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The Convergence of Manufacturing and Service Technologies: A Patent Analysis Approach

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Abstract: Active technological convergence of manufacturing industries and service industries has been emerged as a core and essential phenomenon for recent business environment. Technology convergence has already been the basic force behind the both product innovation and service innovation, changing the ways in which firms interact with their customers. Despite the gravity, there has been limited approach to investigate the technological convergence of manufacturing technologies and service technologies from the empirical perspective. In response, this paper aims to investigate technological convergence between manufacturing technology and service technology using patent analysis. For this purpose, we define the service technology and manufacturing technology. Following on this, we analyze the USPC classification of those technologies to analyze the technological convergence. To investigate the dynamic change of convergence, 10-year-dyanamics are observed. As case studies, three industries which show high level of technological convergence of manufacturing and service - banking, healthcare, and education industries - are selected and analyzed in detail.

Keywords: *Technological convergence, manufacturing, service, technology, patent analysis*

1. Introduction

Traditionally, technology has been a central axis for the manufacturing industry. Quite naturally, development and application of a certain technology used to be the scope of product innovation. However, it is recently argued that the application of technology is not simply resorted to the manufacturing industry, but extended to the service industry (Quinn et al., 1988; Quinn and Paquett, 1990; Kang, 2006). Rather, technology triggers the active convergence of products and services, which has been considered as a core and essential phenomenon for many firms to gain profit (Bore´s et al., 2003). Technological convergence is behind this interesting phenomenon: manufacturing-service convergence. It has already been the basic force behind the both product and service innovation, changing the ways in which firms interact with their customers (Bitner, 2001; Auernhammer & Stabe, 2002; Geum et al., 2011). Therefore, technology convergence occupies a substantial part of product-service convergence, enabling the active associations of two different industries. This phenomenon can be proven by many practical cases of current business environment: companies such as IBM, General Electric, and Xerox have been gaining profits from technology-originated services since the middle of 1990s, exemplifying a shift from the manufacturing-oriented industry to convergence industries (Martinez et al., 2010; Geum et al., 2011). Despite the importance of technological convergence in manufacturing industries and service industries, there has been a limited approach to investigate this phenomenon from the empirical perspective.

The lack of data on investigating the technological convergence being a major impediment, previous research has been resorted to the theoretical investigation of technological convergence, focusing on the discussion of current phenomena of technological convergence (Blackman, 1998; Bores et al., 2003; Stehrer & Worz, 2003; Hacklin, 2008; Hacklin et al., 2009; Lee et al., 2010). Even though some empirical research has tried to investigate the technological convergence (Curran and Leker, 2009; Curran and Leker, 2011), these research have been limited to the manufacturing industries only, or industries with high technology such as information and communication technology (ICT) industry. Research on technological convergence between manufacturing technology and service technology still remains as void in the literature. However, given the substantial dynamics of manufacturing-service convergence, it is highly required to investigate the technological convergence between manufacturing and service. Addressing the limitation of previous research, our study aims to investigate the technological convergence between manufacturing technology and service technology using patent analysis. For this

purpose, we first define the service technology and corresponding manufacturing technology. As an analysis method, we employ patent classification analysis which has been regarded as an imperative means to identify technological convergence and proximity (Tijssen, 1992; Karvonen & Kässi, 2011; Geum et al, 2012). The remainder of this paper is organized as follows. The theoretical and methodological background is discussed in the Literature Review. Next, the research framework of this paper is suggested with overall process and detailed procedure. Next, the result of analysis is provided in the experiment section. Finally, contributions and limitations of this research are discussed in the conclusion.

