A Preliminary Study of Technological Evolution: From the Perspective of the USPC Reclassification

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Abstract
This study aimed to investigate technological evolution from the perspective of the USPC reclassification. The results showed that there existed significant differences among five types of patents based on the USPC reclassification: Patents reclassified to Class 001, Patents with Inter-field Mobilised Codes, Patents with Intra-field Mobilised Codes, Patents with Abolished Codes, and Patents with Original Codes. Patents reclassified to Class 001, mostly related to the topic of "Data processing", performed better than other patents in novelty, linkage to science, technological complexity and innovative scope. Patents with Inter-field Mobilised Codes, related to the topics of "Data processing: measuring, calibrating, or testing" and "Optical communications", involved broader technology topics but had a low speed of innovation. Patents with Intra-field Mobilised Codes, mostly in the Computers & Communications and Drugs & Medical fields, tended to have little novelty and a small innovative scope. Patents with Abolished Codes and patents with Original Codes performed similarly – their values of patent indicators were low. It is suggested that future research extend the patent sample to subclasses or reclassified secondary USPCs in order to understand the technological evolution within a field in greater detail.

Conference Topic
Patent Analysis

Introduction
For patented inventions, their technological novelty is indicated through their U.S. Patent Classification (USPC) assigned by the U.S. Patent Office. However, patent technology codes are an underutilized data resource for research on technological capabilities, technological novelty, technological complexity and technological change (Strumsky, Lobo & van der Leeuw, 2012). In order to fill the research gap, this study takes a first step towards using the USPC reclassification to trace technological evolution in the past two decades. This section introduces basic information regarding the USPC reclassification and sets out the research aim for investigation.

Reclassification of the U.S. Patent Classification (USPC)
The USPC is a system for organizing all U.S. patent documents and many other technical documents into relatively small collections based on common subject matter (USPTO, 2012b, I-1). A combination of a *class* (i.e. a major component) and a *subclass* (i.e. a minor component) is used to indicate every subject matter division in the USPC system. Based on the technology used, each patent is assigned specific USPC technology code(s) to reflect their technological topics. In order to distinguish from other patent classification schemes, this study only focuses on the USPC classification.

According to the USPTO (2012b, I-15), "[r]eclassification is the process of changing classifications assigned to documents classified in the USPC." There are different types of

modification of the USPC codes originally assigned to patents, including: creating, abolishing or modifying USPC class schedules. The USPC reclassification is seen necessary to reflect the evolving technological changes. For instance, Strumsky, Lobo and van der Leeuw (2012) used patent technology codes to study technological change.

Five types of patents based on the USPC reclassification

In order to keep pace with knowledge, modification/updates of classes and subclasses have been made to the Dewey Decimal Classification (DDC) system regularly. For instance, one of the new features in the DDC (Edition 23) was an update of "004–006 Computer science (and parallel provisions in 025.04 Information storage and retrieval systems and 621.39 Computer engineering) to reflect current technical trends" (Online Computer Library Center, 2013, p.3). Therefore, this study aims to investigate technological evolution from the perspective of the USPC reclassification.

As a result of the USPC reclassification, technology codes assigned to patents were created, modified and abolished. To this end, this study divided the utility patents into the following five types, according to the types of the modification of their original USPC:

- **Class 001:** If the record for a patent is incomplete and contains no *Primary Classification*[1], or if the USPTO is unable to assign specific technology codes to the patent, then the patent is reclassified to class 001, titled "CLASSIFICATION UNDETERMINED" (USPTO, 2012b).
- **Intra-field Mobilised Code:** A patent's newly assigned codes are derived from the same technological field as its original codes. Six technological fields are discussed in this paper, which are defined by Jaffe, Trajtenberg and Romer (2005).
- **Inter-field Mobilised Code:** A patent's newly assigned codes are derived from a different technological field from the original codes.
- **Abolished Code:** A patent's original technology codes are abolished and reclassified to new codes based on the Current USPC.
- **Original Code:** A patent's original technology codes remain the same as the newly assigned codes based on the Current USPC.

Based on the aforementioned five types of the utility patents, this study conducts a 20-year trend analysis and compares their variances using six patent indicators.

