Assessing Innovation Capability and Scientific Impact of Industry Through Patented Technologies

Ching-Wen Kang, Hsin-Ning Su
Graduate Institute of Technology Management, National Chung Hsing University, Taichung, Taiwan

Abstract--**Due to the constantly changing nature of our society, the ability to make correct decisions is crucial for decision-makers. Understanding science–technology linkages and knowledge flows are of critical importance for decision-makers. A recent surge of research on patent has given us new opportunities and challenges; and there are many advances that have been made in the area of patent analysis. Therefore, this study aims to measure innovation capability and science-technology linkage by analyzing USPTO patents from 1976 to 2012. Implications obtained in this study are summarized as: 1) innovation capability can be measured by properly selected patent indicator, 2) level of knowledge diffusion and knowledge flows across industries can be evaluated, 3) The proportion of large R&D-intensive companies patent holder and the impact of policies on patent output are analyzed, 4) the relation between a nation's patenting behavior and global patenting activities can be compared.**

I. INTRODUCTION

Due to environmental change on society, under the trend of the knowledge economy, the ability to make correct decisions immediately is important to decision-makers in changing environment. The importance of innovation has been widely recognized, and patent is a method of measuring innovation. The value of an innovation to the innovator can change over time, especially in response to changes in the legal protection (such as patent rights) afforded the innovator [1]. In regional innovation, a research provide an exploratory and a regression-based comparison of the innovation count data and data on patent counts at the lowest possible levels of geographical aggregation [2]. Patent indicators not only can measure the level of innovation, but also understand the flow of knowledge between patents. Quantitative indicators of the technological strengths of individual companies would be an important addition to the financial and economic data used in competitor assessments, merger or acquisition analyses, investment decisions, and corporate planning and management [3]. Innovation has given us new opportunities and challenges; these issues are getting considerable attentions not only from industries, but also from countries. For example; in Italy, service and manufacturing sectors show more similarities than differences with respect to some basic dimensions of innovation processes [4]. The purpose of the research presented in this article is to examine innovation capability by patent citation analysis and patent indicator.

II. LITERATURE REVIEW

A. Importance of patent and innovation linkages

With the increase of globalization, "innovation" in recent years has increased noticeably. Innovation has been particularly influential in contributing insights into business strategy. To business strategy, top management teams diversity has a strong impact on the strategic choice of firms to focus on innovation fields [5]. In addition to measure innovation, patent also can help to understand the knowledge flow. [6]. There is an article aims to contribute to the long-standing debate on the choice of the best proxy to measure innovation and technological diffusion, by offering alternative variables which are tested empirically by means of a panel dataset of 73 countries between 1980 and 2005 [7]. By analyzing patent data, it can measure innovation, and patent have a positive effect on innovation. Patent statistics have been used as a proxy of innovation, a research provided the state of tetra-structure of patent statistics and a new set of patent statistics which could be considered a more reliable proxy for innovation [8].

Over the last two decades, there has been a dramatic increase in the numbers of publications on patent. There are two kinds of motivation to apply patent, one of is to protect innovation, and another is to attack competitors in the market. Policies also affect the development of patent, despite the significance of the policy changes and the wide availability of detailed data relating to patenting, robust conclusions regarding the empirical consequences for technological innovation of changes in patent policy are few [9]. There are many factors can impact the importance of patent, the growing relevance of global considerations and the complexities and costs associated with international patent protection might still diminish the relative importance attached to patents and encourage the use of other modes of protection for innovation [10]. The patent system is critical for country, the perfect patent system can attract foreign direct investment, to ensure inward licensing and to encourage local investment in research [11]. Many companies use patent data to forecast future trend, for example, [12] examine the cross-country patents of company, the findings indicate that cross-country patents are a reasonably good indicator of international activity, especially if labour mobility is considered international in its own right.

B. Patent indicator

One important indicator of technology innovation capability is the numbers of patents [13]. About patent indicators, [14]. A growing number of research studies are now available to shed some light on patent indicator. There is a

research which proposes the indicator is particularly useful to identify emerging technologies and to assess the innovation performance of developing economies [15]. On the other hand, Some studies even developed patent indicators to assess the competitive position of technology-oriented firms [16]. For public sector, like the United States Food and Drug Administration (FDA), by studying bibliometric data of drugs approved by the FDA, a paper investigates different types of innovations (from radical to incremental) in the pharmaceutical industry, and looking at time-to-market aspects, knowledge sources of these innovations, and protection strategies [17]. Generally, patent whether by litigate or not is an indicator to measure innovation, the existence of litigation changes the incentives for firms to invent and patent, and also importantly, for new competitors to appear [18]. In the other words, more litigated patents may can represent higher innovation. Legal changes had to be made to try to adjust the administration of patents to the reality that invention and innovation now primarily result from investment rather than from individual creativity [19]. The influence of patent rights on firm-level innovation varies across industries for example, the impact appears greatest in the scientific instruments and industrial chemicals industries [20]. And in the field of wind power technology, [21] use patent data to gain increased interest in the field of innovation and technological forecasting, the data represent a valuable information source that can be used to plot technological progress over time. [22] proposed a method to compare patent data and knowledge flow can be strengthened dramatically by multiple patent indicators.

