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Investigating Technological Innovation Competitiveness by the Use of Patent-Based Indicators: A Global Comparison

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Abstract--**There has been a rapid change in innovation technological development since the past several decades. Understanding technological development trends, keeping advanced technologies, and acquiring the most inimitable and appropriate technologies are pivotal elements for a country or an organization to maintain its technological innovation competitiveness, but it is rather difficult to evaluate such innovation competitiveness as there is no straightforward way of direct measurement. Therefore, this paper aims to apply selected patent indicators to measure technological innovation competitiveness for global comparison, in order to understand 1) technology development trends, 2) evaluate the technology diffusion trajectories, and 3) understand national technological innovation advantages. The obtain results can not only be served as evidence for decision making on national Science-Tech development, but also be used as a roadmap for strategic planning on organizational patent portfolio.**

I. INTRODUCTION

In order to adapt a rapid change in innovation technological development field, global researches and policymakers have been interested in the extent to which stronger intellectual property rights (IPR), because it can influence industry innovation, international technology transfer, even a national economics [1-3]. However, it is rather difficult to evaluate such innovation competitiveness as there is no straightforward way of direct measurement. Patent, as a type of intangible knowledge capital, have become a large used indicator for measuring intellectual property [4] and valuable knowledge [5, 6].

Patents reflect the latest technological inventions and encompass valuable information related to technology base. Over the last decade, a system of technology Indicators for measuring the technological strengths of companies and countries has been developed. These indicators are based on large number of U.S. patents and patent citations, and provide comparative measures of the activity, impact, speed, and technologies linkage of the technology for thousands of U.S. and foreign companies.

Patents and patent citations have been used to establish the technology indicators. U.S. patent cited count provide important resources for technical of data, it contains for foreign patents and other publications references. The basic technical quality of the indicators is the frequency of a patent is subsequently referenced patent. Cumulative single patent data can be used as countries, companies, and countries to establish technical completion of the indicators. Frequently cited patent is indicates an important technology, because it means it effect a lot of future patents. These patents also can be used to determine the field of cutting-edge technology. Frequently cited patents are beyond the average level of technology patents , it is important to have the vitality of the invention Therefore, these citations is used as the indicators of technical quality, they are also used citations as an important links between literature and technology development. Thus, In order to identify which country is more competitive than the others, the higher citation rate must can be representing the countries have more open than other countries actively [7].

Researchers have been using patent-based index to quantify the development of technology. Most of studies have only investigated the link between enterprise and innovation technology based on different patent index. Traditional patent analysis is more or less uni-dimensional, and tends to just identify technological activity by simply counting and classifying patents. In contrast, Technology Indicators based on patent citation analysis are on more advanced measurements, and allow for quantitative, graphic, and highly precise identification of key aspects of a company or countries' technological competitiveness. Therefore, this study is attempted to supplement the findings of these earlier studies. The research not only be served as evidence for decision making on national Science-Tech development, but also be used as a roadmap for strategic planning on organizational patent portfolio. More particularly, the aim of this paper is to understand 1) technology development trends, 2) evaluate the technology diffusion trajectories, and 3) understand national technological innovation advantages.

To obtain the purpose, this paper analyzes patents granted by the U.S. Patent and Trademark Office (USPTO) between 1976 and 2012, and intends to investigate whether the scientific technology of top countries in the different industry support their countries development and whether there is consistent performance between science and technology.

II. LITERATURE REVIEW

Patent data are well organized and objective data, which are also recognized as a valuable information of for solve various technology management decision problem such as technology analysis [8, 9], technological forecasting [10, 11], policy making [12], strategic planning [13-15], or looking for relationship among countries and industries. The basic analysis and citation network analysis provide valuable information in assessing the performances of different countries, institutions, and technology fields and of knowledge flow patterns [16, 17]. The knowledge flow of the selected patents was first reviewed to investigate whether growing competitiveness in technology R&D is accompanied by intensification of international citation linkage.

The patent analysis provides a way of mapping knowledge evolution with discover of core meaning by each patent. Owing to technology development is a cumulative result. Therefore, a technological field can be viewed as an evolving network in which patent are actors and ties are the technological links [18]. Network analysis is a recently developed method for social structure study and has been already used in innovation studies [19-22]. Previous network analysis research used patent citation to understand technological trajectory or even to forecast technological development by the use of patent references listed in the patent document. A citation relationship technology from an invention is connected to another invention, the initiator of the present invention is based not previous invention [18].

Patent citation network analysis shows how patents are networked together at different stages of technological development for explaining technological change and pointing to the very specific patterns of patent citation information [23]. Citation networking can discover the tracks of knowledge evolution. Patent data contain citation information that link different patents at different stages of technological development that mirror inventive activities and the cumulative process of technological change [23, 24]. The patent analysis provides a way of mapping knowledge evolution with discover of core meaning by each patent. The relationship between patents forms a technological network. Patent citations hold great attraction for the study of knowledge flows. Research in this area uses 'backward' citations to measure knowledge flows. Backward citations are citations to prior patents and have been used to measure technological knowledge acquired by the patenting entities studied [25].