Methodology

Patent bibliometrics

In this study, patent data were collected solely from the United States Patent and Trademark Office (USPTO) database, which is generally accepted and is accessible to the researchers. While there exist different categories of patents (e.g. plant patents, design patents, reissues, and continuations), this study, based on the recommendations offered by Narin (2000), collected the number of regular U.S. utility patents to keep the focus of the database on the key category of patents, which contributes to corporate technological strengths. In order to observe the recent development of patents with the USPC reclassification, this study covered the past two decades. This study used the following six patent indicators to analyse the differences between different types of USPC reclassified patents.

- **Technology Cycle Time (TCT)** indicates the speed of innovation of a patent. Companies with a shorter cycle time than their competitors in a given technology area

[1] According to the USPTO (2012b), U.S. PGPub documents classified in the USPC are assigned one, and only one, principal mandatory classification, known as the *Primary Classification* (PR).

may be advancing more quickly from prior technology to current technology (Narin, 2000).

- **Non-Patent Reference (NPR)** indicates a patent's linkage to science. Narin (2000) proposed that the average rate of citations to scientific papers can be used to indicate the patent's science linkage. Other scholars (Gupta, 2006; Lo, 2010) also regarded the average rate of citations to NPRs as the patents' linkage to science. Therefore, this study used the number of NPRs to indicate the strength of linkage between the patent and science.
- **Patent Reference** indicates the novelty of a patent. A higher number of patent references generally indicate a reduction of invention novelty.
- **USPC Count** indicates the breadth of the technology topics of a patent. If a patent has broader technology topics, it tends to belong to a more highly applicable technological field.
- **Patent Term Extension** indicates the technological complexity of a patent. If the term of a patent is extended, it usually means that the patent involves a higher level of technological complexity and therefore requires more time for examination (Pantros IP, 2013).
- **Patent Claim** indicates the innovative scope of a patent. Patents containing a higher number of claims have been shown to have a wider innovative scope (Pantros IP, 2013).

Data collection

The empirical data analysed in this study were collected from the USPTO Granted Patent Database. The sample was restricted to the utility patents granted from 1994 to 2013. According to the classification system of Jaffe, Trajtenberg and Romer (2005), the U.S. patents were classified into six technological fields: Chemical, Computers and Communications (C&C), Drugs and Medical (D&M), Electrical and Electronics (E&E), Mechanical, and Others. The six fields were used to form the basis for an analysis of the patents with USPC reclassified inter-field or intra-field. USPC patents (with/without reclassification) were identified through the use of XML to compare Original USPC (i.e. USPC codes before reclassification) and Current USPC (i.e. USPC codes after reclassification). USPC reclassified patents in the recent 20 years were collected. In order to conduct a comparison analysis, the sample was randomly selected from the patents with Original USPC Codes that had the same patent count with Current USPC Codes each year.

Descriptive statistics

Descriptive statistics provide brief summaries about the sample and the observations made. Such summaries may be either quantitative (i.e. summary statistics) or visual (i.e. clear graphs). These summaries may either form the basis of the initial description of the data as part of a further statistical analysis, or they may be sufficient in and of themselves for a particular investigation. This study used the Line Chart to analyse the trends of patent counts for all types of the USPC reclassified patents granted each year. For the characteristic differences of each type of the USPC reclassified patents, this study used One-Way ANOVA to conduct significant difference tests on the patents' TCT, NPR, Patent Reference, USPC Count, Patent Term Extended, and Patent Claim.

In statistics, one-way analysis of variance (abbreviated one-way ANOVA) is a technique used to compare means of three or more samples (using the F distribution). The ANOVA tests the null hypothesis that samples in two or more groups are drawn from populations with the same mean values. To do this, two estimates are made of the population variance. If the group means are drawn from populations with the same mean values, the variance between the group means should be lower than the variance of the samples, following the central limit

theorem. A higher ratio therefore implies that the samples were drawn from populations with different mean values (Wikipedia, 2014).

Results

Trends of the USPC reclassified patents

There were 3,342,076 U.S. utility patents granted between 1994 and 2013. Among them, 102,204 patents belonged to the main class in Primary USPC reclassification, which accounted for 3.1% of the total utility patents. Calculations of those patents by their types showed that patents with Abolished Codes accounted for the majority (42.53%), which was followed by patents with USPC Intra-field Mobilised Codes. Patents with Class 001 or Inter-field Mobilised Codes accounted for appropriately 15% respectively. See Table 1.