C. Trend of Taiwan

In the last few decades, many advances have been made in Taiwan. The World Economic Forum (WEF) announced 2013 global competitiveness rankings, Taiwan more progressive than the 2012, ranked 12, and the Council for Economic Planning and Development (CEPD) expressed the industry innovation capability is the key. An article discusses the evolving organizational architecture of these R&D alliances, use several case studies, and seeks to draw comparisons between these institutional innovations in Taiwan and established collaborative arrangements in the USA, Japan and Europe [23]. Some research compare the difference between Taiwan and other countries of patent that the main agent of Korea's technological innovation has been the small number of large companies in the electrical technology field, while Taiwan's patenting activities have been spread among a large number of individuals exploiting nonelectrical and miscellaneous technologies [24]. The university sectors, universities in many countries are designated to create and diffuse innovation knowledge for industry, [25] traced with patent data and discussed that Taiwan's universities not only rely on advanced countries to acquire innovative knowledge, but attempt to absorb and internalize this external knowledge in the context of an innovation system facilitated by the Fundamental Science and Technology Act.

In addition, in other study, it described herein uses USPTO data to assess variations in technological innovation capabilities, and their influence on market performance in Japan, Korea, and Taiwan [26]. The bigger scope to compare Taiwan and other countries is Asian economies, use US patent data to study how the innovative capabilities of Taiwan, South Korea, Hong Kong and Singapore have expanded in relation to emerging economies in Asia and Latin America [27]. For the different industries, there are many literatures discuss impact on patent in Taiwan, [28] discussed the knowledge flows and innovation capability within and across Taiwan's top five major players in the thin film transistor-liquid crystal display (TFT-LCD) industry by patent analysis. Other examples is [29] which mentioned chemical industry, in technological interdependence and knowledge diffusion, it played the significant and indispensable role in Taiwan.

III. RESEARCH METHOD

First, patent data are downloaded to our database from USPTO (United States Patent and Trademarks Office) in 1976 to 2012 (4389348 utility patents in total) and select correct patent indicator to measure innovation. By patent indicator, it also can understand the knowledge flow of different level of organizations, like different countries, industries, and assignee type. In this work, it proposes the following several sections, including basic patent analysis, knowledge flow analysis, and the knowledge flow status of cross-industry. In this paper, SQL is a main and important statistics tool; it can calculate correct information precisely. To address this issue, patent analyses were conducted; it shows the number of basic patent data of worldwide and Taiwan from 1976 to 2012. In what follows, the findings of patent citation have implications for knowledge flow analysis, and discuss "cross-industry" situation. The method is easy to understand and use, the paper is focused on Taiwan, if the countries change into others; this method still can be used. Through the method not only understand knowledge flow and cross-industry situation, but also can measure level of innovation for industries even whole country.

IV. RESEARCH RESULT

A. Patent basis analysis

Next part will discuss the basis patent statistics information and analyze trend of world patent and Taiwan patent.

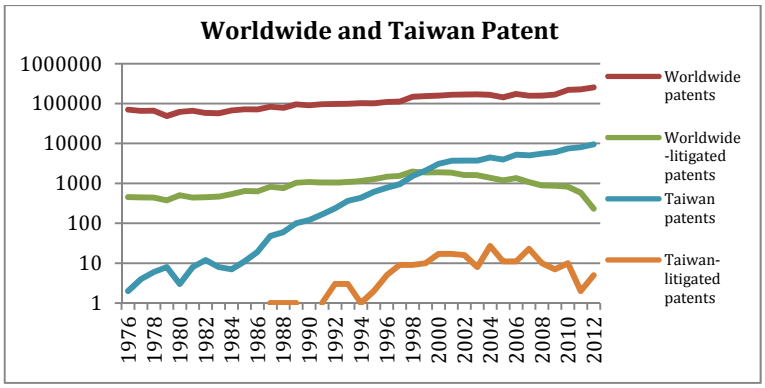

Fig. 1 The number of worldwide and Taiwan patent from 1976-2012

In fig. 1, it shows the total and Taiwan patents from 1976 to 2012. In this research, "worldwide patent" means all patent data from USPTO, also include Taiwan's patent. From this figure, it observes that number of patents, including worldwide and Taiwan have been increasing. The patent amounts of growing appear the certain rate; in addition to the number of worldwide-litigated patents went down in 2009. In Taiwan, the growing rate for number of patents from 1976 to 2000 has rapid growth. After 2000 growing rate has slowed down gradually. The curve of Taiwan litigated-patents looks very wavy, changes of number is unstable. The result shows a specific scale growing for patent amount, whether general patent or litigated patent. In litigated patent side, after 2010, the amount is fewer than before. The reason is that newer patents involve less legal issues than older patents.

