Investigating the Trend of Cross-Disciplinary Evolution in Modern Technological Development

Chuan-Wei Kuo 1, Hsin-Ning Su 2

1 Graduate Institute of Technology Management, National Chung Hsing University, 250 KuoKuang Road, Taichung 402, Taiwan, a3078832@gmail.com

2 Graduate Institute of Technology Management, National Chung Hsing University, 250 KuoKuang Road, Taichung 402, Taiwan, ning@nchu.edu.tw

Under the globalized economy, cross-disciplinary technologies have been gradually developed to meet market demands. However, cross-disciplinary technology evolution has been barely investigated in a systematic approach in literature. This study aims to fill the gap by using patent indicator, i.e. patent count, patent citation, Non-patent reference, litigation probability, to explore how conventional technologies evolve into cross-disciplinary ones in the modern industry. A longitudinal analysis was conducted to observe how technology evolves as a function of time. The results show that cross-disciplinary trends can be observed in a significant number of industries. Firms are encouraged to develop cross-disciplinary technologies in order to strength the value of R&D and respond to the modern globalized economy.

I Introduction

1.1 Background

Over the past few decades of research on the process of technological development, a number of issues have appeared(Hsu, Lien, and Chen 2015)(Gerybadze and Reger 1999), some of which remain controversial in spite of reams of data on technological development. Moreover, some empirical studies have been showing that cross-disciplinary technology have a positive impact to economic and can promote technological progress(Hunter, Perry, and Currall 2011), but there has only a few systematic approach to demonstrate the technology evolution. This paper aims to fill the gap by using the patent citation analysis and patent indicators. Because of we are life in the globalized knowledge economy,

intellectual property becomes a very popular issue(Schmiele 2013), and many empirical studies have proved that patent citation analysis and patent indicators can observe the economic activity comprehensively(Cho and Shih 2011)(Griliches 1998)(Dubarić et al. 2011).

Cross-disciplinary collaboration usually needs to combine the different technology to get a new valuable technology. This paper used patent citation analysis to understand the knowledge flow of the process of technological development. Some research found that litigation patents are more valuable patent than the non-litigation patent(Su, Chen, and Lee 2012), so this study also used litigation patent to do the patent citation analysis. The quality of a new technology has tested by using patent indicators to do a time serious analysis in this paper.

1.2 Important Literature

A growing number of research studies are now available to shed some light on the evolution of the technology(Hunter, Perry, and Currall 2011)(Murmann and Frenken 2006)(Kaplan and Tripsas 2008)(Etzkowitz and Leydesdorff 2000)(Amesse and Cohendet 2001)(Guan and Zhao 2013). The paper in Hunter (2011) (Hunter, Perry, and Currall 2011)provide extensive discussions of the applications of patent activities. The paper in Amesse (2001) proposes a framework for understanding and analyzing the process of technology transfer in the perspective of the knowledge-based economy (KBE)(Amesse and Cohendet 2001). Litigation patent has been proving is more valuable patent than non-litigation patent(Su, Chen, and Lee 2012). Seminal work on calculating litigation probability was carried out by Hsin-Ning Su (2012)(Su, Chen, and Lee 2012). Frietsch (2014) (Frietsch et al. 2014) shows that patent has strongly correlated with export performance. Jiancheng Guan (2013)(Guan and Zhao 2013) shows that members going in for alliance networks will obtain more patent value than members in networks without alliance networks.

1.3 What is the problem?

Given the theoretical positions taken for the study and the status of the field as briefly reviewed above, the study aimed to provide an answer to the following question:

- Whether the combination of different technologies is the trend of industrial development?
- Whether the cross-disciplinary technology is more valuable technology?
- Whether industry decides to develop a cross-disciplinary technology is good or not?

1.4 Why is this problem important?

Technological innovation is usually accompanied by very large cost. Unless it can accurately predict technology trends to avoid worthless innovation (Albright 2002). This paper also wants to know whether is worth to develop a cross-disciplinary. Because the cost of development a new technology is very high, and different degree of cross-disciplinary needs different cost. If we can prove the value of a cross-disciplinary technology, it will have a positive impact on innovation. Moreover, we distinguished the technology depend on the different degree of cross-disciplinary to classify the strength of development comprehensively. It can even accelerate industrial development.

1.5 What literature gap is addressed from solving that problem?

Although substantial studies have been performed on the critical factors that affect the technological evolution of technological development (Corredoira and Banerjee 2015) (J. Kim, Lee, and Cho 2016) (Leoncini 1998), those of systematic investigation the technology trends are still critically lacking. While most of the literature on technological evolution treats only complex technical development process, we intend to introduce the notion of systematic observation and forecasting the trends of the evolution of technology by solving the problems we already mention in this paper.

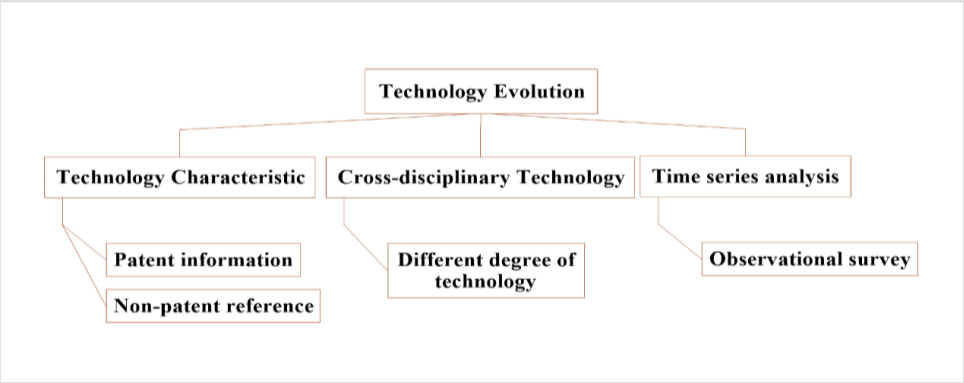
1.6 How is this research solving the problem?

In answering these questions we hope to gain a better understanding of the nature of technological evolution and, most particularly, to be able to decide what kinds of the method can observing and forecasting the technological evolution comprehensively. A number of studies have been conducted using patent information as technology characteristic(Frietsch et al. 2014)(Lee et al. 2012)(Patel and Ward 2011) (B. Kim et al. 2016). This paper used patent information to do the time series analysis and observed the trend of technological evolution. Moreover, this paper classifies the patent by different degree of cross-disciplinary. Different degree of the cross-disciplinary patent will be observed by using the different patent information. This paper clearly solve the problem by the method described above.

1.7 What does this research contribute to the scholarly literature by addressing the problem?

Experimental results are of great interest both for application and scientific research. Through solving the problems, we may have a contribution to make to unravel the mystery of technological evolution. This study may be critically important in laying the groundwork for systematizing study of science and technology trends. While research on these questions is still at a beginning stage, findings will have broad implications in a number of areas as follows: 1) Innovation policies and systems, 2) Patent informatics, big data and data mining, 3) Open innovation and value co-creation. It would seem advisable to make an effort to identify technological evolution through various research methods.

