

# Measurement Method and Application Study on Technological Linkage Oriented to Patent Early-warning

Mier Zhang, Haipeng Li, and Wei Guo

**Abstract**—Technological conflicts and patent litigations have increased rapidly in recent years. Patent early-warning is an important method to coping with the situation. The extension of technological linkage is a major inducer of patent litigation. The study on technological linkage has contributed to conduct patent early-warning. The correlation between patent citations and technological linkage has been analyzed. Technological linkage index is constructed based on patent multi-stage citations and a quantitative method of measuring technological linkage between patent holders is proposed. Taking Apple and Samsung as research samples, the measurement method is applied. The result of time series analysis shows that technological linkage index between them has increased rapidly and this trend keeps ahead of the emergence of patent litigations. Technological linkage index can be employed to analyze and pre-alert for potential patent litigations between specific patent holders.

**Index Terms**—Patent citation, patent early-warning, patent litigation, technological linkage.

## I. INTRODUCTION

Technology innovation is facing complex technical systems. The number of patents is increasing rapidly and there is direct and indirect technological linkage between patent holders. Massive technical conflicts and patent litigations spring up, which has significant impact on technology innovation. Patent litigation has a negative impact on innovation at targeted firms so as to make innovative activities substantially reduced after settlements with litigations [1]. Patent litigation represents an unavoidable business cost to technology developers, reduces the profits that these firms make on their technology investments [2]. Patent litigation reallocates innovation profits between firms that pursued similar technology paths *ex ante*, so it affects incentives to innovate and affects R&D efficiency [3].

In recent years, high-tech industries have become the high incidence area of patent litigations, such as mobile communications, integrated circuit, bio-medicine, and other high-tech industries. And patent litigations have gradually spread from high-tech industries to traditional industries, such as automotive parts, household appliances, machinery manufacturing and so on. Patent litigations have begun to

widespread in China with the rapid growth of patents. And patent litigations have also spread from the developed countries to China and other developing countries. It means that Chinese enterprises are confronted with the challenges of patent litigations in the international and domestic markets.

Therefore, it is in urgent need to conduct patent early-warning to coping with patent litigations in the process of technology innovation. Patents are the technical assets of enterprises. Patent documents not only contain technical information but also reflect relationships among patents. It is necessary to study on measuring technological linkage by patent documents, so as to provide necessary analysis tools to cope with patent litigations.

## II. LITERATURE REVIEW

Studies on technological linkage were mainly about industrial association. Tamamura studied the changes in international industrial structures among Asian countries by industry association analysis method based on the Asian international input-output tables [4]. Indices of industrial linkage were constructed by sector classification catalogue and code of input-output table [5]. Technical correlation was the core performance of the intrinsic linkage between industries. And it showed the relationship of supply and demand in product chain between industries [6]. However, due to different industrial characteristics and diversification development trend of enterprises, enterprises are classified in the same industry and may be at different industrial chains. So it is limited to measure technological linkage by industry association in practical application.

As patent documents contain technical information, patent classification codes have become tools to study technological linkage. Technical proximity was analyzed by patent distribution vectors overlap between countries based on patent classification codes [7]. In the technology space, technical proximity between enterprises was measured by two vectors of patent distribution [8]. Methods of measuring breadth and depth of patents by IPC could be used to weigh technical complexity [9]. The width and depth of 30 technical fields were analyzed by Chinese invention patents based on the measurement of patent complexity and the result was compared with the analysis of European patents [10].

Patent citation has been paid attention in recent years, which provides a new clue for studying technological linkage. Patent citation analysis originally was proposed to measure technological similarity and relevance [11]. Patent citation reflected technological linkage of patents [12]. Patent citation was also used to evaluate the linkage of citing and cited countries, enterprises, science and technology [13]. Due to

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the complexity of data processing, research progress of related studies had been slow for a long time, but it was improved recently. Patent citation could be used to analyze technology overlap and developing venation of molecular design breeding [14]. Patent citation number, citation technological scope and citation rate have influences on technological linkage [15].

