Technological Forecasting & Social Change 106 (2016) 1–10

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Technological convergence in standards for information and communication technologies

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ARTICLE INFO

Article history:
Received 29 March 2015
Received in revised form 3 February 2016
Accepted 4 February 2016
Available online 22 February 2016

Keywords:
Standards
Essential patents
Technological convergence
Entropy
Gravity
Social network analysis
Association rule analysis

ABSTRACT

In recent years, many technologies are converging with information and communication technology (ICT) while several of them are being standardized. In this study, we identify technological convergence in standards related to ICT. We apply the concepts of entropy and gravity, social network analysis, and association rule analysis to the International Patent Classification (IPC) codes of patents that have been declared as essential in the European Telecommunications Standards Institute. Results from our study show the technology fields that have played a major role in technological convergence in standards. In addition, other technology fields that are linked with these important technology fields are identified. During the period 2010–2014, services or facilities specially adapted for wireless communication networks had the highest entropy value and the highest binding force; and visible signaling systems were associated with several technology fields having a high potential to converge with other technology fields. Our findings can contribute to R&D planning for essential patents by suggesting potential technology fields that play a crucial role in technological convergence in related standards and other technological fields that are linked with these potential fields.

1. Introduction

An essential patent is mandatory when manufacturing products that must comply with certain standards (Bekkers et al., 2011). It ensures compatibility among products and has several advantages such as securing market dominance, preventing market entry by competitors, and creating new markets. With the increasing influence of international standards as a result of the World Trade Organization and Technical Barriers to Trade agreements, market power resulting from essential patents is also increasing. Consequently, increasing efforts are being made to obtain essential patents, thereby enabling patent-holders to gain a competitive advantage in the global market.

In recent years, the field of information and communication technology (ICT) has been rapidly standardized, and essential patents are now used as strategic tools in the area of technology trade. As various technologies converge with ICT, the scope of standardization has been expanded from ICT to other fields as well (Lee et al., 2015). Essential patents are being procured in various fields, and the importance of these patents cannot be overemphasized. To secure an essential patent, planning is necessary, beginning from the R&D stage. This requires an understanding of the direction of R&D (Ju et al., 2014), especially regarding the technological convergence of international standards.

Several previous studies have examined essential patents pertaining to policies, strategies, legal questions, economic efficiency, and valuations. Most of these investigations of essential patents have dealt with fair, reasonable, and non-discriminatory terms (FRAND) policies and patent hold-ups (Lemley, 2002, 2007; Lemley and Shapiro, 2013; Lerner and Tirole, 2013; Skitol, 2005). Bekkers et al. (2002) identified a positive relationship between the ownership of essential patents, the position of a firm in an alliance network, and market power. Bekkers et al. (2011) showed that technological value and involvement in the standardization process are the major determinants of the essentiality of a patent. Rysman and Simcoe (2008) observed that the number of citations of patents being declared as essential to implement is a greater indicator of value than patents having the same application year, citation year, and/or technological classification. Delcamp (2011) noted that the incorporation (or lack thereof) of an essential patent into a patent pool influences the value of the essential patent, as measured by the number of forward citations. Jeong and Yoon (2013) proposed a method of exploring promising essential patents based on standards and patent maps. However, no previous studies have investigated issues related to technological convergence of essential patents and standards.

In this study, we aim to identify technology fields that have played a major role in the technological convergence in ICT standards. For this, we use International Patent Classification (IPC) codes, which include the information on technology fields (Han and Sohn, 2015) and were related to patents declared in the European Telecommunications Standards Institute (ETSI). First, we apply the concept of entropy to IPC codes of essential patents to evaluate the potential of each IPC code to determine its convergence with other technological fields in relation to essential patents. Next, the concept of gravity and closeness

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http://dx.doi.org/10.1016/j.techfore.2016.02.003

centrality is employed to derive the binding force of IPC codes. A higher value of binding force of an IPC code implies that the corresponding IPC code intensively interacts with other IPC codes. To calculate the binding force of IPC codes, the closeness centrality of each IPC code is derived by conducting a social network analysis (SNA). Finally, an association rule analysis is performed to identify IPC codes that are linked with major IPC codes. The results of our study are expected to contribute to R&D planning for obtaining essential patents by providing information about IPC codes and their critical role in technological convergence in standards and IPC codes that are linked with these important IPC codes.

This paper is organized as follows. In Section 2, we review previous studies on technological convergence. In Section 3, we describe patent data and methodologies used in the present study. In Section 4, we apply the concepts of entropy and gravity, social network analysis, and association rule analysis to patent data. Lastly, we present the conclusions in Section 5.

2. Technological convergence

Technological convergence is defined as 'the process by which two hitherto different industrial sectors come to share a common knowledge and technological base' (Athreye and Keeble, 2000). It has occurred mainly in ICT fields covering "telecommunications, broadcasting, information technologies, and entertainment" (Borés et al., 2003).