TABLE 1 TOP 10 FIRST ASSIGNEE COUNTRY FOR PATENT, LITIGATED PATENT AND LITIGATED PROPORTION

First Assignee Country	Total Patent	Litigated Patent	Litigated Patent Proportion
United States	1989522	23367	0.01175
Japan	857805	1207	0.00141
Germany	265104	550	0.00207
Korea	101551	186	0.00183
France	96131	281	0.00292
Taiwan	77087	210	0.00272
United Kingdom	73106	447	0.00611
Canada	56496	524	0.00927
Switzerland	46619	244	0.00523
Netherlands	35842	153	0.00427

Table one shows the patent amount of top ten of first assignee countries, United States is the country that has the largest number of total patents and litigated patents, Second is Japan, third is Germany, according to the order, the first assignee countries are Korea, France, Taiwan, United Kingdom, Canada, Switzerland, and Netherlands; In total patents, United States owned 1989522 patents; besides, 23367 litigated patents, is also the largest in all countries. Compare with other countries, this phenomenon represent that patent value of the United States is highly. From litigated patent proportion, only the proportion of the United States over 0.01, 0.01175. Then, focus on Taiwan, it ranked sixth, owned 77087 patents and 210 litigated patents, the litigated patent proportion is 0.00272. Although the patent output of the United States is greater than Taiwan, there are many advances have been made in the area of patent in Taiwan. In brief, it can know the differences in the level of innovation between countries by patent. Patent output is seen to be relevant to innovation.

Table 2 shows worldwide and Taiwan patents, litigated patents for each first assignee type. First assignee type can be divided into seven types; there are "individual", "company", "government", "university", "hospital", "non-profit", and "other or unknown". The largest number of patent belong to "company", it illustrates the company has higher demand for patents than other assignee type. In worldwide patent side, company has applied (be authorized) for 3514952 patents and litigated patents constitute 26328. If according to ranking, the first one is company, second is individual, 527211 patents, third is other or unknown, 149931 patents, then is university,

TABLE 2 WORLDWIDE AND TAIWAN PATENTS AND LITIGATED PATENT FOR ASSIGNEE TYPE

First Assignee Type	Worldwide Patent	Taiwan Patent	Worldwide-Litigated Patent	Taiwan-Litigated Patent
Individual	527211	970	8407	4
Company	3514952	66768	26328	172
Government	71761	4973	228	28
University	85513	2075	625	2
Hospital	5076	37	34	0
Non-profit	34904	1283	201	1
Other/Unknown	149931	981	1082	3
Total	4389348	77087	36905	210

TABLE 3 WORLDWIDE AND TAIWAN PATENTS AND LITIGATED PATENTS AMOUNT FOR INDUSTRIES

Industry	Worldwide Patents	Taiwan Patents	Worldwide-Litigated Patents	Taiwan-Litigated Patents
Chemistry	919632	4810	6686	10
Electrical engineering	1382656	51186	10216	123
Instruments	735305	9494	6291	39
Mechanical engineering	973992	6746	8109	22
Other fields	368468	4668	5542	15
Unknown	9295	183	61	1
Total	4389348	77087	6686	210

85513 patents, government, 71761 patents, non-profit, 34904 patents, the least is hospital, just has 5076 patents. From this table, it can understand which assignee type has the highest demand for patents. In worldwide-litigated patent side, the largest number of litigated patent of first assignee type is still company, 26238 litigated patents. According to ranking, it is identical with worldwide patent.

For Taiwan patent, the first one is company; it owned 66768 patents and 172 litigated patents. The ranking of Taiwan is different from worldwide patent, except the first one both is company, ranking the second is government, 4973 patents, the third is university, 2075 patents, then is non-profit, 1283 patents, other or unknown, 981 patents, individual, 970 patents, and the least is hospital, just has 37 patents. It is worth noting that the positive correlation between patent output and level of innovation does not mean fewer patent output for first assignee type is less innovation. Fewer patents output for first assignee types maybe have other ways to protect their innovation or have the lower demand for patents. Patent just a one of methods to measure level of innovation.

Over the past years there have been many change in industries, in the trend of knowledge economy, especially for high technology industry, they usually attach importance to patent more than traditional industry. Five types of industries can be distinguished into “chemistry”, “electrical engineering”, “instruments”, “mechanical engineering”, “other fields”, and unknown. Whether worldwide patents or Taiwan patents, the largest amount of patents of industries is electrical engineering. Table three shows the worldwide and Taiwan patents and litigated patents amount for industries, it is very obvious that “electrical engineering” is the largest number of patents, 1382656 worldwide patents, 51186 Taiwan patent, 10216 worldwide-litigated patents and 123 Taiwan-litigated patents. The demand for patents of “chemistry” and “mechanical engineering” is similar, and “instruments” lower than chemistry and mechanical engineering. Do not discuss unknown part; the number of patents for other fields is the least. This can be seen that in electrical engineering industry, maybe need more innovative implications, has a high- level of innovation and patent requirement.

B. Knowledge flow and patent citation of Taiwan

Knowledge flow is closely related to the number of cited patent, the level of knowledge flow usually appears positive relation with citing patent amount. To understand the situation of knowledge flow, patent observation is of decisive importance. Increase the flow of knowledge maybe can be seen demand of innovation is enhancing.