All of the researchers attempts use patent statistics as a solid indicator of national innovative capacity [26]. This is also related to the ease of availability of patent data for all countries. Recently, patent values are measured in various ways from individual, enterprise or organization, or national level perspective [7]. Among these measure levels, the technology trends can be gained directly from patent databases.

Various patent indexes also predict economic values from across studies. However, the following patent indicators are generally used in the literature: patent numbers, patent citation counts, different technology classes, the number of claims, the current impact index or technology cycle time. The five key indicators of technology development performance used in the literature and industrial practice are: number of patents, citations per patent, current impact index, technology cycle time, and science linkage [27]. Many of these measures involve the number of citations a patent receives from subsequent patents.

Current impact index (CII) for a particular company is "calculated based upon the number of times patents issued this year cite the patents issued to the chosen company in each of the previous five years. Just as patent citations, high CII implicates high technological value or economic value of the patent [28]. Empirical findings from researchers, which is set in High-tech industry in Japan and the USA, suggest that CII is positively related to market value and there is also a positive relation between CII and stock performance[29].

Each country's size proportional to its technology strength, where technology strength is the product of the number of United States patents invented by inventors in those countries, multiplied by a measure of patent impact, the current impact index. The basis for this index based on patent-to-patent citation [30]. When a U.S. patent is issued it contains several "reference cited of U.S. Patents" which tabular data omitted identifies the prior art upon which the new patent builds. Patents that are highly cited in later U.S. patents tend to be those that contain important high impact discoveries. As a result, weighting a patent count by an appropriate citation ratio rewards a company with important discoveries, and lessens the computed strength of a company whose patents tend to be variations of old technologies.

III. METHODOLOGY AND MEASUREMENT

A. Data Collection

This study gathers the number of utility patents from United States Patent and Trademark Office (USPTO) for the period of 1976-2012. Patent data from US Patent and Trademarks Office (USPTO) are commonly used in empirical studies to measure innovation performance and knowledge flows for its high quality and good availability. Chen and Guan (2010) have used USPTO co-patent data to find that the best knowledge flow efficiency accompanies with a moderate clustering coefficient and small world quotient [31]. Information contained in USPTO is easily accessible, catalogued in the same times, and stored for a long period of times, and therefore their analysis has become the focus of many researches to measure innovation [32-34]. The reason is, there is some defects of patents as internationally comparable indicators [35, 36], such as: the quality of patents varies substantially across countries for legal and economic reasons. Thus, In order to have an internationally patent-based reliable indicator, this research use patents granted at the US Patent Trademark Office (USPTO). Those data is the same as previous research unit used, e.g. ArCo, RAND, UNIDO, and WEF.

This research use different indicators from various perspectives. For evaluating the innovation force, this research used two indexes, Current Impact Index and Technology Strength, and some general indicator to analysis the selected patent to measure technological innovation competitiveness. Besides, the influence of patents on innovation competitiveness is quite complicated. It comes from the side of citation or litigation factors. In the citation factor, the impact will be entangled with time, cited assignee, or different citing patterns. To investigate global development, the downloaded patents are mainly classified from different first assignee countries. Besides, this research selects top 10 countries to understand its knowledge flow by drawing its patent citation network.

B. Methods

This study adopts indicators such as number of patents, citations per patent (CPP), Current impact index (CII), and Technology Strength (TS). The indicators definition as following:

(1) Number of patents (Indicates the level of activity of technology development)- The number of patents issued by the U.S. patent system to an analytical unit (a company, a country, or a technology field).
(2) Citations per patent (Indicates the impact of an analytical unit's patents)- The average number of the citations received by an analytical unit's patents from subsequent patents within a certain period of time.
(3) Current impact index (indicates patent quality and impact of an analytical unit)- The number of times the analytical unit's patents issued in the most recent 5 years had been cited in the current year.
(4) Technology Strength (This indicator reflects overall innovation quality and breadth)- The number of patents multiplied by current impact index.

C. Number of Patents

Number of patents is the basic information for evaluation the trends. Gathering statistical pattern and analyzing granted number of patents can reveal the development profile or technological competitiveness in specific country or industry. E.g., number of granted patents of different industries in specific year by the US patent and Trademark Office (USPTO) will be collected in this study. This indicator helps to evaluate the industry development profile in quantitative viewpoint. By comparing the number of patent in certain time period, the patent granted trend in this period would be revealed. This research use term Pij represents the number of granted patents by country and company i in industry j.