Table 1. Counts of patents with/without USPC reclassification.

Patent with/without USPC Reclassification	Count
Main class in Primary USPC Reclassification	**102,204(100%)**
A. Class 001	15,862(15.52%)
B. Abolished Code	43,465(42.53%)
C. Inter-field Mobilised Code	15,740(15.40%)
D. Intra-field Mobilised Code	27,137(26.55%)
E. Random selection of patents with Original Code	**102,204**

Observed from the yearly distribution of the patent counts of various types of USPC reclassification, it was found that the number of USPC reclassified patents tended to be higher in the early stage, which indicated that the USPC was revised in accordance with the evolution of technologies. From the perspective of the Current USPC, some Original USPC appeared inappropriate in today's context and therefore the count of the USPC reclassified patents has increased. Furthermore, when the advance of newer technologies adopted the Original USPC that was similar to the version of October 2014, the number of USPC reclassified patents decreased in tandem.

The number of patents with Abolished Codes dramatically increased prior to 2000 but dramatically dropped after 2001, meaning that the elimination of main class did not occur after 2001. The number of patents with USPC Intra-field Mobilised Codes was above 1,000 before 2009 and started to decrease after 2010, which was considered relevant to "Technological development for stability". The numbers of patents with USPC Inter-field Mobilised Codes and with Class 001 tended to decrease in 2010, which was also considered relevant to "Technological development for stability".

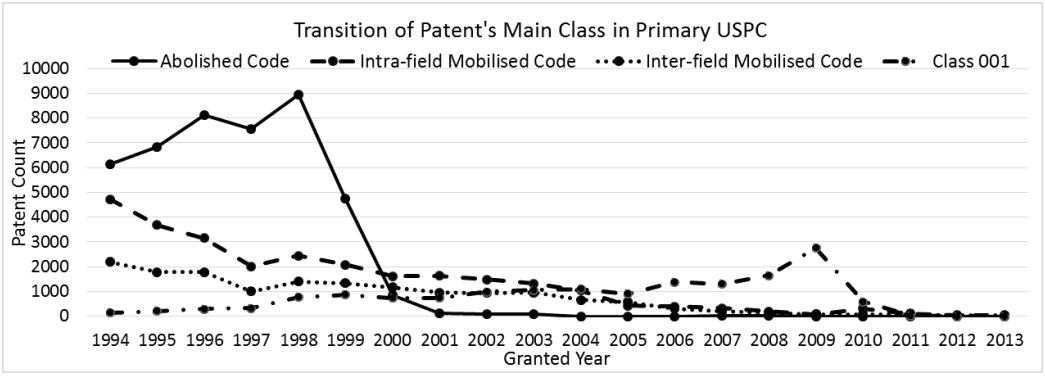

Figure 1. Transition of patents' main class in primary USPC.

Average citation rates were used to represent the quality of patents. This study calculated patents' average citation rates from 1994 to 2013, as shown in Figure 2. Due to the fact that the citation window of patents has become shorter each year, patents' average citation rates also decreased gradually. Figure 2 shows that the average citation rates of patents with Class 001 were the highest, which was followed by patents with USPC Inter-field/Intra-field Mobilised Codes. (They performed similarly in terms of their average cited rates recently.) The average citation rates of patents with Abolished Codes were higher than patents with Original Codes before 2002, but their average citation rates became the lowest among all types of patents.

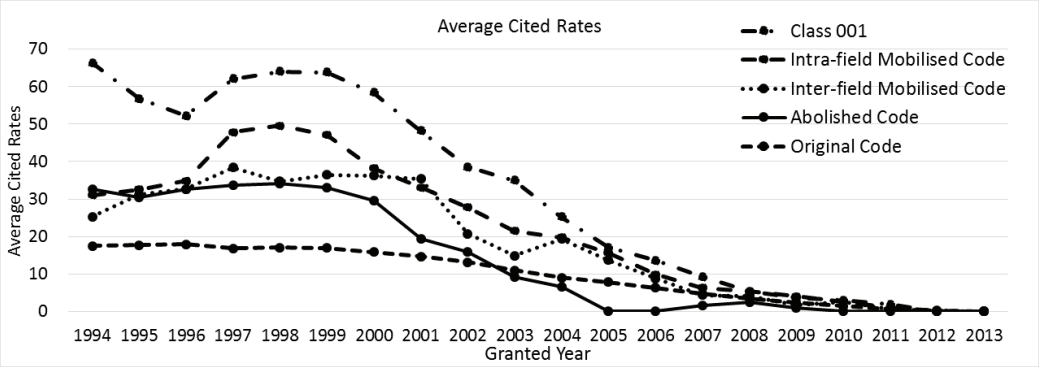

Figure 2. Average cited rates of USPC reclassified patents.