TABLE 4 TOP 10 COUNTRIES CITING WORLDWIDE AND TAIWAN PATENT

Country	Worldwide	Country	Taiwan
United States	2782857	**United States**	26997
Japan	1451935	**Taiwan**	23441
Germany	744564	**Japan**	15936
Korea	324505	**Korea**	8681
France	310402	**Germany**	4495
Canada	294377	**China**	3426
Taiwan	258065	**Singapore**	1943
United Kingdom	255295	**France**	1467
Switzerland	177466	**Canada**	1252
Netherlands	159701	**Netherlands**	1199

From table 4, it selects top ten countries which citing worldwide patent and Taiwan patent. “Worldwide patent” means all patent data in USPTO, including Taiwan patent, and “Taiwan patent” means that first assignee country of patent is Taiwan. In amount of citing worldwide patent, United States is the first, citing 2782857 patents. According to ranking, the second is Japan, 1451935 patents, the third is Germany, 744564 patents, and then countries are Korea, France, Canada, Taiwan, United Kingdom, Switzerland and Netherlands. If increasing a restriction that first assignee country of “cited patent” is “Taiwan”, the first one country is still United States. United States is the country that has the largest number, 26997 of citing Taiwan patent. Then, second is Taiwan, 23441 patents, third is Japan, 15936 patents, according to the order, the countries are Korea, Germany, China, Singapore, France, Canada and Netherlands. It can find out the situation of Taiwan patent cited and understood degree of knowledge flow. United States has cited a great deal of patents to support and apply new patents, it presents that level of knowledge flow is higher than other countries, but this result maybe be related with source of database (USPTO).

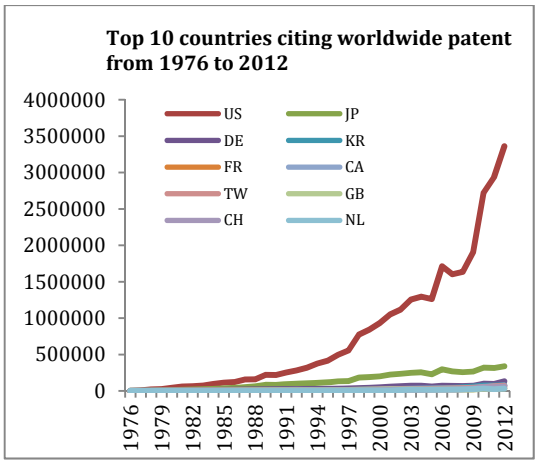

Fig. 2 Top 10 countries citing worldwide patent from 1976 to 2012

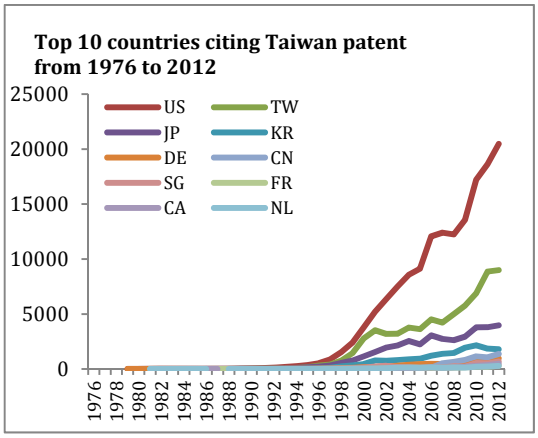

Fig. 3 Top 10 countries citing Taiwan patent from 1976 to 2012

Fig. 2 shows the top ten countries citing worldwide patent from 1976 to 2012. After 1988 United States acted, as a leader in the field of citing patents gradually, especially 2007 to 2012, the growth rate is very high, and United States already citing 3359774 patents in 2012. The second is Japan, after 1996 Japan has grown gradually, but it is still a big gap between United States and Japan. For other eight countries, Germany, Korea, France, Canada, Taiwan, United Kingdom, Switzerland and Netherlands, their growth rate did not as fast as United States. No matter patent application or knowledge flow, the performance of the United States is better than other countries; this result also means innovation development of the United States is higher than other countries. Clearly, except patent of the United States, fig. 3 indicates that Taiwan tends to cite self-country (Taiwan) patents; the number of patent citation has growth obviously after 1997. In 2012, Taiwan has cited 8992 Taiwan patents. The third is Japan; and its growth rate from 1999 to 2009 is similar to Taiwan, after 2009 growth rate slow down gradually. Different from other countries stable growing, the number of patent citation of Korea decreases after 2009, and it represented the demand of Taiwan patents of Korea is reducing gradually. This result may be associated with that Korea government support large enterprise, like Samsung Company is supported from Korean government and has much innovative output.

Fig. 4 shows the sum of first assignee type citing worldwide and Taiwan patents, unlike fig. 2 and fig. 3, patent data is not "over the years". The same patent maybe be cited in different year, if plus patent citation amount directly from every year, then it will cause "double counting" the same patent. Use SQL statistics tool, fig. 4 removes "double counting" data and calculates amount of first assignee type citing worldwide and Taiwan patents. Fig. 4 highlights differences between citing worldwide and Taiwan patents, it can understand the gap between each first assignee type for number of patent citation clearly. Company is the largest number of citing worldwide and Taiwan patents, 3255870 worldwide patents and 42779 Taiwan patents. Hospital is the least number of citing worldwide and Taiwan patents, just citing 23289 worldwide patents and 27 Taiwan patents. Obviously, in addition to company, the number of citing patents for other first assignee type falls behind very much. The principal reason is that company needs many patents to support their new patents, when they apply new patents; they need reference older patents to confirm the direction or claim of new patents whether correct or not.