1.8 Paper Structure:



II Literature Review

2.1 Technological Development

(Arthur 2007) proposed a framework for investigating technological development that has withstood the test of time. Several studies (X. Wang et al. 2015)(Yoon and Park 2007)(Xiang et al. 2013)(Chen 2007) have noted that technology development and R&D (Research and Development) have a strong correlation. Theoretical models of new product development such as (Frankort 2016) need to be confirmed and modified through empirical evidence. The findings of studies examining the use of various forms of research and development have been mixed. An increasing number of recent publications and empirical studies have reassessed the positive contribution that technical cooperation between the different areas can make to technology development (Maietta 2015; Herstad, Aslesen, and Ebersberger 2014).

Under the globalized knowledge environment, many industries are cooperation each other in order to reduce the cost like R&D alliance(Narula and Santangelo 2009). This kinds of strategic alliance can effective integration of research and development capabilities between different industries, it can also develop a more innovative and having more value of a new product. Because of the science and technology for human needs are constantly evolving also(Plotkina and Munzel 2016). In recent years, the company can't rely on a single technology or a single product to survive, it usually need to sustainable development a new technology(Christensen, Olesen, and Kj\aer 2005). In other words, scientific and technological development is moving forward diversified technology. In this paper, the technology development of different intensity classified into different technical development strength. This paper distinguished the different degrees of cross-disciplinary cooperation, it can observing and understanding the technological development trend comprehensively.

Technological development often require a very large resource. Some empirical studies mention that industry-university collaboration can not only reduce the cost but also stimulate more excellent innovation, and many industries cooperated with university for many years. There have been a number of studied that have investigated industry-university collaboration of the impact on innovation(Maietta 2015)(Bodas Freitas, Marques, and Silva 2013)(Etzkowitz and Leydesdorff 2000), and these studies provides a very good research direction. Industry-university collaboration performance is also a very good subject to observe the technological development. The patent information non-patent reference count (NPRCNT) in this paper used to representative the characteristic of industry-university cooperation. Because of this paper also want to observe the effect of industry-university collaboration in technological development (Sung et al. 2015).

For the reasons given above, this paper will illustrate the process of technological development by using different degree of cross-disciplinary technology. In addition, this paper also used patent information to analysis the relationship between industry and university. Because this paper want to use these scientific method to understand the effect of different degree of cross-disciplinary technology.

2.2 Evolution of Technology

Technological change is a critical determinant of the evolution of technology, and technological innovation builds upon prior existing knowledge. In general, the knowledge produced in a technology remains within the same technology.

But for some special technology, knowledge spillovers across technologies also occur(Battke et al. 2016). This kinds of special technology reinforcing the existing technological trajectories, and has the potential to increase technological variety(van den Bergh 2008). Successful innovation depends on knowledge – technological, strategic and market related(Roper and Hewitt-Dundas 2015). From the technically perspective, new technology usually accompany a new technical. There are a lot of new product combines many different technologies, for example: 3D-printing machine, telemedicine machine and wearable electronics(Gebler, Schoot Uiterkamp, and Visser 2014). From the strategic perspective, there have some kinds of new alliance appeared over the past decades, for example: R&D alliance and Strategic Alliance for Industries(Frankort 2016). From the market perspective, product managers must constantly trade-off the level of customer satisfaction to meet their requirements(Chiang et al. 2016).

Technological diversification has received substantial attention from studies, as many firms have increasingly diversified their technological resources(Piening, Salge, and Schäfer 2016). A substantial body of research documents our tendency to cross-disciplinary development (Etzkowitz and Leydesdorff 2000)(Guan and Zhao 2013)(Hunter, Perry, and Currall 2011)(Liew, Shahdan, and Lim 2013)(Holgersson 2013), and (Hunter, Perry, and Currall 2011) provide an excellent review of the methods, findings and structural issues related to analysis technology evolution. The majority of research (Guan and Zhao 2013)(Y. Kim, Kim, and Yang 2012)(Motohashi 2005) in evolution of technology has focused on university-industry Collaboration. (Battke et al. 2016) used the technological knowledge flow to explore the internal or external spillovers for the technologies . This paper considers not only industry-university cooperation but also consider the flow of technology between all sectors (there all have 35 different kinds of sectors for the technology). Moreover, this paper aim to use technical knowledge flow to generate a systematical method to observe the technology evolution. Technological evolution typically accompany the Technological diversification (J. Kim, Lee, and Cho 2016; Y. Wang, Ning, and Prevezer 2015). In order to understanding how important of technology diversification, this paper used technology characteristic (i.e. patent information: non-patent reference count and reference count) and technical knowledge flow (i.e. patent citation (Patel and Ward 2011)) to observe the process of technological diversification by a time series analysis.

There have many empirical studies have used the patent to illustrate a variety of technology-related phenomena(Hoenig and Henkel 2015; Nam, Nam, and Kim 2015; B. Kim et al. 2016; Frietsch et al. 2014; Roper and Hewitt-Dundas 2015).

2.3 Systematic Study of Technological Evolution

In several empirical studies, it has been demonstrated that there are a close association and considerable correlation between Intellectual property and economic performance in international markets (Frietsch et al. 2014)(Grupp and Schmoch 1999)(Ushijima 2013)(Yang and Kuo 2008). Intellectual Property also is a major concern in a wide variety of applications such as economy growth (Gould and Gruben 1996), the value of innovation (Greenhalgh and Rogers 2006), technological capabilities (Fai 2005), and market competition (Patel and Ward 2011). A lot of research shows patents are valuable indicators (Fischer and Leidinger, n.d.)(Grimaldi et al. 2015)(Harhoff et al. 2009)(McQueen 2005). This paper used patent characteristic to generate a systematic approach to observe the evolution of technology. Patent characteristic represent the technology characteristic for the research in this study.

Some empirical studies have provided different kinds of systematic methods and structure for the research. (Frietsch et al. 2014) provided a systematic analysis method to exploring the relationship between technology and economic performance. (Ivanova and Leydesdorff 2014) provided a systematic structure to observe the innovation system of university–industry–government relations. (Hagedoorn and Cloodt 2003) provided a systematic method to measure innovative performance. Combining the advantage above, this paper used a systematic approach to observe the trend of the evolution of technology.

There also have some empirical studies have contribute the research of technology evolution such as (Amesse and Cohendet 2001) enhance the previous studies' findings by providing a much more detailed examination of the trend of cross-disciplinary evolution. (Arthur 2007) need to be confirmed and modified through empirical evidence. The two studies and this paper can complement each other well, for each emphasizes a different aspect of the evolution of technological development. Moreover, there are many different points of view can be explained the evolution of technology, a systematic approach to observe the trend of the evolution of technology is very useful for future research. If the trend of technology evolution can be forecasting, there will have many advantage for different sectors such as industries and government. In addition to decrease the risk of development a new technology and also reduce the cost. For the policy, government can properly use resources. For industries, they may have more confidence in the development of cross-disciplinary technology and drive the industries to innovation (Piening, Salge, and Schäfer 2016). For market, the right policies and healthy competitive environment between industries will drive the market active (Frankort 2016).