USPC reclassified patents among fields

Table 2. Patent counts in technological fields with USPC Reclassification.

	Patent Reclassified to Current Tech Field (%)						
Original Tech Field	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**Sum**
1. Chemical	3,303	62	276	816	684	252	**5,393**
	(61.25)	(1.15)	(5.12)	(15.13)	(12.68)	(4.67)	**(100)**
2. Computer & Communication	135	11,649	16	1,201	81	1,913	**14,995**
	(0.90)	(77.69)	(0.11)	(8.01)	(0.54)	(12.76)	**(100)**
3. Drugs & Medical	958	13	6,260	44	23	96	**7,394**
	(12.96)	(0.18)	(84.66)	(0.60)	(0.31)	(1.30)	**(100)**
4. Electrical & Electronic	155	1,627	49	1,187	124	1,273	**4,415**
	(3.51)	(36.85)	(1.11)	(26.89)	(2.81)	(28.83)	**(100)**
5. Mechanical	979	3,037	74	172	2,773	237	**7,272**
	(13.46)	(41.76)	(1.02)	(2.37)	(38.13)	(3.26)	**(100)**
6. Others	756	94	111	159	323	1,965	**3,408**
	(22.18)	(2.76)	(3.26)	(4.67)	(9.48)	(57.66)	**(100)**
Sum	**6,286**	**16,482**	**6,786**	**3,579**	**4,008**	**5,736**	**42,877**
	(14.66)	**(38.44)**	**(15.83)**	**(8.35)**	**(9.35)**	**(13.38)**	**(100)**

Table 2 displays the U.S. utility patents granted from 1994 to 2013 with USPC reclassified inter/intra-field. It was found, through calculating the variances in the patent count in the original and current technological fields that patents in C&C were reclassified most among all the USPC reclassified patents. Among the patents in original technological fields in C&C, 77.69% belonged to the main class in the Primary USPC Intra-field Mobilised Code, with 12.76% reclassified to Others. Another variance occurred to D&M. 84.66% of the patents belonged to the main class in Primary USPC Intra-field Mobilised Code, with 12.76%

reclassified to Chemical. The last variance occurred to Mechanical. 38.13% of the patents belonged to the main class in Primary USPC Intra-field Mobilised Code, with 41.76% reclassified to C&C. 36.85% of patents in E&E were reclassified to C&C, 28.83% reclassified to Others, and only 26.89% reclassified intra-field.

Statistical differences among five patent groups

Six one-way between subjects ANOVAs were conducted to compare the effect of patents with different USPC reclassification types on patent performance in TCT, NPR, Patent Reference, USPC Count, Patent Term Extended, and Patent Claim. There were all significant differences of indicators on patent performance at the $p<.001$ level for the five types of patents with/without USPC reclassification. Post hoc comparisons using the Dunnett T3 test (Dunnett, 1980) showed significant differences in the mean scores of the six indicators for the patents in different types of the USPC reclassification.

