior, to be able to refrain from doing things, choose essential domain which has certain foundation and the superiority, related to national economy and the people's livelihood and the national security, concentrate efforts, and breakthrough the key; Embarks from the reality urgent demand, try to break through the significant key, the general character technology, support economic society to continue the coordinated development; Focuses long-term, deployed in advance the frontier technology and the basic research, create the new market requirement, the cultivation emergent industry, will eagerly anticipate futures economy society's development(Zhang Jiu-qing, 2003). On the other hand, we must use the socio-economic development fully the material civilization achievement, in the enhancement expenditure the science and technology input accounts for the proportion, simultaneously establishes multiplex, the multi-channel science and technology input system, the adjustment and the optimized investment structure, raises the technical funds operational effectiveness.

4.3 Expanding scientific and technological cooperation and exchange between different main bodies.

On the one hand, we must promote the technical union research which positively the official, produces, studies. A country's scientific research institution may divide into the government scientific research institution, the enterprise scientific research institution, the research university and the non-seeking to make a profit scientific research institution and so on 4 types. Each kind of scientific research institution's sources of fund, the management form as well as the research direction have the difference. Therefore, a good country technology policy must urge the function which fully each kind of scientific research institution completes them to decide, the display respectively unique main body superiority; Must be able to promote between them the communication and the exchange, promotes mutually, communal development. On the other hand, must expand the academic exchanges and the research cooperation diligently, particularly international technical exchange republican cooperation. The academic theory takes one ideology shape, is in itself and in the exchange grows the strength at unceasing “the collision”. But along with the greatly scientific time's arrival, the many wasting assets huge scientific research must in the international scope be able the effective addressing, the technical international cooperation to become the greatly scientific time country scientific policy the important choice pattern. Must encourage the scientific research courtyard, the institutions of higher learning and the overseas research development organization participation or the coordination organization international greatly scientific project, supports our country scientists to hold the post of the leadership position in the important international Academic body.

4.4 Strengthening basic research, in particular strengthening the cross disciplinary research.

According to the characteristic, which thick product to be strong thinly, the progress often with difficulty forecast, of the basic research, we must carry on the comprehensive layout to the basic subject, prominent discipline overlapping, harmonious and seepage, cultivates the new discipline growing point. Between the basic subject, the basic subject and the application discipline, the science and technical, the natural sciences and humanities social sciences' intersecting with the fusion, often causes the new discipline the production, is in the scientific research one of most active parts, but the scientific metrology and the analysis method are also this part of extremely rich vitalities and an application value part. The scientific metrology is to the scientific theory, the scientific rule, the scientific behavior idea quantification, the standardized research system. The science measurement discipline may provides the reliable theory for

the science and technology policy research and the administrative action to rest on, the guiding principle as well as the effective method of work, may say that the scientific metrology is the science and technology management rationale. But the literature metrology is this domain research hot spot, and forms potential of the confluence along with the research tool modernization degree's deepening with other related disciplines(Wang Hong-Xin， Qiu Jun-ping, 2000). Because the literature metrology target's appraisal function with other society evaluating indicator's function is consistent, moreover its research results and the measurement data are also the quantification are precise, is not only advantageous in the literature metrology and the information science quantifying research work breaks through traditional the limitation, in bigger range fully plays its role, but also provides the accurate reliable decision-making as well as the management for our country science and technology policy domain rests on and supports, the formulation fine effective controllable policy or the plan, bring the revolutionary for our country science and technology policy's formulation and imple mentation change.

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