Authors	Key findings
Stephen Roper, Nola Hewitt-Dundasa (2015)	Knowledge flows from internal investments will have a positive impact on innovation outputs.
	Existing knowledge stocks will have a negative moderating effect on the innovation value of knowledge flows from internal investments.
Anthony Breitzman et al. (2002)	Patent analysis is particularly effective in industries with substantial patented technologies, including telecommunications, information technology, pharmaceuticals, biotechnology, chemicals, and automotive.
John Hagedoorn (2002)	Patents can be an appropriate indicator in the context of many high-tech sectors.
Daniel Hoenig, Joachim Henkel (2015)	Add new insights to a recent stream of research on the role of signals in venture capital financing, and in particular of patents as signals
Sangjun Nama et al. (2015)	Some firms in a vantage position in the patent lawsuit may be winners.
Michele Grimaldia, et al (2015)	This paper develops a practical and reproducible framework that can support scholars and practitioners to leverage the value of patents and to extract all possible strategic information from patent portfolio.
Frietsch et al. (2014)	Show that exports are a very useful way of placing a valuation on patents.
	Patents and exports are strongly correlated.
Hsin-Ning Su et al. (2012)	Generated a model can quick and evidence-based way of evaluating the patent value.
Amesse et al. (2001)	This contribution proposes a revised framework for understanding and analyzing the process of technology transfer in the perspective of the knowledge-based economy (KBE).
Jiancheng Guan et al. (2013)	Members going in for alliance networks that combine a high degree of clustering and reach will exhibit more patent value than members in networks without these characteristics.
Auerswald et al. (2000)	This paper used systematically method to modeling technological innovation.
Arthur W. Brian (2007)	This paper mention: invention is a recursive process: it repeats until each challenge or problem (and subproblem, and sub-subproblem) resolves itself into one that can be physically dealt with.
Gregory F. Nemet et al.(2012)	This paper discuss possible explanations for apparently negative impact of external knowledge include both measurement issues and challenges associated with assimilating disparate knowledge.

III Research Method

3.1 Data

A three-phase study was designed to explore the identification, classification, and application of cross-disciplinary technologies. First, this paper observed the knowledge flow of technology activity and identified the cross-disciplinary technology by patent information. In this part, patent information as an important element to identify the cross-disciplinary technology. Second, after identifying the cross-disciplinary technology, this paper used different kinds of patent indicators to classify the technology like patent citation and litigation probability. Patent citation and litigation probability are two of the major patent indicator in this paper, because of some empirical studies have proved that it can explore the technology value comprehensively. Last but not least, this paper analysis the application of cross-disciplinary technologies, and used some statistical methodology to get the research results. To ensure some homogeneity of technology background, all the patent data were selected from the same database. All the patent information this paper used are from PATSTAT database (Patent Statistic Database). PATSTAT database consists of all the patent information of different patent office (For example, European Patent Office (EPO), Unite State Patent and Trademark Office (USPTO) and Japan Patent Office (JPO)) in the world.

3.2 Analytical Method

Multiple indicators is of central interest in the context of measuring innovative performance, and yet, as observed by (Hagedoorn and Cloodt 2003), it is an area that is under-researched and under-discussed, so this paper used the different indicators to observe different phenomenon of the evolution of technology development. The data collection sessions were conducted individually and were integrated for later using and analysis as follows:

- **Identification of cross-disciplinary technology** –
  - In this investigation, we carried out a variety different type of data simulations. The cross-disciplinary technology in this paper means that the patent which citing more than one different sector patent.
- **Classification of cross-disciplinary technology** –
  - This paper used the different patent indicator to distinguish the cross-disciplinary technology in a different level, so we used database to management the data. This part used database to do the data-mining and calculated the litigation probability for the different level of the cross-disciplinary patent. We also do the patent citation analysis to determine the quality of different cross-disciplinary technology.
- **Application of cross-disciplinary technology** –

✧ Some empirical studies have integrated into one table, and this paper classified the studies with different application mode.

IV Results and Discussion

4.1 Table & Diagram

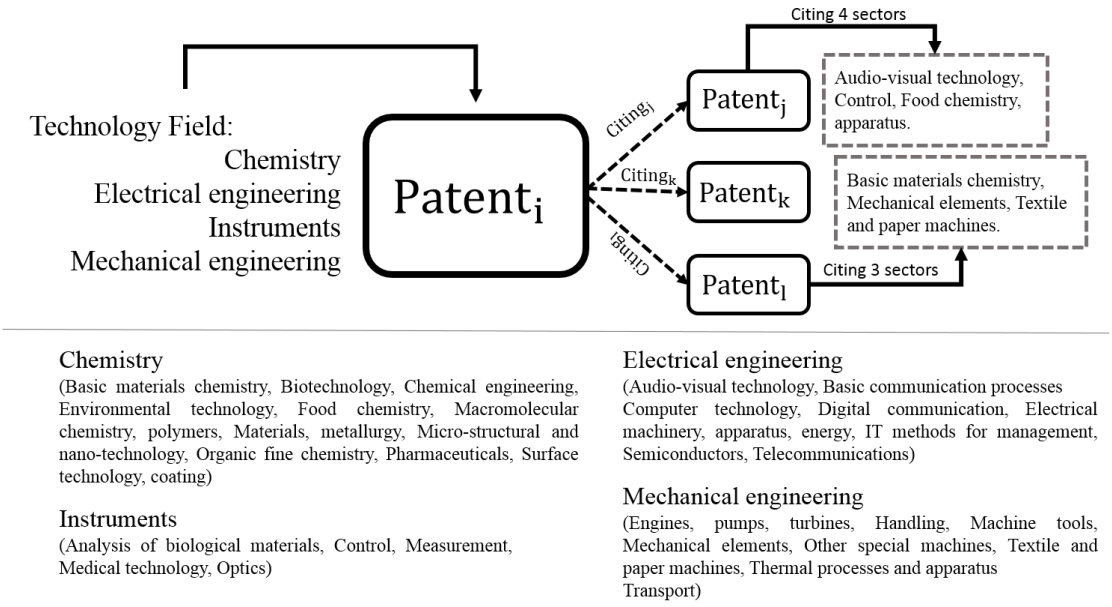


Fig. 1. Schema for patent citations showing forward citations to and from patent of interest, i. Arrows indicate flows of knowledge.

A picture of the experimental setup is depicted in Fig. 1, and Figure 1 metaphorically depicts what happens in that all models in Table 3. Moreover, a mathematical model was developed for the evaluation of the trend of cross-disciplinary evolution in Table 3. Table 1 and Table 2 presents the mean score, standard deviation with five models. The data are used the SQL server to do the data mining, and the analysis used the R statistical software package.