- **TCT Performance:** When the value of TCT is lower, it means a patent involves more fast-moving technologies and a patent tends to cite recently issued patents. Results derived from statistical tests showed: B. Abolished Code (5.7 year) < C. Inter-field Mobilised Code (6.3 year) < E. Original Code. (7.8 year). Short TCT of the patents with Abolished Codes indicated that patents of this kind involved the most fast-moving technologies and the speed of their technological innovation was clearly faster than patents with Inter-field Mobilised Codes. On the contrary, patents with Original Codes tended to be slower in term of their speed of the technological innovation.
- **NPR**: When the number of NPR is higher, it means the linkage of technology to science is stronger. Results derived from statistical tests showed: A. Class 001 (10.4), C. Inter-field Mobilised Code (11.7) & D. Intra-field Mobilised Code (10.7) > E. Original Code (7.9) & B. Abolished Code (5.5). When calculating Science Linkage, the more NPRs were, the stronger the linkage of technology to science was. Therefore, patents reclassified to Class 001, patents with Inter-field Mobilised Codes and Intra-field Mobilised Codes had stronger linkages to science, compared to patents with Original Codes and Abolished Codes.
- **Patent Reference:** When the number of Patent References is low, it indicates the novelty of technology is high. Results derived from statistical tests showed: B. Abolished Code (11.6) < E. patent with Original Code (14.2) < A. Class 001 (19.3) < C. Inter-field Mobilised Code (15.0). It can be inferred that the technological novelty of patents with Abolished Codes was much higher than that of patents with Original Codes. Clearly, the technological novelty of patents with Class 001 or with Inter-field Mobilised Codes tended to be low.
- **USPC Count:** Patents with more USPC counts indicate they involve broader technologies. Results derived from statistical tests showed: C. Inter-field Mobilised Code (5.2) > E. Original Code (4.4) > B. Abolished Code (3.9). The technology breadth of patents with Inter-field Mobilised Codes was the largest. The technology breadth of patents with Abolished Codes was smaller than that of patents with Original Codes.
- **Patent Term Extended:** When the term extension lasts longer, it indicates that a patent involves more complicated technologies. Results derived from statistical tests showed: A. Class 001 (416) > C. Inter-field Mobilised Code (341), D. Intra-field Mobilised Code (307) > E. patent with Original Code (300) > B. Abolished Code (168). It can be inferred that patents with Class 001 involved a higher level of technological complexity than patents with Inter/Intra-field Mobilised Codes. However, the term extension of patents with Abolished Codes was the shortest, indicating that they involved the lowest level of technological complexity.

- **Patent Claim:** When the value of patent claims is higher, it indicates that a patent's innovation scope is wider. Results derived from statistical tests showed: A. Class 001 (22.2) > C. Inter-field Mobilised Code (17.6) > B. Abolished Code (16.5), E. patent with Original Code (15.1). It can be inferred that the innovation scope of the patents with Class 001 or patents with Inter-field Mobilised Codes was obviously wider than that of patents with Abolished Codes and patents with Original Codes.

Technological evolution from the USPC reclassification perspective

This study divided patents granted in the last two decades into two groups, i.e. 1994-2003 and 2004-2013. Observations were made from the evolution of USPC codes as a result of the USPC reclassification. Table 3 shows the USPC with top three most patent counts in the two periods respectively. If a patent was reclassified to Class 001, it meant that there was no specific technology code suitable for the patent. To some extent, it indicated that the patent belonged to emerging technologies or original USPC codes assigned were not appropriate for the patent, which required a new code. Table 3 shows in both periods, the majority of patents reclassified to Class 001 came from Class 707 in the C&C field. This phenomenon reflected the technological uncertainty of patents originally assigned to Class 707, the majority of which were therefore reclassified to Class 001. In the first period, there were 19.7% of patents originally assigned to Class 395 and then reclassified to Class 001. However, due to the abolition of Class 395, their technological description remained unknown.

Table 3. Patents with USPC reclassified in the Class 001 and the Abolished Code groups.

USPC	1994-2003	2004-2013	USPC Description
Original class reclassified to 001 (Class 001)			
707	4,884 (79.6%)	9,684 (99.5%)	Data processing: database and file management or data structures
395	1,206 (19.7%)	0 (0.0%)	(Abolished)
364	19 (0.3%)	0 (0.0%)	(Abolished)
705	0 (0.0%)	18 (0.2%)	Data processing: financial, business practice, management, or cost/price determination
714	0 (0.0%)	7 (0.1%)	Error detection/correction and fault detection/recovery
Current class of original abolished (Abolished Code)			
438	4,895 (11.3%)	1 (4.3%)	Semiconductor device manufacturing: process
714	4,179 (9.6%)	0 (0.0%)	Error detection/correction and fault detection/recovery
710	3,448 (7.9%)	0 (0.0%)	Electrical computers and digital data processing systems: input/output
703	1,314 (3.0%)	2 (8.7%)	Data processing: structural design, modeling, simulation, and emulation
477	2 (0.0%)	2 (8.7%)	Interrelated power delivery controls, including engine control