Under the background of complex technology, the network relationships between patents have growing impacts on technology innovation. Massive patents are overlapping with each other and increase the risk of patent infringement and patent litigations [16]. Patent citations had different characterizes in different industries and occurred frequently in industries with strong technological linkage [17]. Patent-infringement lawsuits graph was constructed to analyze the level of influence of companies based on patent lawsuit information [18]. Technological linkage of patents on shale gas exploration was analyzed by patent map and it revealed that the formation of the patent thicket in this field and its influence on innovation [19].

With the complexity of technical systems, related studies on technological linkage had attracted the attention of academic community. In view of previous studies on technological linkage were mainly around industrial association, patent classification, and patent citations. Trends of using patent citations to analysis technological linkage need to be paid attention. Previous studies were based on single-stage citation which owing to the limitation of databases and analysis tools. With the development of databases and analysis tools in recent years, it is necessary and possible to carry out researches based on patent multi-stage citations for measuring technological linkage. And the measurement will help to pre-alert potential patent litigations.

### III. METHODOLOGY

#### A. Research Design

The study is aimed at proposing a quantitative method of measuring technological linkage between enterprises. Patents are the technical assets of enterprises. Patent documents not only contain technical information but also reflect relationships among patents. Patent citation is used to illustrate that the appearance of the focus patent is based on the knowledge involved in cited patents [20]. Patent citation information reflects the inheritance and accumulation of technologies and it can be used to measure technological linkage between enterprises.

Patent citations include not only direct citation but also indirect citation. Under the background of complex technical composition, researches directly or indirectly involve patents of enterprises. It is difficult to reveal indirect technological linkage only by direct citation. It is need to further mine patent citation. Compared with direct citation, multi-stage citations covering direct and indirect citation information can reveal the complex technological linkage between enterprises, especially indirect linkage. New patent analysis platforms such as Thomson Innovation and Patentics provide technological means to analyze patent multi-stage citations in recent years.

Therefore, with the development of patent databases and analysis tools, the study proposes a quantitative method of measuring technological linkage based on patent multi-stage citations. First, by analyzing the correlation between patent citation and technological linkage, technological linkage index is constructed to measure technological linkage between enterprises based on patent multi-stage citations. Then, research samples are selected to analyze their patent citation data and the corresponding time series data. The data are analyzed by the measurement method to make a quantitatively measurement and trend analysis of technological linkage.

#### B. Patent Citation

Due to technological progress is a process of cumulative innovation, each discovery is building on previous findings [21]. Inventors inevitably reference prior technologies in technology innovation. A patent citing other patents directly is defined as patent single-stage citation. Technological linkage of single-stage citation is closely connected. Because of easily access data for statistical analysis, single-stage citation has been used as data source of citation analysis [22]. However, with complex technical systems, single-stage citation can't reveal complex and indirect technological linkage, so it needs to mine patent citation information further.

Patent multi-stage citation refers that a patent cites other patents directly or indirectly, which covers both direct and indirect citation information between patents. Indirect citation relationship between patents should be taken into account when analyzing patent citation information. Patent citation information is expanded gradually to analyze multi-stage citation information [23]. As shown in Fig. 1, using patent P1 for sample, P1 directly citing P2 is one-stage citation, P1 citing P3 and P4 are two-stage citation, P1 citing P5 is three-stage citation. Mining multi-stage citations through P1 can reveal indirect technological linkage between P1 and P3, P4, P5.

Compared with single-stage citation, multi-stage citation information can be mined to reveal direct and indirect citation relationship between patents and trace back the origin and evolution of related prior technologies. Multi-stage citation information can clarify intricate technological linkage between enterprises and better reveal the corresponding basic patents information. To obtain more technological information, a longer Citation Chain should be considered [24]. To this end, through mining patent citation information, the study proposes the quantitative method for making a quantitatively measurement and trend analysis of technological linkage based on patent multi-stage citation relationship between enterprises.

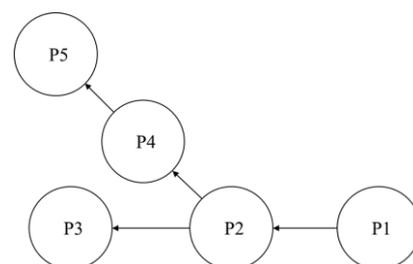


Fig. 1. Patent citation diagram.