	Model I		Model II		Model III	
Variable	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Citing 2 Sectors	400784.59	228433.54	55119.15	35690.09	157001.15	98085.85
Citing 3 Sectors	262972.70	155953.10	38865.41	24577.66	112300.74	74748.93
Citing 4 Sectors	154883.11	95568.79	23709.70	14777.84	68021.96	46924.62
Citing 5 Sectors	87798.93	58287.17	14253.70	9458.60	38291.41	28072.71
Citing 6 Sectors	50775.22	35371.16	8456.19	5997.53	21015.33	15768.59
Citing 7 Sectors	31332.63	23317.54	5348.30	4147.48	12426.04	9478.95
Citing 8 Sectors	19275.41	14733.46	3449.74	2716.95	7377.70	5878.49
Citing 9 Sectors	11778.78	8854.16	2265.37	1789.21	4317.70	3400.74
Citing over 10 Sectors	33580.04	27761.75	5436.63	4785.37	12442.56	10590.18

Table 1 Descriptive statistics (n = 4,667,855 observations), 1976-2013

Source: USPTO, own calculations.

	Model IV		Model V	
Variable	Mean	Std. dev.	Mean	Std. dev.
Citing 2 Sectors	96726.63	57961.18	64856.00	37214.90
Citing 3 Sectors	62505.37	37494.00	35268.30	20320.10
Citing 4 Sectors	38002.04	23463.36	18026.52	10614.23
Citing 5 Sectors	21971.33	14604.40	9404.81	5999.68
Citing 6 Sectors	14060.67	10013.25	5245.22	3539.87
Citing 7 Sectors	9014.07	7254.26	3171.74	2349.87
Citing 8 Sectors	5731.00	4647.15	1915.07	1514.71
Citing 9 Sectors	3586.81	2851.76	1037.48	789.39
Citing over 10 Sectors	10746.63	9324.27	2631.74	2114.32

Table 2 Descriptive statistics (n = 4,667,855 observations), 1976-2013

Source: USPTO, own calculations.

Table 3 offers a taxonomy that reflects the linear regression result with five different models for observing the value of different cross-disciplinary patent. The dependent variable in regression function is time cited count for patents, and the independent valuable in regression function is the degree of cross-disciplinary for patents (Fig. 1.). Model I generated a linear regression function by all patents, and Model II, Model III, Model IV and Model V generated a linear regression function by using patent in different technology sectors. (i.e. Model II used Chemistry, Model III used Electrical Engineering, Model IV used Instruments and Model V used Mechanical Engineering patents as object perspective). The results show a striking significant of high degree of cross-disciplinary (citing over 10 sectors) in different models.

	Model I	Model II	Model III	Model IV	Model V
Constant	2625.5	-900.485	7660.785	1959.255	-891.698
Citing 2 Sectors	0.642***	0.727***	0.539***	0.734**	0.996***
Citing 3 Sectors	0.764***	0.205***	0.436***	0.175***	-0.08
Citing 4 Sectors	-0.572***	0.046	0.185	-0.048	-0.054
Citing 5 Sectors	0.058	0.025	0.048	0.002	-0.027
Citing 6 Sectors	0.164***	-0.025	0.05	0.118***	0.008
Citing 7 Sectors	0.075	0.050**	-0.065	0.061	-0.007
Citing 8 Sectors	0.064	-0.057	-0.023	-0.007	-0.014
Citing 9 Sectors	0.013	0.053**	0.009	0.011	-0.044
Citing over 10 Sectors	0.073***	0.060***	0.069***	0.064***	0.042***
R^2	1	0.999	0.999	0.998	0.997

***p < 0.01: Significance level.

**p < 0.05: Significance level.

*p < 0.10.

Table 3 The result of estimates of multi factor line regression with five models. (n = 4,667,855 observations), 1976-2013

Source: USPTO, own calculations.

Fig.2 and Fig.3 used the Stacked Area Chart to demonstrate the yearly number of the different patent application (Fig.2 shown the patent count of cross-disciplinary patent and Fig.3 shown the litigation patent count of the cross-disciplinary patent). The results reflected in Fig.2 indicate that technical indeed continue toward cross-disciplinary development. Fig.3 indicate that technological development has gradually focused on high level of cross-disciplinary. Because it needs a lot of time and money to go through the process of patent litigation, and high level of cross-disciplinary clearly worth.

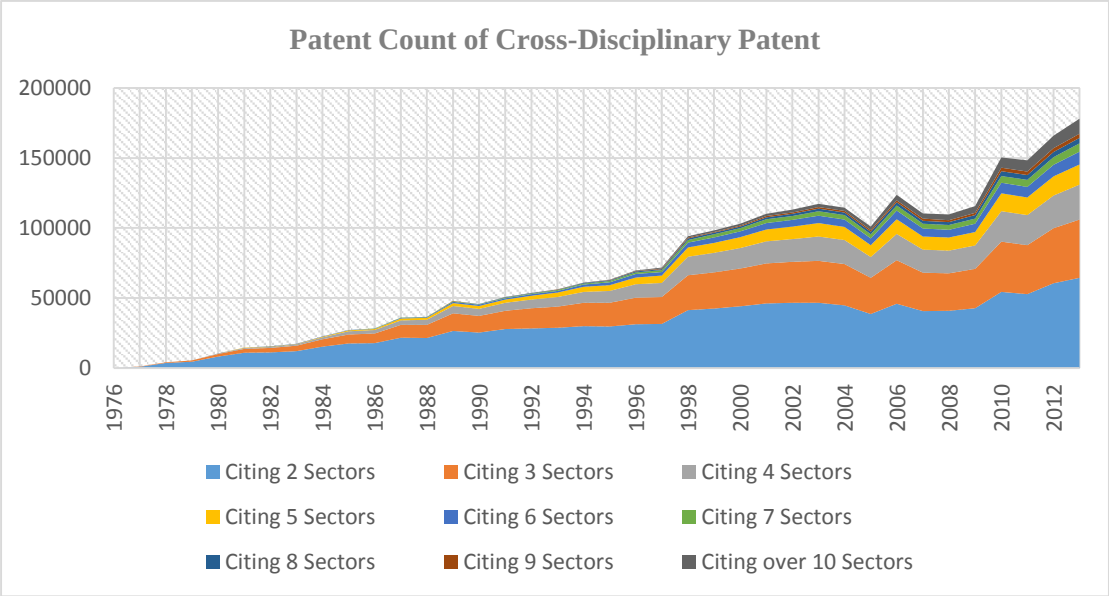


Fig. 2. Cross-disciplinary patent count, 1976-2013

Source: PATSTAT, own calculations.