For patents with Abolished Codes, it meant that their original codes did not align with the technological evolution any more, and thus the codes were abolished and the patents were reclassified to new codes. As shown in Table 3, the majority of patents with Abolished Codes

occurred in the first period, with only 23 patents of this kind in the second period. In the first period, the majority of patents whose original USPC codes were abolished were reclassified to Classes 438 (11.3%), 714 (9.6%), 710 (7.9%), and 703 (3.0%). Patents reclassified to Class 438 were about semiconductor device manufacturing in the E&E field, and those reclassified to Classes 714, 710 and 703 focused on technologies in the C&C field. Based on the patents reclassified to Class 001 and with Abolished Codes, it was found that the USPC reclassification tended to occur in the C&C and E&E fields in the first period and in the C&C field in the second period.

According to Table 2, patents with Intra-field Mobilised Codes mainly occurred in the C&C (77.69%) and D&M (84.66%) fields. Therefore, Table 4 focuses on the top three Intra-field Mobilised Codes, and Figures 3 and 4 present the flow of the patents between USPCs in the two fields, where the flow occurred more than ten patents. In the C&C field, the USPC reclassification in both periods mainly occurred from Class 345 to Class 715 (28.8% and 26.6%), which was about "Operator interface processing" and from Class 369 to Class 720 (11.8% and 5.1%), which was about "Information storage or retrieval". Additionally, in the first period, there remained 10.2% of patents reclassified from Class 707 to Class 715, which was also about "Operator interface processing". In the second period, there remained 6.2% of patents reclassified from Class 707 to Class 709, which was about "Multicomputer data transferring". In the D&M field, the USPC reclassification occurred from Class 128 to Class 600 (68.0%) which was about "Surgery" in the first period, and from Class 514 to Class 424 (76.4%) which was about "Drug, bio-affecting and body treating compositions" in the second period. The code mobilisation within the same field occurred due to the extension of the original USPC.

Table 4. USPC reclassification: the Intra-field Mobilised Code group.

Main Class of USPC		Count	
Original	**Current**	**1994-2003**	**2004-2013**
Intra-field Mobilised Code in C&C			
345	**715**	2,793(28.8%)	516(26.6%)
369	**720**	1,144(11.8%)	98(5.1%)
707	**715**	991(10.2%)	96(5.0%)
707	**709**	68(0.7%)	120(6.2%)
Intra-field Mobilised Code in D&M			
128	**600**	3,909(68.0%)	4(0.8%)
514	**424**	626(10.9%)	389(76.4)
606	**623**	227(3.9%)	18(3.5%)
514	**435**	17(0.3%)	26(5.1%)
435	**424**	49(0.9%)	21(4.1%)

345: Computer graphics processing and selective visual display systems; **369:** Dynamic information storage or retrieval; **707:** Data processing: database and file management or data structures; **709:** Electrical computers and digital processing systems: multicomputer data transferring; **715:** Data processing: presentation processing of document, operator interface processing, and screen saver display processing; **720:** Dynamic optical information storage or retrieval

128: Surgery; **424:** Drug, bio-affecting and body treating compositions; **435:** Chemistry: molecular biology and microbiology; **514:** Drug, bio-affecting and body treating compositions (an integral part of Class 424); **600:** Surgery (an integral part of Class 128); **606:** Surgery (an integral part of Class 128); **623:** Prosthesis (i.e., artificial body members), parts thereof, or aids and accessories therefor

Observed from the patents with Intra-field Mobilised Codes, it showed that in the C&C field those patents were related to "Operator interface processing" in both periods. In the D&M field those patents were related to "Surgery" in the first period and "Drug, bio-affecting and body treating compositions" in the second period. Observed from the patents with Inter-field Mobilised Codes, it showed that the USPC codes were mainly mobilised from the E&E and Mechanical fields to the C&C field, as seen in Table 2. Statistics on the top three USPC mobilisation were detailed in Table 5, and Figures 5 and 6 present the flow of the patents between USPCs among the three fields, where the flow occurred more than ten patents. In the first period, the USPC reclassification mainly occurred from the E&E field to the C&C field, for example from Class 348 to Class 375 (64.6%) about "Pulse or digital communications", and from Class 346 to Class 374 (20.6%) about "Thermal measuring and testing". However, in the second period, inter-field code mobilisation was not obvious. It can be seen that the topics of technological evolution were different in the two periods.