2. Literature Review

Technological convergence: From the work of Rosenberg in 1963 (Rosenberg, 1963), technological convergence has been widely discussed in many literatures (Lee et al., 2010). Technological convergence is defined as the process by which different industries come to share similar technological bases (Rosenberg, 1963). It is prompted by the rise of some generic technologies that can be applied to a wealth of different products (Gambardella & Torrisi, 1998). Many different areas have been involved in the technological convergence, such as information and communications technology (ICT), robotics, medical industry, education industry, and banking industry. Especially, digital convergence, driven by ICT industry, involves analog–digital integration, wired–wireless integration, voice–data integration, and service–device integration, which result in convergence of networks and telecom-broadcasting convergence. Previous research on technological convergence is mainly concerned with the theoretical and practical investigation of technological convergence, including an ex ante definition of convergence or in-depth explanation of current phenomena of technological convergence (Stehrer & Worz, 2003; Hacklin, 2008; Hacklin et al., 2009; Lee et al., 2010). Extended from the theoretical investigation, some research have devoted to the managerial and policy implications which are incurred by the technological convergence (Blackman, 1998; Bores et al., 2003).

Patent analysis: Patents have long been used as a proxy measure for technological power (Grilliches, 1990). The basic method for patent analysis was the bibliometric analysis which simply counts the number of patents (Wartburg et al., 2005). Extended from the bibliometric analysis, some advanced techniques have been employed such as citation analysis and classification analysis. Patent citation analysis is based on the assumption that more frequently cited patents have higher technological power (Narin et al., 1987). Another important strength of citation analysis is to identify similarities between technologies (Lee et al., 2009). Since we can assume that cited patents are closely related to the original patents, patent citation can be considered as an important measure for technological convergence. Patent classification analysis is another important method to measure the similarity of two patents. Patent class refers to the way the examiners of a patent office arrange patent documents according to the technical features (Geum et al., 2012). Since the same document may be classified in several classes, the co-classification can be used to identify the relationships between technologies. To investigate the technological convergence, there have been a few studies to employ patent document. Since patent documents are an ample source for technical and commercial knowledge (Ernst, 2003), it has been actively used as a proxy for measuring technological convergence. Some research considers patents as a useful source to analyze the technology-driven convergence, demonstrating convergence between the pharmaceutical, the chemical, the nutrition and the cosmetics industries (Curran and Leker, 2009; Curran and Leker, 2011).

3. Research Framework

Figure 1: Overall process of this paper

Define the target technological field: First, as a preliminary work, we define the target technological field to be investigated. Technological fields that show a high level of technological convergence between manufacturing technology and service technology are selected as objects of this study.

Define the service technology: The next step is to define the service technology. Since the service technology has rarely been discussed and has not been defined systematically (Lee et al., 2011), defining the service technology is an important but hard task. In this study, we employ business method (BM) patents, categorized as a 705 class in United States Patent and Trademark Office (USPTO) database, as a service technology. A BM patent is defined as a method of administering, managing, or operating an enterprise or organization (Koda, 2000; Han et al., 2011). These BM patents describe the real world business models of manufacturing and the service field in electronic environments, thus have been utilized as sources of information that can explain the business process or method thoroughly (Han et al., 2011). Even if a BM patent deals with the process and methods of general businesses, its main application area has been the service industry. For this reason, literature has discussed the characteristics of BM patent as related to the service. The 705 class which deals with BM patents is defined as "data processing: financial, business practice, management, or cost/price determination."

Define the manufacturing technology: After defining the service technology, we define the corresponding manufacturing technology associated with the service technology. Since the scope of manufacturing technology is too broad and thus extremely hard to be organized, we redefine the manufacturing technology here as "*manufacturing technology associated with the service technology*." For this reason, we collect the associated manufacturing technology using backward citation of identified service technology. In other words, patents cited in the service technology (which is collected in the previous step) are considered as candidates for manufacturing technology. Among those patents, patents except 705 class are finally considered as manufacturing technology.

Examine the technological convergence using patent classification: To investigate the technological convergence of manufacturing technology and service technology, we employ classification analysis. Since the USPC system is one of the most representative classification systems for technologies (Lee et al., 2011), we use USPC classification system. The USPCs are collected and analyzed for manufacturing technologies which are cited by service technologies. Since those technologies can be considered as converging technologies themselves, analysis of USPCs of those manufacturing technologies can provide a significant implication for technological convergence.

Analyze the dynamic changes of convergence: To investigate the dynamics of technological convergence, we conduct the dynamic analysis by changing the target period. For each period, service patents and associated manufacturing patents are analyzed.