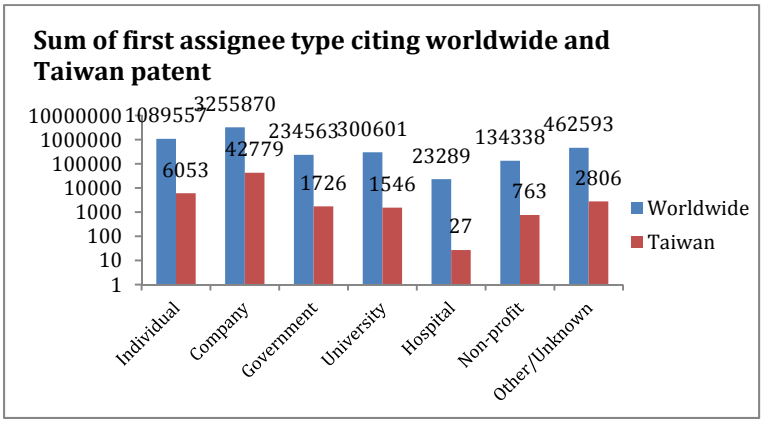

Fig. 4 Sum of first assignee type citing worldwide and Taiwan patent

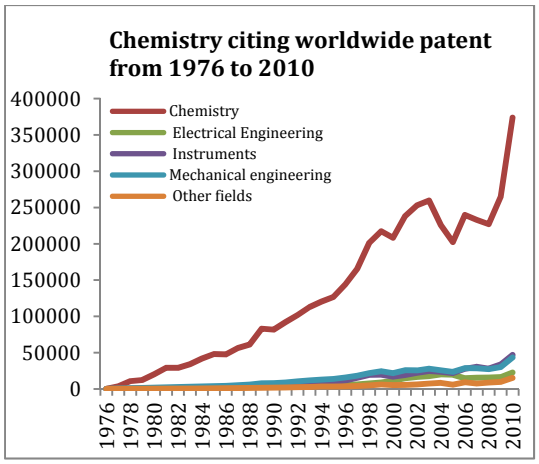

Fig. 5 Chemistry industry citing worldwide patent from 1976 to 2010

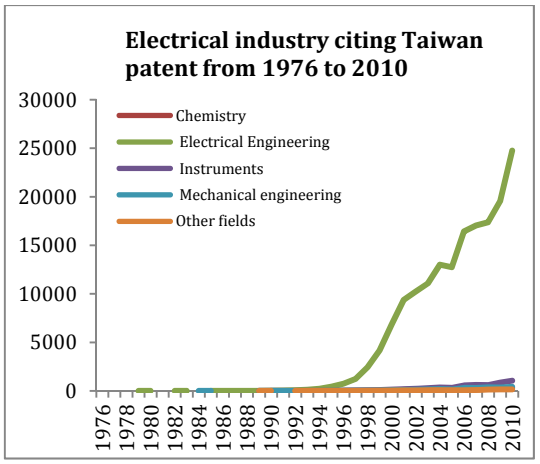

Fig. 8 Electrical engineering industry citing Taiwan patent from 1976 to 2010

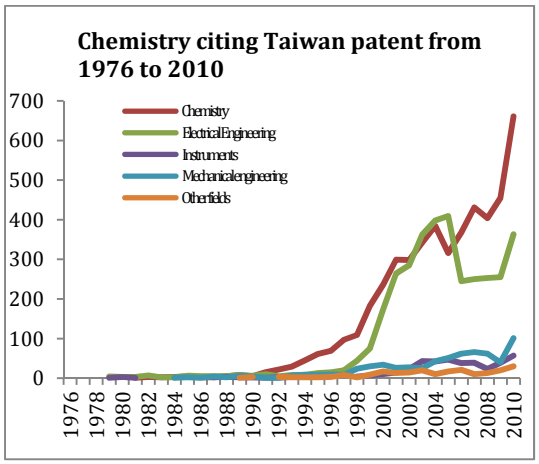

Fig. 6 Chemistry industry citing Taiwan patent from 1976 to 2010