D. Citations Per Patent (CPP)

CPP is the number of citations per patent within a certain time period. CPP value is mainly used to measure the impact of each patent, and it displays the influence of patents on scientific and technical progress. CPP reflects patent quality and innovation level to some extent. When the number of patents increases rapidly, CPP are likely to be lower than the true long-term citation rates. This is because recent patents have not accumulated citations over any give citation window. This study compares the e impact of an analytical unit's patents from evaluating CPP. In order to describe the latest of CPP in each individual, the past 5 years were measured. The equation of CPP of a individual as follows:

$$CPP=\frac{NC}{N} \qquad (1)$$

Where NC represents the sum of citations within a certain period, and N is the total number of patents within the same period [37].

E. Current Impact Index (CII)

CII means the Current Impact Index. This research modifies the formula by selecting only several critical countries as the denominator rather than the whole global countries. This study uses the average cited number of patents in a certain year and compares it to the average value from previous five years for evaluating CII. The equation of CII of a country as follows:

$$CII_i \frac{100C_i/\sum_i C_i}{100C_i/\sum_i K_i} \qquad (2)$$

Where C_i represents the cited number of patents in a certain year, and country i produced from previous 5 years, K_i is the number of patents, country i produced during the past 5 years [38].

F. Technology Strength (TS)

Technology Strength is a quality-weighted portfolio size, defined as the number of patents multiplied by current impact index. Using Technology Strength you may find that although one company has more patents, a second may be technologically more powerful because its patents are of better quality.

Number of patents shows an individual's (company or countries) R&D investment and output and CII represents the individual's importance in the technology domain by their citation situation [38]. TS of i individual in j industry, TS_{ij} , can be computed by its number of patent and its CII as follow:

$$TS_{ij}=P_{ij} \text{ x } CII \qquad (3)$$

IV. SOCIAL NETWORK ANALYSIS

The social network analysis is a sociological study linking individual level and overall level of theory [39]. By social exchange relationship retrospective and structure of a social network, it can be seen how resources are exchanged in the network and how the network members is positioned thereby affecting the exchange of resources, as well as what type of resource exchange is important in different environments [22, 40, 41]. Social network analysis aims to detect and interpret the patterns of social ties among actors using statistics and visualization [42].

Social network analysis has been already used in innovation studies [20-22, 43]. A social network usually represents a social structure of individual, organizations, or countries that interact with one another. Individual, organizations and countries, commonly referred to as ''actors'', can be represented as actors and their complex interrelations as edges. The concept of the social networks has been used in literature to explore relative position of network actor as well as create a social network map to understand how network actors are linked directly or indirectly to other actors. A citation relationship technology from an invention is connected to another invention, the initiator of the present invention is based not previous invention [44].

In social network theory, central indicators can be used to detect actors' control of resources and the size of the control range. From the point of view of the level of organizational behavior that the network center is one of the sources of influence, the higher the centrality of the individual in the organization, the higher influence [34]. The higher the degree of centrality, the more informal power and influence the actor possess, and thus the more important role the actor plays in the network.

In this study, the citation network was constructed using NETDRAW software, in which actors represent the countries and the edges among them represent the citations among countries. The sizes of the actors are determined by degree centrality (DC), which is a measure of the number of direct connections between actors. (DC of a actor in the network is based on the number of direct connections between that actor and other actors. Generally, the actors with higher DC are more central to the structure and generally have greater potential to influence other actors).

V. RESULTS

As shown in Table 1, US patent count, share, and growth rate by country. The rank is ordered by the total count of patent for the time period of 1976 to 2012. Patent count by country gradually increased year by year in recent three years, only two countries (DE and NL) change their patent counts ups and downs. For all the obtained patents, countries with the most patents are United State (US), Japan (JP), and Germany (DE), but the count of patents of South Korea higher than Germany in the last three years.

The share of patents shown the similar result, but it can more clearly understand the differences between the various countries. In the Share of US Patents, United Kingdom (GB), Canada (CA), Switzerland (CH), Netherlands (NL) are very close, ratio is not high. Taiwan (TW) and France (FR) is similar, but South Korea (KR) almost three times the TW and FR. the location and condition of KR is quite close TW, it is no wonder a lot of researches want to study the reason of KR's rise. Although the accumulate count of patents in Korea did not higher than Germany, but the patent count of KR is higher than DE at present. US and JP is relatively higher than other countries. Japan is four times of Germany, and US is almost two times of JP. Japan and the United States are not the same; there is no broad geographic and population. Be seen with the national number of the population is not necessarily proportional to the degree of innovation.

In this study, quantitative data from the USPTO also brought out several interesting points regarding the growth rates of patent between 2010 and 2012. The findings reflect GB, FR, and TW was growing rapidly.

In Table 2 and 3, Top 10 Citations per patent. For all the obtained patents between 2008 and 2012, the Top 10 Cited per patent by First assignee countries is the famous company in the world. First assignee with the most citation patent is IBM, Microsoft, and Samsung. But the first assignee with the most patents is IBM, Samsung, and Canon. The patent count of Canon and Microsoft are quite close. The R & D capability of IBM, Microsoft, and Samsung cannot be ignored. IBM and Microsoft are the long history of large companies, but Samsung is not. It is worthy of study, what kind of policy and the environment caused by the rise of Samsung.