3. Case Study

Data: To illustrate the working of our approach, we conducted a case study of technological convergence. We used the USPTO database (http://uspto.gov/) to identify the convergence pattern between manufacturing technology and service technology. To compare the convergence pattern between different industries, three industries where technological convergence actively happens are selected: banking industry, healthcare industry, and education industry. These industries, in common, show a great level of technological convergence as well as technological advances. Technology plays a key role to the prosperity of those industries by enhancing the performance of products or services, diversifying the delivery modes, and enlarging the communication channel. Especially, technological innovation in banking (Morone and Berg, 1993), healthcare (Schoolerman, 1993), and education (Hill, 1999) has led the prosperity of service industry. To investigate the convergence of each industry, the first step is to download the patents for both service and manufacturing. To investigate the convergence dynamics, data was collected for three-year period: 2000-2003. 2004-2006, and 2007-2009. Since the technological convergence between service technology and manufacturing technology is a recent phenomenon, we investigate the 10-year dynamics. Table 1 shows the number of service and manufacturing patents for each industry.

Table 1: Number of patents for each industry

period	Banking Service patents	Mfg. patents	Healthcare Service patents	Mfg. patents	Education Service patents	Mfg. patents
2001-2003	42	348	47	439	14	179
2004-2006	55	400	62	604	17	174
2007-2009	100	672	123	878	28	216

4. Results

Banking industry: To investigate the technological characteristics of those converging technologies, we investigate the class information of manufacturing technology. Since the service technology is defined as the patents categorized as 705 class, we investigate the class information of manufacturing technology only. Since those manufacturing technologies have contributed to develop the service technology in each convergence industry, we call it converging technologies. Table 2, 3, and 4 describes the result of top 10 classes for manufacturing technologies for each period.

Table 2: Top 10 classes for manufacturing technology for banking: 2001-2003

Class	Class description	count
235/379	Banking systems	50
235/380	Credit or identification card systems	16
709/202	Processing agent	5
382/140	Reading micro data including an optical imager or reader	5
713/176	Authentication by digital signature representation or digital watermark	5
235/381	Systems controlled by data bearing records with vending	4
435/005	Measuring or testing process involving enzymes or micro-organisms; composition or test strip therefore; processes of forming such composition or test strip involving virus or bacteriophage	3
209/534	Sorting paper money	3
709/218	Remote data accessing using interconnected networks	3
380/030	Particular algorithmic function encoding : public key	3

Table 3: Top 10 classes for manufacturing technology for banking: 2004-2006

Class	Class description	Count
235/379	Banking systems	68
235/380	Credit or identification card systems	12
209/534	Sorting paper money	12
235/381	Systems controlled by data bearing records with vending	8
380/030	Particular algorithmic function encoding : public key	7
194/206	Control mechanism actuated by check, other than coin (e.g., slug, token, card, etc.), which is mutilated or retained by pliant currency	6
345/173	Display peripheral interface input device : touch panel	3
713/157	Multiple computer communication using cryptography: chain or hierarchical certificates	3
283/058	Banking: checks	3
709/229	Computer-to-computer session/connection establishing: network resources access controlling	3

Table 4: Top 10 classes for manufacturing technology for banking: 2007-2009

Class	Class description	count
235/379	Banking systems	117
235/380	Credit or identification card systems	21
209/534	Sorting paper money	10
235/381	Systems controlled by data bearing records with vending	6
235/487	Records	5
380/280	Key management control vector or tag	4
235/383	Systems controlled by data bearing records: mechanized store	4
380/277	Key management	4
382/100	Applications	4
382/115	Applications: personnel identification (e.g., biometrics)	4
709/219	Remote data accessing: accessing a remote server	4

Since the target industry is a banking industry, technologies such as banking system technologies show great dominance. For all period, the most cited classes are the same: class of 235/379 (banking system) and 235/380 (credit or identification card system) are the dominant manufacturing technology to trigger the technological convergence between products and services in the banking industry. However, the dynamic differences between periods are also easily identified. Reading, processing, and bearing technologies are importantly considered at the early 2000 whereas the management and application technologies are highly cited in the late 2000. For example, classes such as 380/280, 235/383, 380/277, 382/100, and 382/115 are recently related to the service technology, emphasizing the management and application of those service technologies.