### C. Multi-stage Citation

Due to universal existence of citation relationship between patents, a technical patent not only has single-stage technological linkage with patents of direct citation but also has indirect technological linkage with patents of multi-stage citations. With the increase of citation stages, the information of related patents associated with target patents will be more comprehensive. When patent citation stages are excessive, the further citation relationship away from target patent, the more interference information it will have [25]. Technological linkage of each stage patent citation between the patent and target patent will decrease gradually with the increase of citation stages. Therefore, the appropriate citation stage should be set by patent multi-stage citation relationship for measuring technological linkage.

The essence of the appropriate citation stage in fact is determined by the number of subjects with intermediary role that two subjects can establish technological linkage between them. Small-world Theory is a more mature theory about this field at the moment. Small-world Theory usually indicates that the relationship of two subjects can be established by no more than five other subjects, which means that you could meet any stranger by up to five people [26]. Small-world Theory was gradually applied to many fields and involved subjects further expanded from people to other types of subjects. Many social networks in the real world also fit the characteristics of small-world networks [27].

In recent years, some scholars have found that there is a small-world phenomenon in patent citation network. Patent citation network can indeed fit the characteristics of small world by studying its power-law connectivity distribution and exhibits preferential connectivity behavior [28]. Because the patent citation network is in accordance with the characteristics of small world network, it can establish patent citation linkage within five stages if there is a technological linkage between two patentees. Therefore, five-stage citation can be set to quantitatively measure technological linkage between enterprises. In addition, the study will also do further analysis and verification for the rationality of setting multi-stage citation stage to five-stage through subsequent research application.

### D. Measurement Method

Because patent citation number can reveal technological linkage between enterprises and technological linkage can be measured by patent multi-stage citation, patent multi-stage citation can be used to analyze and extract patent citation number. It should consider not only the number of patents related to one-stage citation but also two-stage citation and above stages citations. Certainly, different stages of patent citation information have different influences and contribution on technological linkage. With the increase of citation stages, each stage patent citation will gradually decrease the influence and contribution on technological linkage.

Considering different influences of each stage patent citation on technological linkage, the study needs to determine the weight of each stage patent citation. Capturing the technological importance of a patent, a discount factor was needed to down-weight the indirect citation relationship

with the patent, and the factor was set to 0.5 [29]. So each stage patent citation is given the corresponding weight decreasing by the rate of 0.5. On the basis of above study, multi-stage citation index (*MCI*) between patentee *i* and patentee *j* is constructed.

$$MCI_{i,j} = \sum_{k=1}^5 \frac{1}{2^{k-1}} P_{ik} \quad (1)$$

where:

*MCI<sub>i,j</sub>* represents the multi-stage citation index of patentee *i* citing patentee *j*

*k* represents the stage of patentee *i* citing patentee *j*

*P<sub>ik</sub>* represents the number of patents holds by patentee *i* at the citation stage *k*

Under normal conditions, multi-stage citation index (*MCI<sub>i,j</sub>*) of patentee *i* citing patentee *j* is not consistent with multi-stage citation index (*MCI<sub>j,i</sub>*) of patentee *j* citing patentee *i*. To directly reveal and measure technological linkage between patentees, technological linkage index (*TLI*) is constructed based on multi-stage citation index, the average of multi-stage citation index *MCI<sub>i,j</sub>* and *MCI<sub>j,i</sub>* of two patentees, for quantitatively measurement and trend analysis of the technological linkage between patentee *i* and patentee *j*.

$$TLI_{ij} = \frac{MCI_{i,j} + MCI_{j,i}}{2} \quad (2)$$

where:

*TLI<sub>ij</sub>* represents the technological linkage index between patentee *i* and patentee *j*

*MCI<sub>i,j</sub>* represents the multi-stage citation index of patentee *i* citing patentee *j*

*MCI<sub>j,i</sub>* represents the multi-stage citation index of patentee *j* citing patentee *i*

To calculate multi-stage citation index and technological linkage index of patentee *i* and patentee *j*, firstly, with the support of Thomson Innovation, some retrieve criteria like keywords are used to retrieve patents of patentee *i*. Then, citation information of each patent is gradually expanded to count the number of patents that has a citation relationship with patentee *j* within five stages. Similarly, retrieve patents of patentee *j* and count the number of patents that has a citation relationship with patentee *i* within five stages. Finally, based on citation stages and the corresponding number of patents, multi-stage citation index and technological linkage index of patentee *i* and patentee *j* can be calculated.