TABLE1. US PATENT COUNT, SHARE, AND GROWTH RATE BY COUNTRY

Rank	First Assignee Country	No. of Patent			Share of US Patent			Growth Rate
		2010	2011	2012	2010	2011	2012	2012
1	US	98750	100596	112964	25.32%	25.78%	28.94%	12.29%
2	JP	45407	46860	51659	11.64%	12.01%	13.23%	10.24%
3	DE	11267	10883	12447	2.89%	2.79%	3.19%	14.37%
4	KR	11680	12304	13222	3.00%	3.15%	3.39%	7.46%
5	FR	3948	4141	5106	1.01%	1.06%	1.31%	23.30%
6	TW	7479	8044	9547	1.92%	2.06%	2.45%	18.68%
7	GB	2418	2439	3024	0.62%	0.63%	0.77%	23.99%
8	CA	2979	3188	3588	0.76%	0.82%	0.92%	12.55%
9	CH	2348	2391	2758	0.60%	0.61%	0.71%	15.35%
10	NL	2515	2443	2833	0.64%	0.63%	0.73%	15.96%

TABLE2. TOP 10 CITATIONS PER PATENT (2008-2012)

FirstAssignee	No. of Patent	CitedCNT	CitedAVG
International Business Machines Corporation	27269	26902	0
Microsoft Corporation	12803	22010	1
Samsung Electronics Co., Ltd.	19129	14657	0
Canon Kabushiki Kaisha	12806	10292	0
Intel Corporation	7476	9660	1
Kabushiki Kaisha Toshiba	10192	8191	0
Micron Technology, Inc.	4902	8102	1
Sony Corporation	10505	7962	0
Cisco Technology, Inc.	4539	7835	1
Silverbrook Research Pty Ltd	2747	7283	2

TABLE3. TOP 10 NO. OF PATENT (1976-2012)

FirstAssignee	No. of Patent	CitedCNT	CitedAVG
International Business Machines Corporation	72049	979685	13
Canon Kabushiki Kaisha	46338	418631	9
Samsung Electronics Co., Ltd.	36772	166818	4
Hitachi, Ltd.	35066	401051	11
Kabushiki Kaisha Toshiba	33161	321607	9
General Electric Company	32101	340646	10
Sony Corporation	31688	247541	7
Fujitsu Limited	25289	237380	9
Matsushita Electric Industrial Co., Ltd.	24142	246382	10
NEC Corporation	23621	240119	10

To investigate industrial development for different companies, the downloaded patents are classified into five industries, namely "Electrical engineering", "Instruments", "Chemistry", "Mechanical engineering" and "Other fields". The study found that the number of large patent cited most well-known for manufacturing or research and development of consumer electronic products such as computers, mobile phones, cameras, and network-related equipment. A number of interesting finding s emerged from this analysis.

International Business Machines, Microsoft, Samsung, and Canon Kabushiki Kaisha are companies mainly from the "Electrical engineering" industry. IBM has technologies mainly concentrated in Computer technology, and followed by the Semiconductors. Many years ago, International Business Machines Corporation has developed Optics technology and Textile and paper machines technology in Mechanical engineering industries. Since 1984, IBM began to focus Computer technology, Semiconductors, Audio-visual technology until today.

Microsoft also has technologies mainly concentrated in Computer technology, but followed by the Telecommunications. Technologies of Samsung concentrated in Telecommunications, and followed by the Computer technology and Audio-visual technology. In early period, Canon mainly focused on “Instruments”, and has technologies concentrated in "Optics". But it has become computer technology of electrical engineering industry in recent two year, and second high in Optics of Instruments industries.

The technological position of countries also shown in results is further illustrated by the fact that among the top 10 companies, there is five U.S. Company and only three JP companies with higher patent citations in latest five years.

As shown in Table 4, Top 10 First Assignee Country’s Current Impact Index & Technology Strength. It means the rank countries based on their technological strength and Current Impact Index. CII is a quality indicator of technological innovation. CII top three countries were United State (US), Switzerland (CH), and Taiwan (TW). The data indicate that the quality of patents in these three countries is quite good, especially Switzerland.

Table 5, shows the top 10 companies ranked by this definition of Current Impact Index and technological strength. Note that the first three companies, Micron Technology, Intel Corporation, International Business Machines, are all US company. Micron Technology has highest score in CII and TS analysis. These studies also note that only one company has much higher than expected Current Impact Indexes: a citation impact ratio based on the previous five year's patents, with an expected value of 1.00. For example, the value of 1.23 indicates that Micron Technology's last five years' patents are cited 23 percent more than expected in the U.S. patent system. Micron Technology is best known for producing many forms of semiconductor devices. Develop the high quality patent might be one of the reason that it can survive in the rapid development of technology. Compared with IBM, This result also indicates some relationship between number of patents and valuable patent. Filing a lot of patents does not mean get a lot of high-quality patents, but the company is increase market opportunities for diversification and accumulation of knowledge.