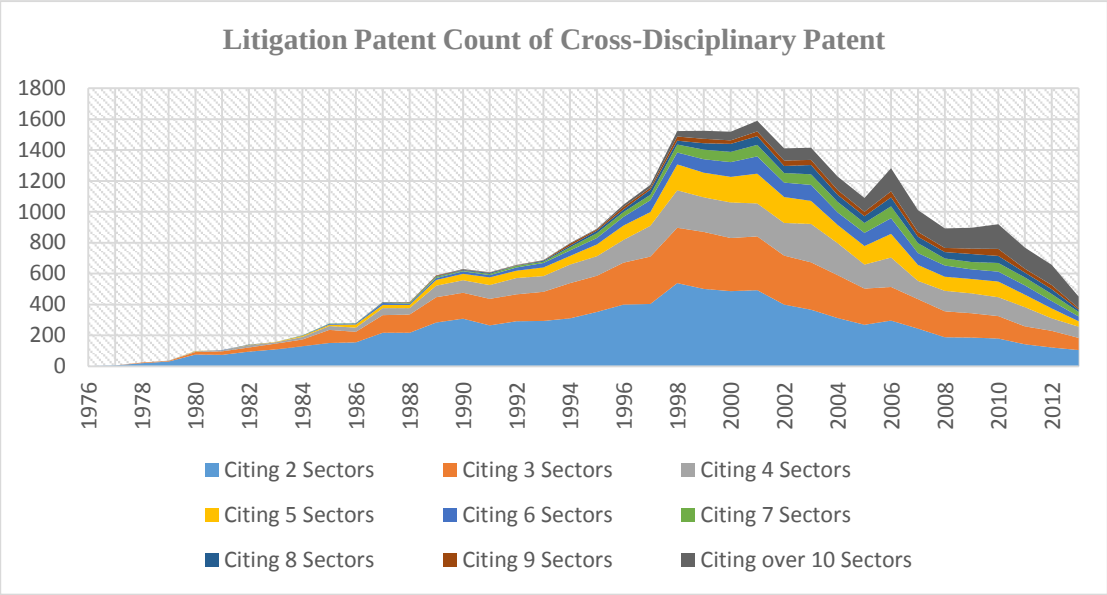


Fig. 3. Litigation patent count of cross-disciplinary patent, 1976-2013

Source: PATSTAT, own calculations.

Fig.4 presents the ratio of total litigation patent with different degree of cross-disciplinary technology. The most important finding from Fig. 4 support the notion that the high cross-disciplinary technology has gradually replaced the low cross-disciplinary technology and become the main valuable patents.

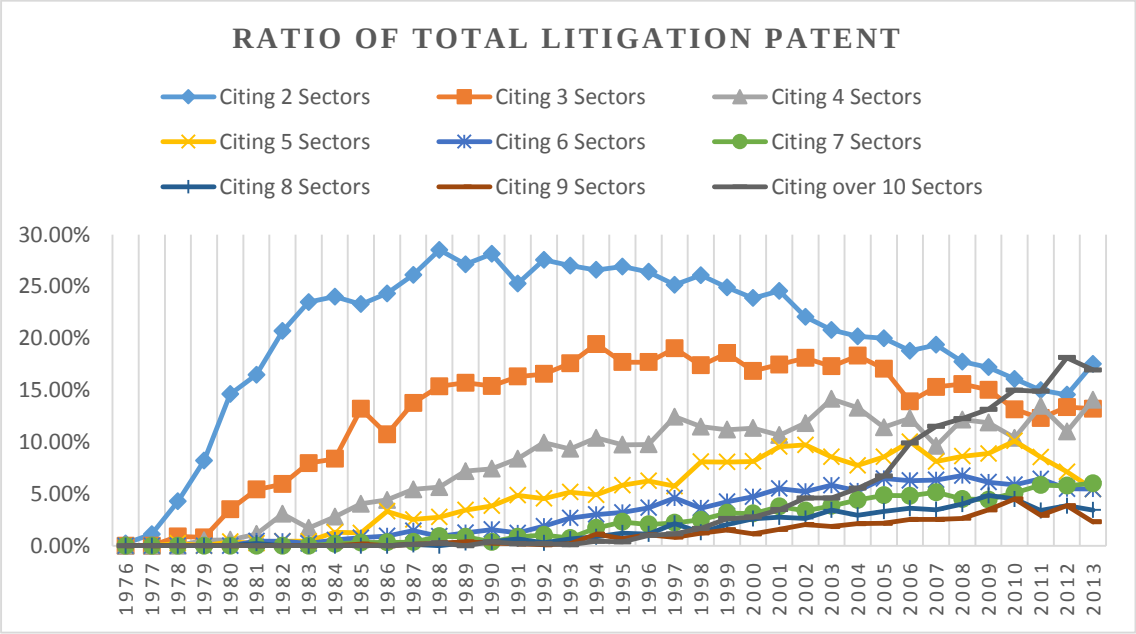


Fig. 4. Ratio of litigation patent count (compare with all litigation patent), 1976-2013

Source: PATSTAT, own calculations.

Average non-patent reference and reference count of different degree of cross-disciplinary patent and are given in Figure 5 and Figure 6 respectively. The results of Figure 5 shows that high degree of cross-disciplinary patent may have higher count of non-patent referent count than low degree of cross-disciplinary patent. Figure 6 shows that high degree of cross-disciplinary patent indeed have high number of reference than low degree of cross-disciplinary patent.

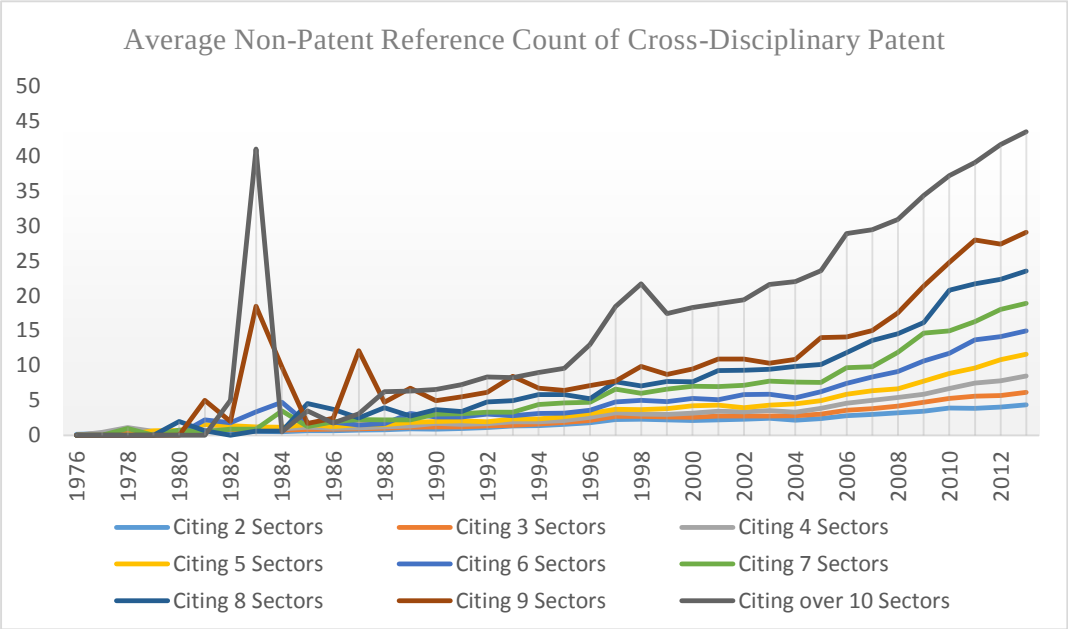


Fig. 5. Average Non-Patent Reference Count of Cross-Disciplinary Patent, 1976-2013

Source: PATSTAT, own calculations.