## IV. RESEARCH APPLICATION

### A. Sample Selection

Patent data are typical big data, one of the most comprehensive and continually updated resources of technological information. To avoid data overflow in calculation process, it is necessary to select a particular technical field and meet certain conditions in the selection of research samples. First, the chosen industry is a

representative important technical field and can reflect development characteristics of contemporary mainstream technology. Second, the chosen research samples should have influential typical enterprises, attach great importance to the effect of patent and have patent accumulation. Third, patent citation data should be complete and the required data can be obtained from the database for statistical analysis.

According to above criteria, take Apple Inc. (Hereafter, Apple) and Samsung Electronics (Hereafter, Samsung) as research samples based on patent data of smartphones in the United States. Smartphone can reflect development characteristics of contemporary mainstream technology involving in mobile communications, electronic information, software, and other technical fields. In recent years, Apple and Samsung have applied for and accumulated a large number of patents in smartphone field. In addition, the United States has more complete patent citation data for a long period and the patent citation data can be obtained from a public database as basic data for subsequent research.

*B. Data Mining*

Patent multi-stage citations can lead to explosive exponential growth of the number of involved patents. It is a challenge for analyzing multi-stage citations by massive patents. New patent analysis platforms such as Thomson Innovation and Patentics provide possibilities for analyzing patent multi-stage citations in recent years. Patent analysis platform of Thomson Innovation, provided by Thomson Reuters, not only covers patent data and scientific literatures from more than 90 countries (regions) but also has functions of accurate retrieval, text clustering, and patent citation analysis. It provides technological support for big data analysis of patents.

To measure technological linkage between Apple and Samsung, it is needed to filter out their patents in advance. With the support of Thomson Innovation, the study uses key words to retrieve patents in smartphone, and key words are determined by industrial patent analysis report [30]. Samples data of 2002 is selected as starting point, because Apple and Samsung launched the first smartphone respectively in 2007 and in 2003. Considering the update delay of patent statistics, samples data of 2014 is selected as cutoff point.

TABLE I: PATENT LITIGATIONS BETWEEN APPLE AND SAMSUNG

YEAR	NUMBER	
	NEW	ACCUMULATED
2002	0	0
2003	0	0
2004	0	0
2005	0	0
2006	0	0
2007	0	0
2008	0	0
2009	0	0
2010	0	0
2011	15	15
2012	9	24
2013	29	53
2014	0	53

TABLE II: PATENTS OF SAMSUNG CITING APPLE

YEAR \ STAGE	1	2	3	4	5
2002	0	1	2	4	0
2003	0	3	2	1	0
2004	0	3	3	2	1
2005	0	4	4	0	1
2006	0	6	9	3	0
2007	0	3	17	13	3
2008	1	11	17	5	2
2009	2	4	19	6	1
2010	4	9	15	7	0
2011	6	20	25	11	3
2012	14	9	18	10	4
2013	26	33	23	17	4
2014	73	142	141	37	0

Patents were screened and merged by patentee codes to extract patent litigations between Apple and Samsung. First, based on the selected patents, plaintiffs (PF) and defendants (DF) were used to extract litigation patents between Apple and Samsung. Then, the litigation patents were clarified and counted to obtain the number of patent litigations between them. Last, due to patent litigations were cumulative results on business and technology innovation over the years, based on the number of new patent litigations each year, the accumulated patent litigations were calculated in Table I.

Based on the filtered patents, it is needed to clarify the citation information that Samsung cites Apple. Firstly, patent citation analysis function of Thomson Innovation is used to analyze multi-stage citations of Samsung and expand citations step by step. Then, by retrieving citations stage by stage, each patent citation stage of Samsung citing Apple is counted. Finally, the number of patents corresponding to citation stage is calculated as basic data for measuring multi-stage citation index of Samsung citing Apple in Table II.

TABLE III: PATENTS OF APPLE CITING SAMSUNG

YEAR \ STAGE	1	2	3	4	5
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	1	1	0	0	0
2006	1	1	0	0	0
2007	1	1	0	0	0
2008	2	1	0	0	0
2009	1	5	1	0	0
2010	11	9	3	0	0
2011	8	22	4	0	0
2012	19	11	2	0	0
2013	61	37	2	1	0
2014	130	108	10	0	0

Similarly, multi-stage citation of Apple citing Samsung should be analyzed. Firstly, patent multi-stage citation of Apple is expanded step by step. Then, by retrieving from direct citation to each citation stage by stage, each patent citation stage of Apple citing Samsung is counted. Finally, the number of patents of Apple corresponding to each citation stage is calculated as basic data for measuring multi-stage citation index of Apple citing Samsung in Table III.