In order to measure technological convergence, several studies have conducted co-occurrence network analysis for assignees, applicants, inventors, and IPC classification as well as patent citation network analysis by using patent information (Curran et al., 2010; Curran and Leker, 2011; Karvonen and Kässi, 2013; Jeong and Kwon, 2014). Curran et al. (2010) monitored convergence in scientific fields by using co-authorship, citation, and co-citation analysis of academic papers and monitored convergence in industrial fields by applying patent citation network analysis. Curran and Leker (2011) compared the convergence between nutraceuticals and cosmeceuticals fields, and ICT fields by using patent IPC co-classification analysis. Karvonen and Kässi (2013) investigated technological convergence in radiofrequency identification value chains by applying a patent citation analysis based on IPC codes.

In addition, several studies have developed indices of technological convergence such as the network, Jini, and entropy indices (Chen and Chang, 2012; Gauch and Blind, 2015), cross entropy updating method (Xing et al., 2011), Rao–Stirling index, and Herfindahl index (Gambardella and Torrisi, 1998). Gambardella and Torrisi (1998) applied the Herfindal index to patent data during 1984–1992 in order to measure technological diversification. Chen and Chang (2012) suggested an entropy-based patent technique for investigating the influences of related technological diversification and unrelated technological diversification on technological competences and firm performance. Gauch and Blind (2015) compared the technological convergence between technologies and standards by applying the entropy index to the technology classification of German patents and standards. Xing et al. (2011) suggested a method of measuring industry convergence by using the input–output table of 122 industrial sectors for the years 1997 and 2002. In their study, both static and dynamic industry convergences were considered by applying a cross-entropy technique of updating input–output tables. Moreover, Cho and Kim (2014) proposed a methodological index that includes the concepts of entropy and gravity to measure technological convergence and identify the interaction and attraction of each node.

Although the phenomenon of technological convergence is observed in several standards, technological convergence in standards and essential patents are yet to be identified. In this study, we investigate important technology fields in technological convergence in ICT standards by applying the concepts of entropy and gravity (Cho and Kim, 2014). In addition, we identify other technology fields that are associated with the important technology fields that have a high potential to be converged with other technology fields by using an association rule analysis.

3. Data and methods

In this study, we analyze patents that have been declared as essential in ETSI, which is a representative standards-setting organization related to the ICT industry. Although several ICT-related standards-setting organizations exist, we only analyze patents declared as essential in ETSI; data on patents declared as essential in other similar organizations possess several errors and lack patent numbers. The data used in this study were obtained from the intellectual property rights homepage of ETSI, which provides information received from declarants to the public. The data, as of June 2014, include the standard name; declarant's name and country; patent number; declaration, application, registration date; and IPC codes.

A total of 158,439 patents have been declared as essential in ETSI, but most of these patents have missing patent numbers or duplicate information. We selected patents filed in the USPTO,[1] EPO,[2] JPO,[3] KIPO,[4] and SIPO[5] because these patents accounted for more than 75% of the total essential patents. In addition, we removed those patents having incomplete patent numbers to arrive at a reduced total of 7590 patents. These patents were related to 969 standards and 917 seven-digit IPC codes. On an average, patents are associated with two standards. Altogether, out of 7590 patents, 3666 patents (48.30%) were linked to two or more standards, whereas 783 patents (10.32%) were connected to five or more standards. Information about these patents is listed in Table 1. The standards, on an average, are related to 20 patents. Information concerning standards that are related to several patents is listed in Table 2.

We classified the data on essential patents into four time categories to reflect the pattern of declaring patents in ETSI (See Fig. 1). The time categories include the following periods: 1997–2000, which is characterized by low declaration; 2001–2003, which is characterized by a slight increase in declaration; 2004–2009, which is characterized by declarations for 3rd generation partnership project (3GPP); and 2010–2014, which is characterized by declaration for 3GPP and long-term evolution (LTE).

The proportion of patent declarations from different countries are as follows: the United States (60.67%), Finland (9.22%), Korea (9.00%), Japan (6.57%), China (5.30%), and other countries (9.24%). The proportion of patents declared by different declarants are as follows: Motorola (22.75%), Qualcomm (16.69%), InterDigital (14.36%), NOKIA (9.22%), Samsung (4.34%), and others (32.64%). The main declarants for the different periods are shown in Table 3. Major declarants by period were as follows: Alcatel (1997–2000), Nokia (2001–2003), Qualcomm (2004–2009), and Motorola (2010–2014).

In this study, we rely on the concept of entropy, which represents the degree of technological diversification (Gemba and Kodama, 2001; Chen and Chang, 2012). It is used to evaluate the potential of each IPC code to determine its convergence with other technological fields as they relate to essential patents. The entropy of each IPC code is defined mathematically as follows:

$$Entropy_i = -\sum_j p_{j|i} \log_2\left(p_{j|i}\right) \quad (1)$$

where j is an IPC code that is different from IPC code i, and $p_{j|i}$ is the number of essential patents associated with both IPC i and IPC j divided by the total number of essential patents associated with IPC i. A higher

[1] United States Patents and Trademark Office.
[2] European Patent Office.
[3] Japan Patent Office.
[4] Korean Intellectual Property Office.
[5] State Intellectual Property Office of the People's Republic of China.