TABLE 4. TOP 10 FIRST ASSIGNEE COUNTRY'S CURRENT IMPACT INDEX & TECHNOLOGY STRENGTH

Country	2010			2011			2012		
	No. of Patent	Current Impact Index(CII)	Technology Strength(TS)	No. of Patent	Current Impact Index(CII)	Technology Strength(TS)	No. of Patent	Current Impact Index(CII)	Technology Strength(TS)
US	98750	1.25	123677.18	100596	1.35	136250.28	112964	1.32	149273.86
JP	45407	0.40	18074.63	46860	0.43	20167.59	51659	0.54	27674.46
DE	11267	0.36	4047.37	10883	0.30	3306.23	12447	0.46	5778.96
KR	11680	0.53	6236.89	12304	0.61	7475.85	13222	0.57	7555.43
FR	3948	0.33	1303.22	4141	0.54	2253.96	5106	0.41	2097.11
TW	7479	0.81	6026.77	8044	1.08	8654.94	9547	0.98	9376.52
GB	2418	0.38	915.55	2439	0.39	957.08	3024	0.38	1134.00
CA	2979	0.46	1359.35	3188	0.53	1694.89	3588	0.57	2050.29
CH	2348	2.87	6747.65	2391	2.86	6840.08	2758	2.70	7436.75
NL	2515	0.47	1172.04	2443	0.61	1484.35	2833	0.64	1821.21

TABLE5. TOP 10 FIRST ASSIGNEE'S CURRENT IMPACT INDEX & TECHNOLOGY STRENGTH

Corp.	2010			2011			2012		
	No. of Patent	Current Impact Index(CII)	Technology Strength(TS)	No. of Patent	Current Impact Index(CII)	Technology Strength(TS)	No. of Patent	Current Impact Index(CII)	Technology Strength(TS)
International Business Machines	3862	0.52	2014.96	4176	0.53	2197.89	4709	0.46	2173.38
Canon Kabushiki Kaisha	2566	0.43	1115.65	2682	0.47	1270.42	2569	0.46	1185.69
Hitachi, Ltd.	729	0.43	316.96	813	0.37	299.53	634	0.31	195.08
Motorola, Inc.	85	0.35	29.57	6	0.11	0.63	0	0.00	0.00
General Electric Company	747	0.35	259.83	910	0.42	383.16	996	0.38	383.08
Kabushiki Kaisha Toshiba	960	0.48	459.13	1146	0.47	542.84	1348	0.38	518.46
Texas Instruments Incorporated	270	0.30	82.17	234	0.37	86.21	252	0.31	77.54
Micron Technology, Inc.	3201	1.30	4175.22	2834	1.26	3579.79	2032	1.23	2500.92
Intel Corporation	1147	0.52	598.43	990	0.53	521.05	942	0.46	434.77
Xerox Corporation	945	0.91	862.83	865	0.47	409.74	1020	0.38	392.31

Patent citations are simply a direct indicator of this crucial role of the patent as an active element in the transfer and advance of science and technology, the technology transfer aspect of patent citations reflects. In Figure 1, Citation Rate between top 10 first assignee countries. The size of actor is proportional to its degree centrality (DC). Self-Citation Rate focused on US and JP, then the order is DE, FR, TW, KR. Citation direction mostly in the United States, only the United States and Japan over the average mutual citations. The patent citations of other countries are concentrated in Japan and the U.S. On average, each country has a lot of citation from the own country. The reason might be language or industry trends of region. But there are still a few countries cited by U.S. and Japanese patent higher than their own country, such as NL and CA. To summarize the salient features of the analysis, several finding are of interest. US citing JP are almost one third of JP citing US. It means United States Patent have a major impact on the Japanese Patent Development. According to our CII result, the quantity and quality of U.S. patents were also higher than in Japan. What factors have led to this high citation rate of US patent? A partial explanation for this may lie in the fact that the US has more patent with development value than JP. The finding lead us to believe that the technological and industries development in US is relatively opened, so most of US patent develop technology base on patent from other countries.