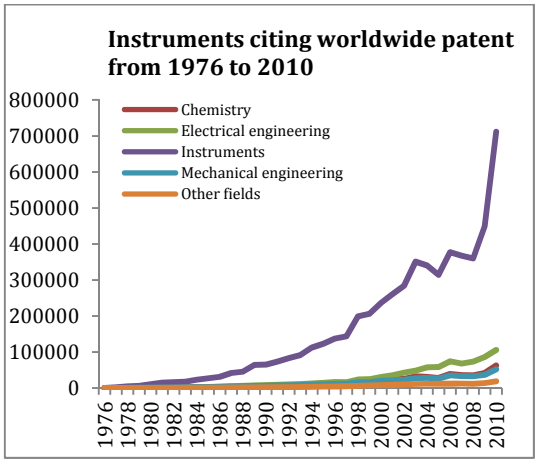

Fig. 9 Instruments industry citing worldwide patent from 1976 to 2010

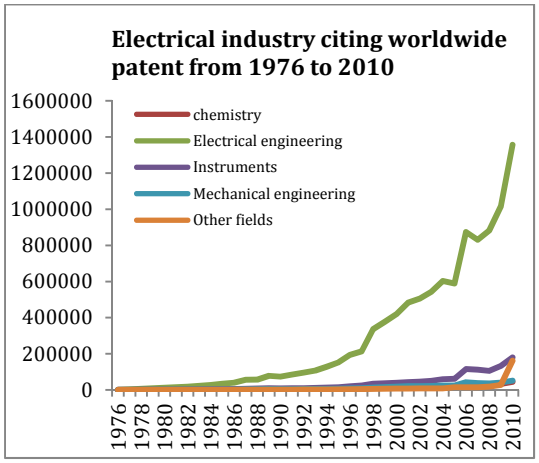

Fig. 7 Electrical engineering industry citing worldwide patent from 1976 to 2010

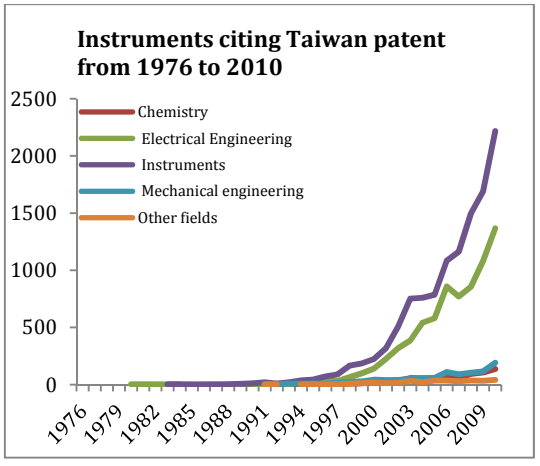

Fig. 10 Instruments industry citing Taiwan patent from 1976 to 2010

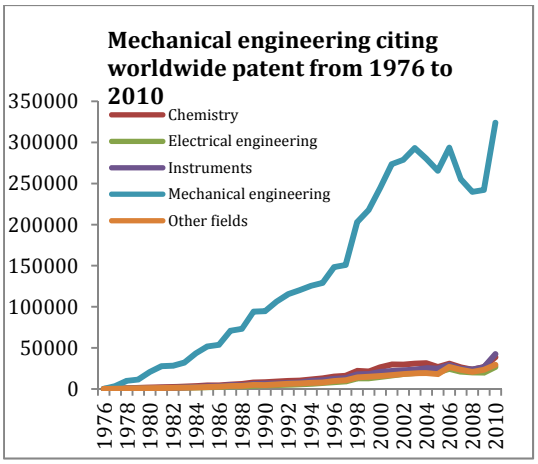

Fig. 11 Mechanical engineering industry citing worldwide patent from 1976 to 2010