Healthcare industry: Table 5, 6, and 7 shows the top 10 classes for manufacturing technology for healthcare industry. Similar to the banking industry, the dominant class for technological convergence is same for all period: 600/300 (Diagnostic testing). However, details are quite different for each period. In the first period of 2000-2003, basic technologies for healthcare system play a key role in the technological convergence. Therefore, measurement system, detailed technologies for diagnostic testing, and data recording system are identified as the key converging technologies. However, in the period of 2004-2006, technologies for specific purposes are found, such as communication for handicapped, sensor controls, and printed matter methods (such as fingerprint) are considered as an important class for technological convergence. Finally, in the period of 2007-2009, more advanced technologies are identified. In this period, technologies related to the application and commercialization of the healthcare industry are commonly identified, such as remote data assessing, emergence communication, electric computers and digital processing system, credit card system, and personal identification system. Based on these technologies, we can assume that the basic development of the healthcare industry are finalized, thus technologies related to the actual commercialization are developed in this period.

Table 5: Top 10 classes for manufacturing technology for healthcare: 2001-2003

Class	Class description	count
600/300	Diagnostic testing	39
433/024	Method of positioning or aligning teeth	9
600/301	Diagnostic testing via monitoring a plurality of physiological data, e.g., pulse and blood pressure	8
702/177	Measurement system: due time monitoring (e.g., medication clock, maintenance interval)	5
368/010	Time measuring systems or devices combined with disparate device	5
119/051.02	Feeding device: having electronic identification and feed control	4
706/045	knowledge processing system	4
600/483	Diagnostic testing: simultaneously detecting cardiovascular condition and diverse body condition	4
434/236	Psychology	3
600/513	Diagnostic testing: detecting heartbeat electric signal and diverse cardiovascular characteristic	3
235/375	Systems controlled by data bearing records	3

Table 6: Top 10 classes for manufacturing technology for healthcare: 2004-2006

Class	Class description	count
600/300	Diagnostic testing	48
600/301	Diagnostic testing via monitoring a plurality of physiological data, e.g., pulse and blood pressure	12
433/024	Method of positioning or aligning teeth	10
235/375	Systems controlled by data bearing records	7
434/112	Communication aids for the handicapped	6
604/067	Means for introducing or removing material from body for therapeutic purposes: sensor controls pump, motor, or pressure driven means	6
604/066	Means for introducing or removing material from body for therapeutic purposes: sensor responsive to body condition	4
283/067	Printed matter: method	4
600/483	Diagnostic testing: simultaneously detecting cardiovascular condition and diverse body condition	4
434/262	Anatomy, physiology, therapeutic treatment, or surgery relating to human being	3
235/380	Credit or identification card systems	3
709/202	Distributed data processing: processing agent	3

Table 7: Top 10 classes for manufacturing technology for healthcare: 2007-2009

Class	Class description	count
600/300	Diagnostic testing	66
600/301	Diagnostic testing via monitoring a plurality of physiological data, e.g., pulse and blood pressure	12
235/375	Systems controlled by data bearing records	11
709/217	Remote data accessing	7
379/045	Emergency or alarm communications: central office responsive to emergency call or alarm (e.g., "911", operator position display)	6
221/002	Processes with recorder, register, indicator, signal or exhibitor	6
709/200	Electrical computers and digital processing systems: multicomputer data transferring: miscellaneous	5
235/380	Credit or identification card systems	5
704/009	Linguistics: natural language	5
382/115	Personnel identification (e.g., biometrics)	4
709/203	Distributed data processing: client/server	4
706/045	Knowledge processing system	4
709/229	Network resources access controlling	4
600/523	Diagnostic testing: signal display or recording	4