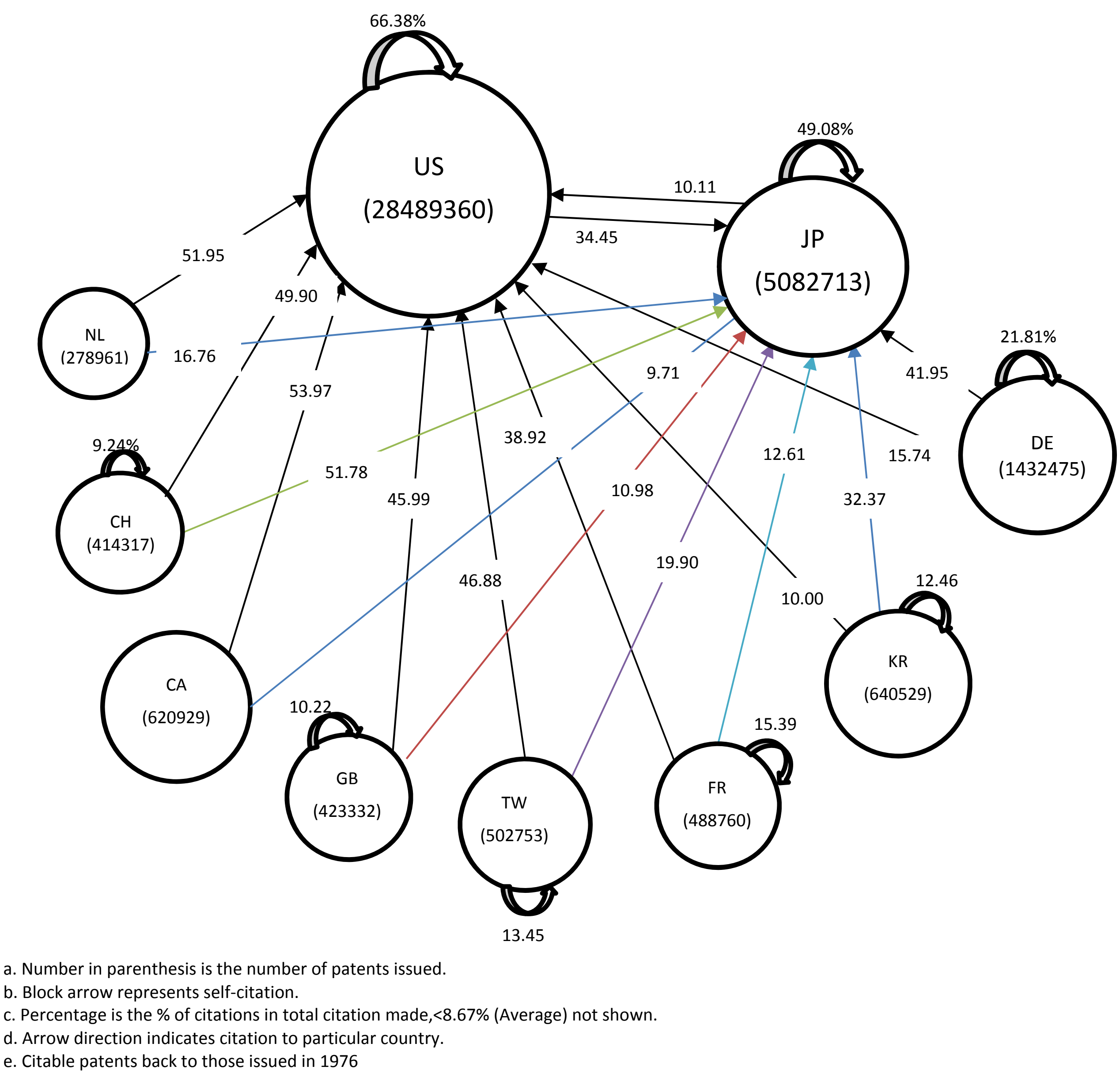

Fig1. Citation Rate

VI. DISCUSSION AND CONCLUSION

The objective of this paper was to investigate the innovation capability between different countries by using count of patents, CII, and patent citations. The citation rate analysis on patent citation is demonstrated in this study to explore how countries competitiveness can be evolved from a citation network which represents the essential structure of national innovation capacity. This study also confirms the network analysis can be used to find the relation between countries and patented technology, as well as the main innovators competitiveness. Besides, Patents with high centralities are easily to be top centrality in other related citation network. it means technology diffusion and technology transition are closely associated together, and critical patents are important in all aspects of national competitiveness. Owing to the rapid development and ardent enthusiasm for technology globally, internationally citations of technology patents have shown a steady growth. Therefore, the proportion of internationally citation patents also exhibits an overall upward trend. For the level of patent growth rate showed that the overall patent growth rate exceeded the overall average rate of the 10 countries: FR & GB. The two high technology capability countries filing and exceeding patent other countries in recent years. The results indicated that if countries have higher patent count with wider technological diversity, it can take advantage of new technological opportunities more often, and reduce the risk of missing new technological opportunities. Such as US, higher patent count might be the reason that can get highest current impact index scores. Furthermore, the countries can also exploit the economy of scope in their broader technological competencies to coordinate the innovation with complementary support. On the other hand, this study shows that a small count of patents does not mean poor quality patents, for example, the count of patents of Switzerland is less than Japan, Germany, Korea, France, Taiwan, United Kingdom, and Canada. But the result shows that Switzerland have a lots of high quality patents. Besides, Countries with limited resources can develop more valuable patents based on existing patents. Patent citation analysis is a recent development which uses bibliometric techniques to analyze the value of patent information. Construction of technology indicators being an important use of patent citations, various patent citations based technological indicators and their applications. At the strategic perspective, several citations implications can be drawn from this study. One of the most fascinating and a useful aspect of patent citation analysis is how it can reveal the structure of the technological relationships among countries: which countries are central to a given technology, and how technology "transfers" from one country-to-country.