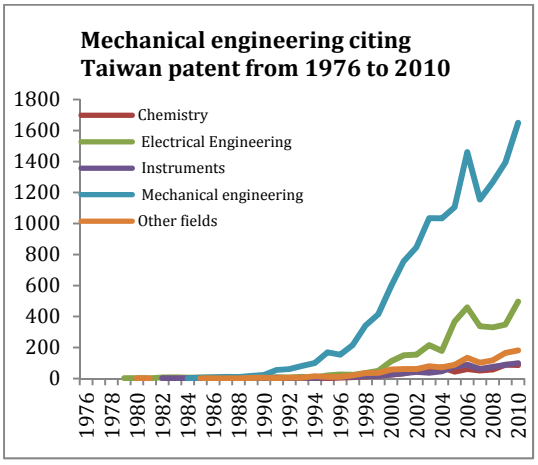

Fig. 12 Mechanical engineering industry citing Taiwan patent from 1976 to 2010

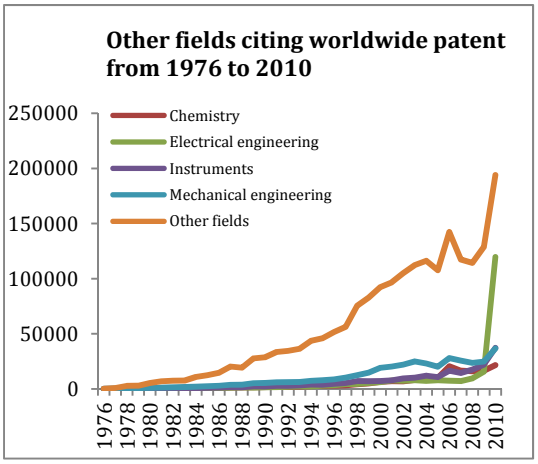

Fig. 13 Other fields industry citing worldwide patent from 1976 to 2010

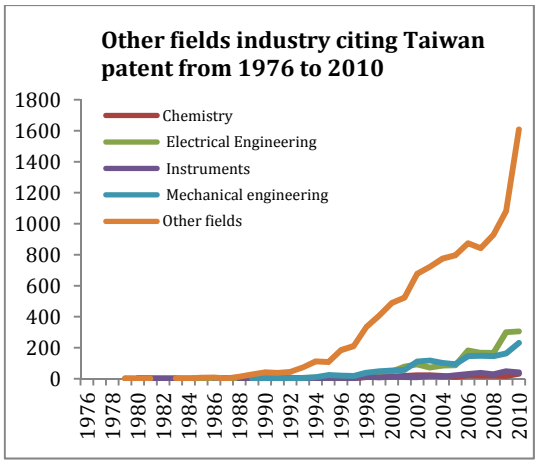

Fig. 14 Other fields industry citing Taiwan patent from 1976 to 2010

The fig. 5 to 14 present the each industry citing worldwide and Taiwan patent from 1976 to 2010, it demonstrated that citing between industry and industry is tendency to citing self-industry. Fig. 5 and fig. 6 are chemistry industry citing worldwide and Taiwan patent from 1976 to 2010, fig. 5 shows that chemistry almost citing the same industry worldwide patent, but fig. 6 is different from fig. 5, after 1997 it has cited not only chemistry industry, but also electrical engineering industry Taiwan patents. This result represents that knowledge flow appear "cross-industry" situation, "electrical engineering" industry proportion of all citing Taiwan patents in each industry is the most, compare with other industries (chemistry, instruments, mechanical engineering, other fields). Fig. 7 and fig. 8 are electrical engineering industry citing worldwide and Taiwan patent from 1976 to 2010. In citing worldwide patent, after 2005 electrical engineering industry start to cite instruments industry patents gradually, and after 2009 electrical engineering industry start to cite patent of other fields industry. It means that probability of "cross-industry" situation will higher than before. On the other hand, in citing Taiwan patent, electrical engineering industry almost citing self-industry patents, fewer citing other industries patents. Fig. 9 and 10 are instruments industry citing worldwide and Taiwan patent from 1976 to 2010. The relation between fig. 9 and 10 is similar to relation between fig. 5 and fig. 6 (chemistry industry). Instruments industry also cites many electrical engineering industry patents expect self-industry patents, this situation is more evident in citing Taiwan patents.

Fig. eleven and 12 are mechanical engineering industry citing worldwide and Taiwan patent from 1976 to 2010. Fig. eleven shows that mechanical engineering industry has more requirements to cite other industries patents; in addition to cite self-industry, it cited more other industries patents than other industries. In citing Taiwan patent side, the number of patents citing electrical engineering industry start to grow after 1999. Fig. thirteen and 14 are other fields industry citing worldwide and Taiwan patent from 1976 to 2010. Except for citing self-industry patents, fig. thirteen shows other industries also citing many other industries patents, especially electronic

engineering industry, the number of patents citing electrical engineering industry has rapid growth after 2009, and it has cited 119739 electrical engineering industry patents in 2010. Fig.forteen presents other fields industry citing Taiwan patent, self-industry is still the most one. It is different from other industries, unlike other industries are tended to cite electrical engineering industry patents, other fields industry also citing many mechanical engineering industry patents. From fig. 5 to fig. 14, it can summarize that the knowledge flow of "chemistry industry", "mechanical engineering industry" and "other fields industry" higher, and patent self-industry citation of "electrical engineering industry" is the most. Electrical engineering industry knowledge or patent is the most be needed by other industries due to each industry citing the higher proportion of electrical engineering industry patents.

For the sake of providing a visual picture of the patent citation of each industry, consider the graphic representation in fig. 15. As same as fig. 4 it removes "double counting" data and calculates amount of industries citing worldwide and Taiwan patents. In sum of industries citing worldwide patents, chemistry industry has cited 2376621 patents, is the most one. The second is electrical engineering industry, 2196700 patents, then is mechanical engineering industry, 1808468 patents, instruments industry, 1327261 patents, and last one is other fields industry, 6310202 patents. In sum of industries citing Taiwan patents, electrical engineering industry is the most one, 36480 Taiwan patents. Fig. fifteen just shows the sum of patent citation, it cannot find out the knowledge flow or cross-industry citation situation.

C. Taiwan patent output top 10 for company

Table five shows the number of Taiwan patent for top ten companies, the restriction is that first assignee type equal company and first assignee country is Taiwan.

"Hon Hai Precision Ind. Co., Ltd." has owned 7235 Taiwan patents; Hon Hai group is a very famous company that produces electronics products in the world. The second is "Taiwan Semiconductor Manufacturing Co., Ltd.", the world's first dedicated semiconductor foundry, which established in 1987, has owned 6431 Taiwan patents. This company operates three advanced 12-inch wafer fabs, four eight-inch wafer fabs, and one six-inch wafer fab in Taiwan. The third is a leading global semiconductor foundry; "United Microelectronics Corp." has owned 33431 Taiwan patents, and it provides advanced technology and manufacturing for applications spanning every major sector of the IC industry. The fourth is "AU Optronics Corp." which has own 2079 Taiwan patents. AU Optronics Corp. operates production lines of various generations, capable of offering TFT-LCD panels from small to large sizes and provides customers with high efficiency solar solutions. The fifth is "Macronix International Co., Ltd.", a leading integrated device manufacturer in the Non-Volatile Memory market, has owned 1831 Taiwan patents and provides a full range of NOR Flash, NAND Flash, and ROM products.

Next, the companies are "VIA Technologies, Inc.", a foremost fabless supplier; "Mediatek Inc.", a leading fabless semiconductor company for wireless communications and