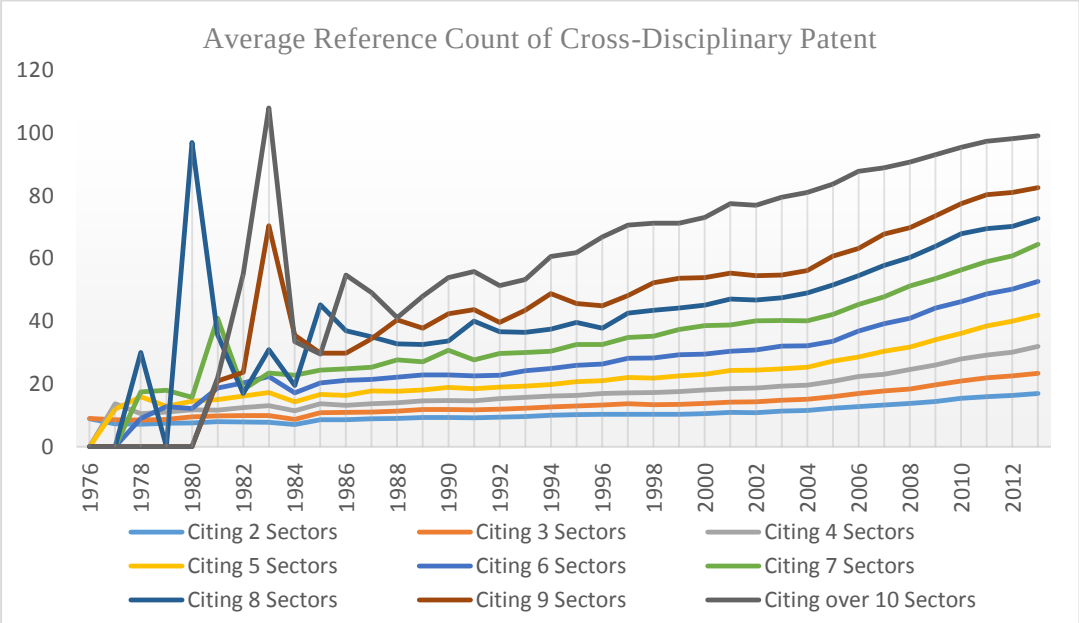


Fig. 6. Average Reference Count of Cross-Disciplinary Patent, 1976-2013

Source: PATSTAT, own calculations.

4.2 Explain finding from Table and Diagram

There have several as follows:

A. Technical indeed continue toward cross-disciplinary development in Fig.2.

B. Technological development has gradually focused on high level of cross-disciplinary in Fig.3.

C. Fig.4 shown the high cross-disciplinary technology has gradually replaced the low cross-disciplinary technology and become the main valuable patents.

D. Fig.5 shown that the higher the degree of cross-disciplinary has the higher probability for generating an industry-university cooperation.

E. Fig.6 shown that high degree of cross-disciplinary patent indeed have high number of reference than low degree of cross-disciplinary patent.

4.3 Dialogues between result and literature review component 2 and component 1

What factors have led to the overwhelming popularity of the cross-disciplinary? Probably the major reason for its success is the fact that such techniques are more valuable. The second reason for cross-disciplinary popularity is the fact that over time transitive, more and more industries tried to cooperate with other field's industries. One explanation for this is that technological diversification has become a trend no matter for different perspective to observe.

Through the results we can systematic understanding the trend of evolution of technology and technology development is continuing towards diversity. Moreover, cross-disciplinary technology will become the mainstream trend. This paper already mention above through the past studies in literature review.

4.4 Check whether research questions have been answered

There have three answer for answering the research questions as follows:

1. Whether the combination of different technologies is the trend of industrial development?

- Yes, Fig.2 and Fig.3 can illustrate that diversification is the development trend of the technology.

2. Whether the cross-disciplinary technology is more valuable technology?

- Yes, through Fig.4 demonstrate the ratio of litigation patent count of cross-disciplinary technology, and the cross-disciplinary technology become the main valuable patents. (some empirical studies have proved that litigation patent is more valuable patent than non-litigation patent(Su, Chen, and Lee 2012))

3. Whether industry decides to develop a cross-disciplinary technology is good or not?

- Yes, cross-disciplinary technology can improve the value of the product, and may deepen the relationship between industries.

V Conclusion

5.1 Summarize important findings of this research

Three of these findings are worth summarizing: 1) Technical indeed continue toward cross-disciplinary development, 2) Technological development has gradually focused on high level of cross-disciplinary, 3) The proportion of the high degree of the cross-disciplinary patent of total litigation patent has an increasing trend.

5.2 Review the quality of data and research method

Data were collected primarily by means of raw data from PATSTAT database, which have been used in several empirical studies such as (Frietsch et al. 2014). Research method is use time series analysis, and the result were examined.

5.3 Management implication

These findings in this paper lead us to believe that continued research and development of cross-cutting technology should be used in order to accelerate industrial upgrading. The results of this study clearly support the notion that industries can enhance the competitiveness by developing the cross-disciplinary technology.

5.4 Contribution to theory

The present study enhance the previous studies' findings (Amesse and Cohendet 2001) by providing a much more detailed examination of the trend of cross-disciplinary evolution. Theoretical models of the structure of invention such as (Arthur 2007), need to be confirmed and modified through empirical evidence. The two studies and this paper can complement each other well, for each emphasizes a different aspect of the evolution of technological development.

5.5 The limitation of this study

Discussion of these element of economic and political environment is beyond the scope of this paper. It is not within the scope of this paper to provide an extended discussion of the ongoing debates.

5.6 The suggestion for future research

The study does suggest that the detailed study of how cross-disciplinary acts are performed over time is a promising line of inquiry. Future research is obviously required, but this is an exciting first step.

VI Reference

Albright, Richard E. 2002. “What Can Past Technology Forecasts Tell Us about the Future?” Technological Forecasting and Social Change, TF Highlights from ISF 2001, 69 (5): 443–64. doi:10.1016/S0040-1625(02)00186-5.

Amesse, Fernand, and P Cohendet. 2001. “Technology Transfer Revisited from the Perspective of the Knowledge-Based Economy.” Research Policy, Codification of Knowledge:, 30 (9): 1459–78. doi:10.1016/S0048-7333(01)00162-7.

Arthur, W. Brian. 2007. “The Structure of Invention.” Research Policy 36 (2): 274–87. doi:10.1016/j.respol.2006.11.005.

Battke, Benedikt, Tobias S. Schmidt, Stephan Stollenwerk, and Volker H. Hoffmann. 2016. “Internal or External spillovers—Which Kind of Knowledge Is More Likely to Flow within or across Technologies.” Research Policy 45 (1): 27–41. doi:10.1016/j.respol.2015.06.014.

Bodas Freitas, Isabel Maria, Rosane Argou Marques, and Evando Mirra de Paula e Silva. 2013. “University–industry Collaboration and Innovation in Emergent and Mature Industries in New Industrialized Countries.” Research Policy 42 (2): 443–53. doi:10.1016/j.respol.2012.06.006.

Chen, Chung-Jen. 2007. “Information Technology, Organizational Structure, and New Product Development—The Mediating Effect of Cross-Functional Team Interaction.” IEEE Transactions on Engineering Management 54 (4): 687–98. doi:10.1109/TEM.2007.906831.