Statistics show that patent citations between Apple and Samsung are mainly distributed from one-stage citation to three-stage citation and the corresponding number of patents in five-stage citation is little. It shows that the patent citation relationship of one-stage citation to five-stage citation can be used to reveal technological linkage between Apple and Samsung if there do have. It also demonstrates the rationality of setting multi-stage citation stage for five-stage citation from the realistic aspects.

C. Data Analysis

Based on the above citation stage and the corresponding number of patents, multi-stage citation index is calculated respectively according to the proposed measurement method. Table IV shows that multi-stage citation index of Apple citing Samsung and Samsung citing Apple both rapid rise in nearly a decade. Especially since 2009, multi-stage citation indexes have explosive growth trends. Multi-stage citation index of Samsung citing Apple rises from 9.56 in 2009 to 183.88 in 2014, and multi-stage citation index of Apple citing Samsung correspondingly jumps from 3.75 to 186.50.

Technological linkage index between Apple and Samsung is calculated based on their multi-stage citation indexes in Table IV. Data analysis shows that technological linkage index increases in nearly a decade, an average annual growth rate of 58.3%. Especially since 2009, their technological linkage index began to rise sharply from 6.66 in 2009 to 185.19 in 2014, an average annual growth rate of 94.5%. Thus, technological linkage between Apple and Samsung tends to be close and it becomes the technical background of subsequent technical conflicts and patent litigations.

TABLE IV: MULTI-STAGE CITATION INDEX (MCI) AND TECHNOLOGICAL LINKAGE INDEX (TLI)

INDEX YEAR	MCI <sub>S,A</sub>	MCI <sub>A,S</sub>	TLI <sub>AS</sub>
2002	1.50	0.00	0.75
2003	2.13	0.00	1.06
2004	2.56	0.00	1.28
2005	3.06	1.50	2.28
2006	5.63	1.50	3.56
2007	7.56	1.50	4.53
2008	11.50	2.50	7.00
2009	9.56	3.75	6.66
2010	13.13	16.25	14.69
2011	23.81	20.00	21.91
2012	24.50	25.00	24.75
2013	50.63	80.13	65.38
2014	183.88	186.50	185.19

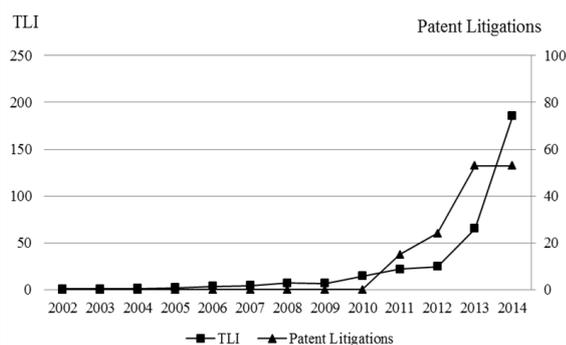


Fig. 2. Technological linkage index and patent litigations.

Under the background of complex technical systems, there is direct or indirect technological linkage between enterprises. Apple and Samsung have frequently accused each other of infringing smart phone patents since 2011 [31]. The result of time series analysis shows that technological linkage index between Apple and Samsung has increased rapidly and this trend keeps ahead of the emergence of patent litigations shown in Fig. 2. Therefore, technological linkage index could be applied to conduct patent early-warning and cope with potential patent litigations.

V. CONCLUSION

By analyzing the correlation between patent citation and technological linkage, technological linkage index is constructed based on patent multi-stage citation and a quantitative method of measuring technological linkage between enterprises is proposed. Taking Apple and Samsung as research samples, the measurement method is applied. The result of time series analysis shows that technological linkage index between them has increased rapidly, indicating that their technological linkage is becoming close, and this trend keeps ahead of the emergence of patent litigations. Therefore, the method could be applied to conduct early-warning for potential patent litigations in the process of technology innovation.

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