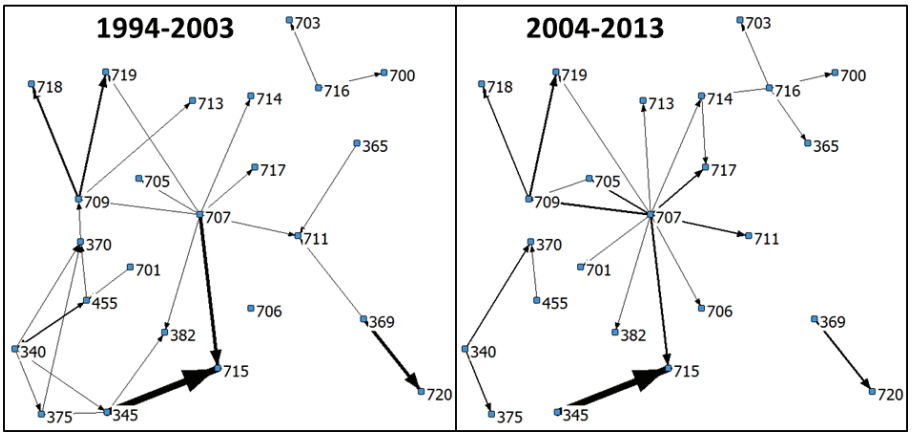

Figure 3. The flow of patents between USPCs in the C&C field.

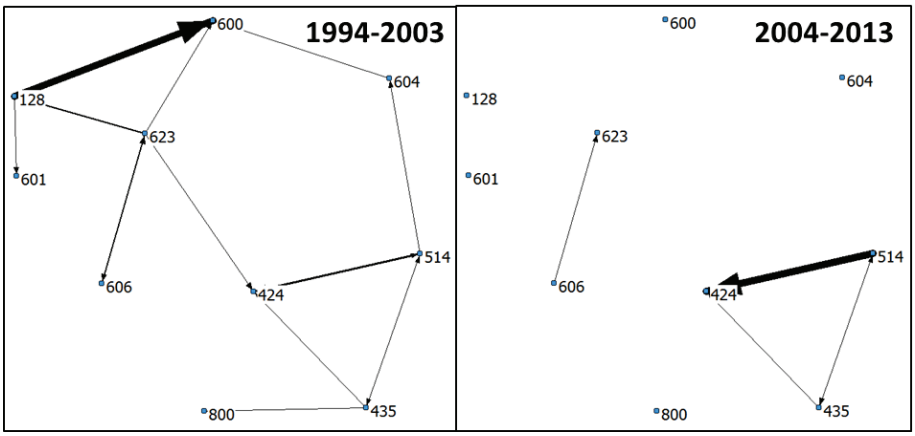

Figure 4. The flow of patents between USPCs in the D&M field.

Looking at patents with Inter-field Mobilised Codes from the Mechanical field to the C&C field, the flow of the mobilisation tended to occur from Class 359 to Class 398 (94.8% and 37.8%) about "Optical communications" in both periods.

Observed from the patents with Inter-field Mobilised Codes, it showed that patents with the USPC reclassification from the E&E field to the C&C field focused on the technology topics of "Pulse or digital communications" and "Thermal measuring and testing" in the first period, but focused on "Data processing: measuring, calibrating, or testing" in the second period. As

for patents with USPC reclassification from the Mechanical field to the C&C field, they tended to be related to "Optical communications" in both periods.

Table 5. USPC reclassification: the Inter-field Mobilised Code group.