Chiang, Tzu-An, Z. H. Che, Te-Wei Wang, and Jian-Hong Chen. 2016. “Demand-Oriented Multi-Objective Planning Method for Electronic Product Technology Development.” Applied Mathematical Modelling. Accessed February 12. doi:10.1016/j.apm.2015.10.024.

Cho, Ta-Shun, and Hsin-Yu Shih. 2011. “Patent Citation Network Analysis of Core and Emerging Technologies in Taiwan: 1997-2008.” Scientometrics 89 (3): 795–811. doi:10.1007/s11192-011-0457-z.

Christensen, J. F, M. H Olesen, and J. S Kj\aer. 2005. “The Industrial Dynamics of Open Innovation—Evidence from the Transformation of Consumer Electronics.” Research Policy 34 (10): 1533–49.

Corredoira, Rafael A., and Preeta M. Banerjee. 2015. “Measuring Patent’s Influence on Technological Evolution: A Study of Knowledge Spanning and Subsequent Inventive Activity.” Research Policy 44 (2): 508–21. doi:10.1016/j.respol.2014.10.003.

Dubarić, Ervin, Dimitris Giannoccaro, Rune Bengtsson, and Thomas Ackermann. 2011. “Patent Data as Indicators of Wind Power Technology Development.” World Patent Information 33 (2): 144–49. doi:10.1016/j.wpi.2010.12.005.

Etzkowitz, Henry, and Loet Leydesdorff. 2000. “The Dynamics of Innovation: From National Systems and ‘Mode 2’ to a Triple Helix of University–industry–government Relations.” Research Policy 29 (2): 109–23. doi:10.1016/S0048-7333(99)00055-4.

Fai, Felicia M. 2005. “Using Intellectual Property Data to Analyse China’s Growing Technological Capabilities.” World Patent Information 27 (1): 49–61. doi:10.1016/j.wpi.2004.08.004.

Fischer, Timo, and Jan Leidinger. n.d. “Testing Patent Value Indicators on Directly Observed Patent value—An Empirical Analysis of Ocean Tomo Patent Auctions.” Research Policy, no. 0. doi:10.1016/j.respol.2013.07.013.

Frankort, Hans T. W. 2016. “When Does Knowledge Acquisition in R&D Alliances Increase New Product Development? The Moderating Roles of Technological Relatedness and Product-Market Competition.” Research Policy 45 (1): 291–302. doi:10.1016/j.respol.2015.10.007.

Frietsch, Rainer, Peter Neuhäusler, Taehyun Jung, and Bart Van Looy. 2014. “Patent Indicators for Macroeconomic Growth—the Value of Patents Estimated by Export Volume.” Technovation 34 (9): 546–58. doi:10.1016/j.technovation.2014.05.007.

Gebler, Malte, Anton J. M. Schoot Uiterkamp, and Cindy Visser. 2014. “A Global Sustainability Perspective on 3D Printing Technologies.” Energy Policy 74 (November): 158–67. doi:10.1016/j.enpol.2014.08.033.

Gerybadze, Alexander, and Guido Reger. 1999. “Globalization of R&D: Recent Changes in the Management of Innovation in Transnational Corporations.” Research Policy 28 (2–3): 251–74. doi:10.1016/S0048-7333(98)00111-5.

Gould, David M., and William C. Gruben. 1996. “The Role of Intellectual Property Rights in Economic Growth.” Journal of Development Economics 48 (2): 323–50. doi:10.1016/0304-3878(95)00039-9.

Greenhalgh, C., and M. Rogers. 2006. “The Value of Innovation: The Interaction of Competition, R&D and IP.” Research Policy 35 (4): 562–80. doi:10.1016/j.respol.2006.02.002.

Griliches, Z. 1998. “Patent Statistics as Economic Indicators: A Survey.”

Grimaldi, Michele, Livio Cricelli, Martina Di Giovanni, and Francesco Rogo. 2015. “The Patent Portfolio Value Analysis: A New Framework to Leverage Patent Information for Strategic Technology Planning.” Technological Forecasting and Social Change 94 (May): 286–302. doi:10.1016/j.techfore.2014.10.013.

Grupp, Hariolf, and Ulrich Schmoch. 1999. “Patent Statistics in the Age of Globalisation: New Legal Procedures, New Analytical Methods, New Economic Interpretation.” Research Policy 28 (4): 377–96.

Guan, Jiancheng, and Qingjun Zhao. 2013. “The Impact of University–industry Collaboration Networks on Innovation in Nanobiopharmaceuticals.” Technological Forecasting and Social Change 80 (7): 1271–86. doi:10.1016/j.techfore.2012.11.013.

Hagedoorn, John, and Myriam Cloodt. 2003. “Measuring Innovative Performance: Is There an Advantage in Using Multiple Indicators?” Research Policy 32 (8): 1365–79. doi:10.1016/S0048-7333(02)00137-3.

Harhoff, Dietmar, Karin Hoisl, Bettina Reichl, and Bruno van Pottelsberghe de la Potterie. 2009. “Patent Validation at the Country level—The Role of Fees and Translation Costs.” Research Policy 38 (9): 1423–37. doi:10.1016/j.respol.2009.06.014.

Herstad, Sverre J., Heidi Wiig Aslesen, and Bernd Ebersberger. 2014. “On Industrial Knowledge Bases, Commercial Opportunities and Global Innovation Network Linkages.” Research Policy 43 (3): 495–504. doi:10.1016/j.respol.2013.08.003.

Hoenig, Daniel, and Joachim Henkel. 2015. “Quality Signals? The Role of Patents, Alliances, and Team Experience in Venture Capital Financing.” Research Policy 44 (5): 1049–64. doi:10.1016/j.respol.2014.11.011.

Holgersson, Marcus. 2013. “Patent Management in Entrepreneurial SMEs: A Literature Review and an Empirical Study of Innovation Appropriation, Patent Propensity, and Motives.” R&D Management 43 (1): 21–36.

Hsu, Chia-Wen, Yung-Chih Lien, and Homin Chen. 2015. “R&D Internationalization and Innovation Performance.” International Business Review 24 (2): 187–95. doi:10.1016/j.ibusrev.2014.07.007.

Hunter, Emily M., Sara Jansen Perry, and Steven C. Currall. 2011. “Inside Multi-Disciplinary Science and Engineering Research Centers: The Impact of Organizational Climate on Invention Disclosures and Patents.” Research Policy 40 (9): 1226–39. doi:10.1016/j.respol.2011.05.024.

Ivanova, Inga A., and Loet Leydesdorff. 2014. “Rotational Symmetry and the Transformation of Innovation Systems in a Triple Helix of University–industry–government Relations.” Technological Forecasting and Social Change 86 (July): 143–56. doi:10.1016/j.techfore.2013.08.022.

Kaplan, Sarah, and Mary Tripsas. 2008. “Thinking about Technology: Applying a Cognitive Lens to Technical Change.” Research Policy 37 (5): 790–805. doi:10.1016/j.respol.2008.02.002.