Because the patent citations can identify prior trends, it also can reveal not only the technical relationship between the just issued patent and the prior art patent, but also a knowledge link between the technologies of the country which owned the prior cited. Results of the present study represent the most complete time period to date in obtaining direction of technologies development between different countries. This should not surprise us. As emphasized by Leoncini in their research paper, citations are a reasonably informative signal of success; it means country will be more correlated with value than innovation technology [22]. Besides, that self-citation is largely positive for value, opens up a very interesting avenue of research. The self-citation variable gives us a window into technological competition, in the sense that it may inform us about the extent to which countries have externalized knowledge spillovers, or the strength of their competitive position and other countries in their industry.

Future work should explore the ways in which this finding varies by industry and technology field, and the meaning of the size relationship that this research found. Other variations on the results include more exploration of the shape of the citations relationship. The importance of highly cited patents changed over time with patent regime. As result, the country with a citation rate above average includes both small and large countries. It would be useful to sort out whether these are different from each other, and also the extent to which the results relating to an average citation rate of more than average are themselves driven by a few patents. This research would be useful to explore other research. In addition, Several issues that are not considered in this study can be further investigated to refine this research in the future, e.g. 1) Use other patent database to explore the relevant topics, and compare results with different databases; 2) focus on specific countries by using different selected issues, 3) patent indicators can be used to sort out the problem of lack direction. Moreover, this study explored the several patent indicators, number of patents, current impact index, and patent citations, upon countries' innovation capability. Future studies can focus on other patent indicators to explore the relevant topics, and compare to this study. Finally, this study hoped that the research results can be beneficial to managers, researchers, or governments, and contributed to relevant studies and future researches as reference.

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REFERENCES

[1] E. Helpman, "Innovation, imitation, and intellectual property rights," National Bureau of Economic Research1992.

[2] B. K. Smarzynska, "The composition of foreign direct investment and protection of intellectual property rights: evidence from transition economies," The World Bank2002.

[3] P. J. Smith, "Are weak patent rights a barrier to U.S. exports?," *Journal of International Economics,* vol. 48, pp. 151-177, 1999.

[4] P. C. Grindley and D. J. Teece, "Intellectual Capital," *CALIFORNIA MANAGEMENT REVIEW,* vol. 39, 1997.