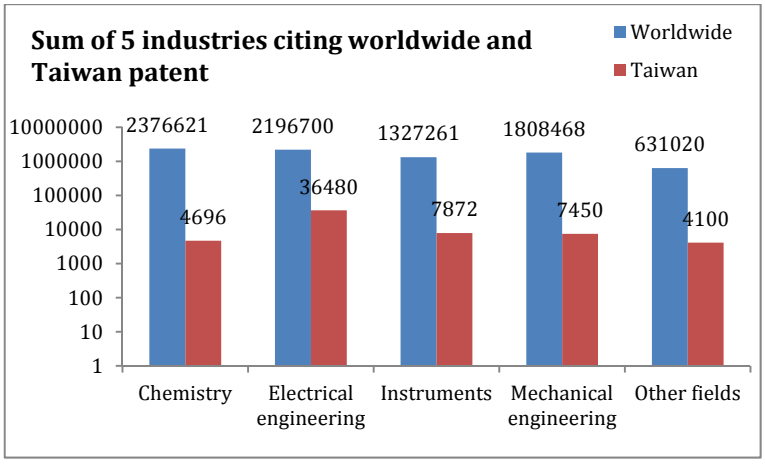

Fig. 15 Sum of 5 industries citing worldwide and Taiwan patent

TABLE 5 TOP 10 COMPANIES FOR TAIWAN PATENT

No.	Company	Patent	No.	Company	Patent
1	HON HAI Precision Industry Co., Ltd.	7235	**6**	VIA Technologies, Inc.	1417
2	Taiwan Semiconductor Manufacturing Co., Ltd.	6431	**7**	Mediatek Inc.	1295
3	United Microelectronics Corp.	3431	**8**	Delta Electronics, Inc.	1078
4	AU Optronics Corp.	2079	**9**	Winbond Electronics Corp.	924
5	Macronix International Co., Ltd.	1831	**10**	Inventec Corporation	920

digital multimedia solutions; "Delta Electronics, Inc.", a world-leading developer and supplier of telecom power systems, uninterruptible power supplies, medium-voltage drives, and solar and wind-energy solutions; "Winbond Electronics Corp." which owns three main business groups: DRAM Product, NOR Flash and Memory IC Manufacturing; and "Inventec Corporation", that provides personal computer ODM business. In summary, these top ten companies almost are high technology companies and electronic engineering industry, the result is similar to table three that shows in electrical engineering industry, has more requirement of innovation and patent.

V. CONCLUSION

A. Global and local relevance of Taiwan science base

In this paper, it can be known that proper selected patent indicator can measure innovation capability. Compared with the United States, Japan, Germany, Korea and France patent, Taiwan has long been a step behind in developing its patent output. The growing rate of number of Taiwan patents from 1976 to 2000 still has rapid growth, and proportion of patent litigation is less. In first assignee type, company of worldwide and Taiwan patent are the most; it shows the company has higher demand for patents than other assignee type, it also can understand that company has more innovative implications than other first assignee type. In industry, electrical engineering industry needs more innovative implications and patent requirement than other industries. Also, the company has high patent output all belong to high technology industry, each of which is a science-based company with a strong international orientation. In other words, although Taiwan innovative ability has improved, still should be focused on enhancing self-advantage and industrial competitiveness.

B. Patent citations for measuring innovation/ level of knowledge diffusion and knowledge flows across industries

In this paper, it presents "patent citation" as patent indicator and can understand the situation of knowledge flow. For patent citation of first assignee country, United States has cited a great deal of patents to support and apply new patents, it represents that level of knowledge flow is higher than other countries. In citing Taiwan patent of first assignee country, the first one country is still United States, and second is Taiwan. For patent citation of first assignee type, when company applies new patents, they need reference older patents to confirm the direction or claim of new patents whether correct or not so company is citing more patents to support their new patents. In other words, company has a greater ability to innovate, above figures and tables lend support to this idea. For worldwide patent citation of industry, the obvious condition is that all patent citations for industries were strongly correlated with self-industry. Focus on Taiwan patent citation; electrical engineering industry proportion of all citing Taiwan patents in each industry is the most compare with other industries (chemistry, instruments, mechanical engineering, other fields). The level of knowledge flow of chemistry industry, mechanical engineering industry and other fields industry are higher than other industries. In patent self-industry citation, electrical engineering industry is the most, and this industry's knowledge or patent are the most be needed by other industries due to each industry citing the higher proportion of electrical engineering industry patents.

C. R&D-intensive companies patent holder and the impact of policies on patents output

For a country, new technical inventions may have significant economic benefits; the government's policy for enterprise innovation output was highly correlated. Countries with competitive science-based industries require a sustained strong public-sector science and engineering base in broad areas accompanied by an attractive mix of government-funded facilities such as centres of scientific and technological excellence, training of qualified R&D personnel, national and regional research networks, knowledge transfer centres, subsidies and tax-breaks [30]. United States science and technology policy is tending to market incentives, public sectors support many R&D investment on the basis. Take Korea for example, Korea government support large enterprise, like Samsung Company is supported from Korean government and has much innovative output. Much government policy is crucial in developing of industry. In Taiwan, the government focuses on linking forward, technology energy and policy research knowledge database by observation and analysis of trends of long-term external environment, and strengthen linkage between economic development and industrial technology. Due to the patent output gradually slowed down in recent years, science and technology policy should focus on improve incentives for patent applications and strengthen the international patent cooperation.

D. Recommendations for future research

In conclusion, future research is obviously required, compare with other countries, such as the geographical proximity of Japan and Korea, Taiwan patent output lower than these countries. In patent citation, foreign patents citing Taiwan patents constitute the other mode for investigating the international knowledge flow. Future research should investigate the contribution of the large public research sector, international knowledge flow and knowledge producers' nation or worldwide orientation. Among the many topics to be explored in future research, some important ones can be listed as follows. More careful studies of cross-industry patent citations, plus the qualification of their first assignee country, and discuss the linkage between science and technology. Through observing knowledge flows between academia and industry can understand the level of industry-academia cooperation. Observe the patent output of public research institutions to understand and predict the degree of innovation in the country.

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