Kim, Bongsun, Eonsoo Kim, Douglas J. Miller, and Joseph T. Mahoney. 2016. “The Impact of the Timing of Patents on Innovation Performance.” Research Policy 45 (4): 914–28. doi:10.1016/j.respol.2016.01.017.

Kim, Jungho, Chang-Yang Lee, and Yunok Cho. 2016. “Technological Diversification, Core-Technology Competence, and Firm Growth.” Research Policy 45 (1): 113–24. doi:10.1016/j.respol.2015.07.005.

Kim, Younghwan, Wonjoon Kim, and Taeyong Yang. 2012. “The Effect of the Triple Helix System and Habitat on Regional Entrepreneurship: Empirical Evidence from the U.S.” Research Policy 41 (1): 154–66. doi:10.1016/j.respol.2011.08.003.

Lee, Changyong, Yangrae Cho, Hyeonju Seol, and Yongtae Park. 2012. “A Stochastic Patent Citation Analysis Approach to Assessing Future Technological Impacts.” Technological Forecasting and Social Change 79 (1): 16–29. doi:10.1016/j.techfore.2011.06.009.

Leoncini, Riccardo. 1998. “The Nature of Long-Run Technological Change: Innovation, Evolution and Technological Systems.” Research Policy 27 (1): 75–93. doi:10.1016/S0048-7333(98)00025-0.

Liew, M. S., T. N. Tengku Shahdan, and E. S. Lim. 2013. “Enablers in Enhancing the Relevancy of University-Industry Collaboration.” Procedia - Social and Behavioral Sciences, 3rd World Conference on Learning, Teaching and Educational Leadership, 93 (October): 1889–96. doi:10.1016/j.sbspro.2013.10.135.

Maietta, Ornella Wanda. 2015. “Determinants of University–firm R&D Collaboration and Its Impact on Innovation: A Perspective from a Low-Tech Industry.” Research Policy 44 (7): 1341–59. doi:10.1016/j.respol.2015.03.006.

McQueen, Douglas H. 2005. “Growth of Software Related Patents in Different Countries.” Technovation 25 (6): 657–71. doi:10.1016/j.technovation.2003.10.005.

Motohashi, Kazuyuki. 2005. “University–industry Collaborations in Japan: The Role of New Technology-Based Firms in Transforming the National Innovation System.” Research Policy 34 (5): 583–94. doi:10.1016/j.respol.2005.03.001.

Murmann, Johann Peter, and Koen Frenken. 2006. “Toward a Systematic Framework for Research on Dominant Designs, Technological Innovations, and Industrial Change.” Research Policy 35 (7): 925–52. doi:10.1016/j.respol.2006.04.011.

Nam, Sangjun, Changi Nam, and Seongcheol Kim. 2015. “The Impact of Patent Litigation on Shareholder Value in the Smartphone Industry.” Technological Forecasting and Social Change 95 (June): 182–90. doi:10.1016/j.techfore.2015.01.015.

Narula, Rajneesh, and Grazia D. Santangelo. 2009. “Location, Collocation and R&D Alliances in the European ICT Industry.” Research Policy 38 (2): 393–403. doi:10.1016/j.respol.2008.11.005.

Patel, Darshak, and Michael R. Ward. 2011. “Using Patent Citation Patterns to Infer Innovation Market Competition.” Research Policy 40 (6): 886–94. doi:10.1016/j.respol.2011.03.006.

Piening, Erk P., Torsten Oliver Salge, and Sebastian Schäfer. 2016. “Innovating across Boundaries: A Portfolio Perspective on Innovation Partnerships of Multinational Corporations.” Journal of World Business. Accessed February 12. doi:10.1016/j.jwb.2016.01.001.

Plotkina, Daria, and Andreas Munzel. 2016. “Delight the Experts, but Never Dissatisfy Your Customers! A Multi-Category Study on the Effects of Online Review Source on Intention to Buy a New Product.” Journal of Retailing and Consumer Services 29 (March): 1–11. doi:10.1016/j.jretconser.2015.11.002.

Roper, Stephen, and Nola Hewitt-Dundas. 2015. “Knowledge Stocks, Knowledge Flows and Innovation: Evidence from Matched Patents and Innovation Panel Data.” Research Policy 44 (7): 1327–40. doi:10.1016/j.respol.2015.03.003.

Schmiele, Anja. 2013. “Intellectual Property Infringements due to R&D Abroad? A Comparative Analysis between Firms with International and Domestic Innovation Activities.” Research Policy 42 (8): 1482–95. doi:10.1016/j.respol.2013.06.002.

Su, Hsin-Ning, Carey Ming-Li Chen, and Pei-Chun Lee. 2012. “Patent Litigation Precaution Method: Analyzing Characteristics of US Litigated and Non-Litigated Patents from 1976 to 2010.” Scientometrics 92 (1): 181–95. doi:10.1007/s11192-012-0716-7.

Sung, Hui-Yun, Chun-Chieh Wang, Mu-Hsuan Huang, and Dar-Zen Chen. 2015. “Measuring Science-Based Science Linkage and Non-Science-Based Linkage of Patents through Non-Patent References.” Journal of Informetrics 9 (3): 488–98. doi:10.1016/j.joi.2015.04.004.

Ushijima, Tatsuo. 2013. “Patent Rights Protection and Japanese Foreign Direct Investment.” Research Policy 42 (3): 738–48. doi:10.1016/j.respol.2012.09.010.

Van den Bergh, Jeroen C. J. M. 2008. “Optimal Diversity: Increasing Returns versus Recombinant Innovation.” Journal of Economic Behavior & Organization 68 (3–4): 565–80. doi:10.1016/j.jebo.2008.09.003.

Wang, Xuefeng, Pengjun Qiu, Donghua Zhu, Liliana Mitkova, Ming Lei, and Alan L. Porter. 2015. “Identification of Technology Development Trends Based on Subject–action–object Analysis: The Case of Dye-Sensitized Solar Cells.” Technological Forecasting and Social Change 98 (September): 24–46. doi:10.1016/j.techfore.2015.05.014.

Wang, Yuandi, Lutao Ning, and Martha Prevezer. 2015. “Technological Diversification in China from 1986 to 2011: Evidence from Patent Data.” Technological Forecasting and Social Change 99 (October): 54–66. doi:10.1016/j.techfore.2015.06.019.

Xiang, Xi-Yao, Hong Cai, Shui Lam, and Yun-Long Pei. 2013. “International Knowledge Spillover through Co-Inventors: An Empirical Study Using Chinese Assignees’ Patent Data.” Technological Forecasting and Social Change 80 (1): 161–74. doi:10.1016/j.techfore.2012.07.003.

Yang, Chih-Hai, and Nai-Fong Kuo. 2008. “Trade-Related Influences, Foreign Intellectual Property Rights and Outbound International Patenting.” Research Policy 37 (3): 446–59. doi:10.1016/j.respol.2007.11.008.

Yoon, Byungun, and Yongtae Park. 2007. “Development of New Technology Forecasting Algorithm: Hybrid Approach for Morphology Analysis and Conjoint Analysis of Patent Information.” IEEE Transactions on Engineering Management 54 (3): 588–99. doi:10.1109/TEM.2007.900796.