Education industry: Finally, table 8, 9, and 10 shows the top 10 classes for manufacturing technology for education industry. Similar to the previous cases, the dominant class for technological convergence is almost same for all period: 434/350 (Response of plural examinees communicated to monitor or recorder by electrical signals), except the final period of 2007-2009. At the early period (2001-2003), basic technologies such as data processing, computer logic, and related means for data processing are considered as important manufacturing technologies for the education industry. In the middle period (2004-2006), technologies related to the advanced features are developed, such as computer graphics processing and operator interface for plural users or sites (e.g., network). Basic technologies for education are already developed for the first two periods (2001-2003 and 2004-2006), thus the application and advanced technologies are developed in the final period (2007-2009). For example, classes such as computer network monitoring and management, remote data accessing, and network resources controlling emerge as important classes for technological convergence. Especially, technologies with network show a great improvement, which reflects the practical circumstance of education industry. With the rise of mobile device, application of network management or remote control is considered as a key factor for education.

Table 8: Top 10 classes for manufacturing technology for education: 2001-2003

Class	Class description	count
434/350	Response of plural examinees communicated to monitor or recorder by electrical signals	10
600/300	Diagnostic testing	6
434/323	Cathode ray screen display included in examining means	5
434/322	Question or problem eliciting response	4
463/017	Including means for processing electronic data: lot match or lot combination (e.g., roulette, lottery, etc.)	3
434/236	Psychology	3
434/258	Physical education: developing or testing coordination	3
434/118	Computer logic, operation, or programming instruction	3
434/362	Electrical means for recording examinee's response	3
235/380	Credit or identification card systems	3

Table 9: Top 10 classes for manufacturing technology for education: 2004-2006

Class	Class description	count
434/350	Response of plural examinees communicated to monitor or recorder by electrical signals	10
434/322	Question or problem eliciting response	7
600/300	Diagnostic testing	6
709/217	Remote data accessing	3
434/262	Anatomy, physiology, therapeutic treatment, or surgery relating to human being	3
706/045	Knowledge processing system	3
514/725	Vitamin a compound or derivative	3
706/059	Knowledge processing system: creation or modification	2
345/440	Computer graphics processing: graph generating	2
434/118	Computer logic, operation, or programming instruction	2
715/733	Operator interface: for plural users or sites (e.g., network)	2
434/353	Grading of response form	2
706/023	Neural network: control	2
434/362	Electrical means for recording examinee's response	2
709/218	Remote data accessing using interconnected networks	2
273/243	Chance device controls amount or direction of movement of piece	2
715/205	Presentation processing of document: hypermedia	2

Table 10: Top 10 classes for manufacturing technology for education: 2007-2009

Class	Class description	count
434/322	Question or problem eliciting response	6
709/224	Computer network monitoring	4
709/223	Computer network managing	3
600/300	Diagnostic testing	3
709/217	Remote data accessing	3
434/350	Response of plural examinees communicated to monitor or recorder by electrical signals	3
709/229	Network resources access controlling	3
709/218	Remote data accessing using interconnected networks	2
434/107	Business or economics	2
715/735	Operator interface: configuration	2
700/291	Energy consumption or demand prediction or estimation	2
715/736	Network managing or monitoring status	2
455/446	Radiotelephone system: including cell planning or layout	2
703/011	Simulating nonelectrical device or system: biological or biochemical	2
434/236	Psychology	2

5. Conclusion

This study aims to investigate the technological convergence between manufacturing technology and service technology using patent classification analysis. For this purpose, we first define the service technology and corresponding manufacturing technology. Then, we employ patent classification analysis to investigate the technological convergence between manufacturing and service technologies. This paper contributes to the fields in twofold. First, the process of defining service technology and corresponding manufacturing technology is suggested using citation analysis. This can provide a fruitful chance for further research to investigate the relationship between manufacturing technologies and service technologies. Second, we suggest a method to investigate the technological convergence using classification analysis. Based on the definition of manufacturing technology associated with the service technology, we regard the class information as a proxy for investigating the technological convergence. Despite the contribution, however, this paper is still subject to some limitations. First, the definition of service technology requires further in-depth consideration. Even if BM patents are frequently applied to the service sector, it might be hard to consider all BM patents as service patents. Second, currently, we employ patent classification analysis as a means to investigate the technological convergence, since the target patents are derived based on the consideration of technological convergence process. However, more advanced techniques can be employed such as co-classification analysis.

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