[5] Z. Griliches, "Patent Statistics as Economic lndicators," *Joumal _of Economic,* 1990.
[6] A. Pakes and Z. Griliches, "Patents and R and D at the firm level: A first look," ed: National Bureau of Economic Research Cambridge, Mass., USA, 1980.
[7] T. K. Ryu and Y. J. Han, "Indicator for Evaluating National Patent Performance: Comparative Analysis among the 30 OECD Countries," *Journal of Intellectual Property Rights,* vol. 17, pp. 103-110, 2012.
[8] M. E. Mogee and R. G. Kolar, "International patent analysis as a tool for corporate technology analysis and planning: Practitioners forum," *Technology Analysis & Strategic Management,* vol. 6, pp. 485-504, 1994.
[9] M. E. Mogee, "Using patent data for technology analysis and planning," *Research-Technology Management,* vol. 34, pp. 43-49, 1991.
[10] S.-H. Chen, *et al.*, "Identifying and visualizing technology evolution: A case study of smart grid technology," *Technological Forecasting and Social Change,* vol. 79, pp. 1099-1110, 2012.
[11] S.-H. Chen, *et al.*, "Detecting the temporal gaps of technology fronts: A case study of smart grid field," *Technological Forecasting and Social Change,* vol. 79, pp. 1705-1719, 2012.
[12] E. Mansfield, "Patents and innovation: an empirical study," *Management science,* vol. 32, pp. 173-181, 1986.
[13] W. B. Ashton and R. K. Sen, "USING PATENT INFORMATION IN TECHNOLOGY BUSINESS PLANNING. 2," *Research-Technology Management,* vol. 32, pp. 36-42, 1989.
[14] H. Ernst, "Patent information for strategic technology management," *World Patent Information,* vol. 25, pp. 233-242, 2003.
[15] S.-J. Liu and J. Shyu, "Strategic planning for technology development with patent analysis," *International Journal of Technology Management,* vol. 13, pp. 661-680, 1997.
[16] U. Schmoch, "Tracing the knowledge transfer from science to technology as reflected in patent indicators," *Scientometrics,* vol. 26, pp. 193-211, 1993.
[17] H. Small, "Visualizing science by citation mapping," *Journal of the American society for information science,* vol. 50, pp. 799-813, 1999.
[18] J. M. Podolny, *et al.*, "Networks, knowledge, and niches: Competition in the worldwide semiconductor industry, 1984-1991," *American journal of sociology,* pp. 659-689, 1996.
[19] M.-H. Chang and J. E. Harrington, "Innovators, imitators, and the evolving architecture of social networks," Working Papers, The Johns Hopkins University, Department of Economics2005.
[20] L. Fleming, *et al.*, "Small worlds and regional innovation," *Organization Science,* vol. 18, pp. 938-954, 2007.
[21] J. Guan and Z. Chen, "The technological system of Chinese manufacturing industry: A sectorial approach," *China Economic Review,* vol. 20, pp. 767-776, 2009.
[22] R. Leoncini, *et al.*, "Intersectoral innovation flows and national technological systems: network analysis for comparing Italy and Germany," *Research Policy,* vol. 25, pp. 415-430, 1996.
[23] I. Von Wartburg, *et al.*, "Inventive progress measured by multi-stage patent citation analysis," *Research Policy,* vol. 34, pp. 1591-1607, 2005.
[24] B. L. Basberg, "Patents and the measurement of technological change: A survey of the literature," *Research Policy,* vol. 16, pp. 131-141, 1987.
[25] E. Duguet and M. MacGarvie, "How well do patent citations measure flows of technology? Evidence from French innovation surveys," *Economics of Innovation and New Technology,* vol. 14, pp. 375-393, 2005.
[26] J. L. Furman, *et al.*, "The determinants of national innovative capacity," *Research Policy,* vol. 31, pp. 899-933, 2002.
[27] F. Narin, "Tech-line background paper," *CHI Research, Inc., Haddon Heights, NJ, downloadable at www. chiresearch. com,* 2000.
[28] Z. Deng, *et al.*, "Science and technology as predictors of stock performance," *Financial Analysts Journal,* pp. 20-32, 1999.
[29] M. Hirschey and V. J. Richardson, "Valuation effects of patent quality: A comparison for Japanese and U.S. firms," *Pacific-Basin Finance Journal,* vol. 9, pp. 65-82, 2001.
[30] F. Narin and D. Olivastro, "Patent citation cycles," *Library trends,* vol. 41, pp. 700-709, 1993.
[31] Z. Chen and J. Guan, "The impact of small world on innovation: An empirical study of 16 countries," *Journal of Informetrics,* vol. 4, pp. 97-106, 2010.
[32] R. Belderbos, "Overseas innovations by Japanese firms: an analysis of patent and subsidiary data," *Research Policy,* vol. 30, pp. 313-332, 2001.
[33] Z. Ma and Y. Lee, "Patent application and technological collaboration in inventive activities: 1980–2005," *Technovation,* vol. 28, pp. 379-390, 2008.
[34] C. Lo Storto, "A method based on patent analysis for the investigation of technological innovation strategies: The European medical prostheses industry," *Technovation,* vol. 26, pp. 932-942, 2006.
[35] K. Pavitt and P. Patel, "The international distribution and determinants of technological activities," *Oxford Review of Economic Policy,* vol. 4, pp. 35-55, 1988.
[36] D. Archibugi and M. Pianta, "Specialization and size of technological activities in industrial countries: The analysis of patent data," *Research Policy,* vol. 21, pp. 79-93, 1992.
[37] J. Zheng, *et al.*, "International collaboration development in nanotechnology: a perspective of patent network analysis," *Scientometrics,* pp. 1-20, 2013.
[38] A. F. Breitzman and F. Narin, "Method and apparatus for choosing a stock portfolio, based on patent indicators," ed: Google Patents, 2001.
[39] D. Harhoff, *et al.*, "Citation frequency and the value of patented inventions," *Review of Economics and statistics,* vol. 81, pp. 511-515, 1999.
[40] R. Henderson, *et al.*, "Universities as a source of commercial technology: A detailed analysis of university patenting, 1965-1988," *Review of Economics and statistics,* vol. 80, pp. 119-127, 1998.
[41] W. W. Lewis, *The power of productivity: Wealth, poverty, and the threat to global stability*: University of Chicago Press, 2004.
[42] W. de Nooy, *et al.*, *Exploratory social network analysis with Pajek* vol. 27: Cambridge University Press, 2005.
[43] S.-C. Chang, "The TFT–LCD industry in Taiwan: competitive advantages and future developments," *Technology in Society,* vol. 27, pp. 199-215, 2005.
[44] X. Li, *et al.*, "Patent citation network in nanotechnology (1976–2004)," *Journal of Nanoparticle Research,* vol. 9, pp. 337-352, 2007.