Main Class of USPC		Count	
Original	**Current**	**1994-2003**	**2004-2013**
Inter-field Mobilised Code from E&E to C&C			
348	**375**	989(64.6%)	2(2.1%)
346	**374**	316(20.6%)	0(0.0%)
257	**365**	21(1.4%)	3(3.2%)
257: Active solid-state devices (e.g., transistors, solid-state diodes); **346:** Recorders; **348:** Television; **365:** Static information storage and retrieval; **374:** Thermal measuring and testing; **375:** Pulse or digital communications			
Inter-field Mobilised Code from Mechanical to C&C			
359	**398**	2,837(94.8%)	17(37.8%)
235	**705**	22(0.7%)	0(0.0%)
359	**369**	15(0.5%)	0(0.0%)
235: Registers; **359:** Optical: systems and elements; **369:** Dynamic information storage or retrieval; **398:** Optical communications; **705:** Data processing: financial, business practice, management, or cost/price determination			

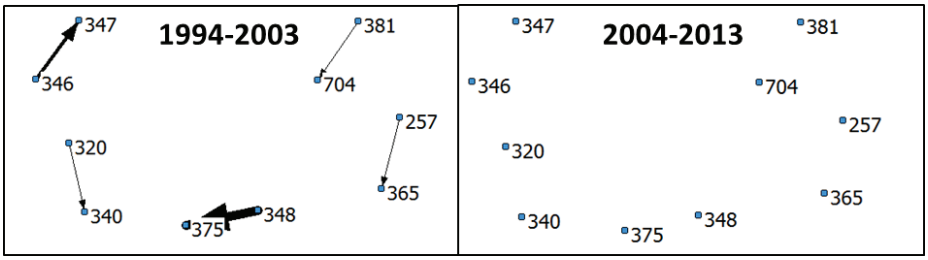

Figure 5. The flow of patents between USPCs from the E&E to the C&C field.

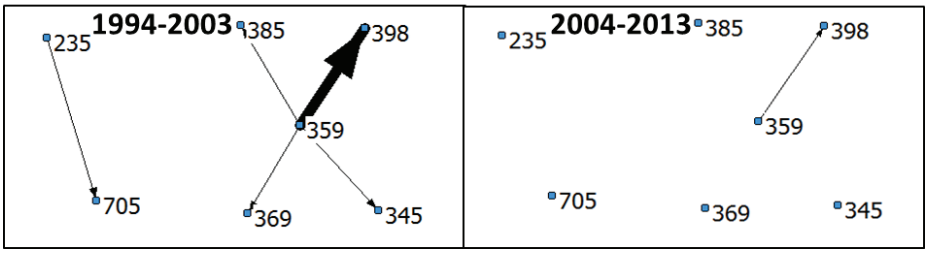

Figure 6. The flow of patents between USPCs from the Mechanical field to the C&C field.

Conclusion and Discussion

The majority of USPC reclassified patents occurring prior to 2000 and in the Computer & Communications field

With the advance of new technologies, the USPC system is updated quarterly in March, June, September and December (USPTO, 2012a). Newly granted patents were assigned with technology codes derived from the latest version of the USPC. Accordingly, their original USPC technology codes were less likely to be reclassified. This study found that the number of patents with main class in primary USPC reclassification hit the highest prior to 2000 and began to decrease every year after 2001. Patents with Abolished Codes accounted for 42.53%

and the majority of the patents were granted prior to 2000. Next were patents with Intra-field Mobilised Codes, which accounted for 26.55%. For the average citation rates every year, patents reclassified to Class 001 were ranked as top, and patents with Original Codes were ranked as bottom. Due to the USPC reclassification, patents with Intra-field Mobilised Codes occurred most frequently in the C&C field, and patents with Inter-field Mobilised Codes occurred most frequently from the Mechanical field to the C&C field.

USPC reclassified patents showing significant differences in patent indicators

Six one-way between subjects ANOVAs were conducted to compare the effects of patents in different groups by the USPC reclassification, according to their patent performance in TCT, NPR, Patent Reference, USPC Count, Patent Term Extended, and Patent Claim. Different results were obtained for the different types of patents, as below.

- **Patents reclassified to Class 001:** They got higher values of NPR, Patent Reference, Patent Term Extended and Claims Count, indicating that they performed better than other patents (whether they were reclassified or not) in novelty, linkage to science, technological complexity and innovative scope. Therefore, USPTO needs to re-examine appropriate USPC technology codes for them or assign appropriate codes to them when the new codes are created.
- **Patents with Inter-field Mobilised Code**: Compared to patents reclassified to Class 001, they got more USPC counts and longer TCT, indicating that they involved broader technology topics and therefore their codes assigned were mobilised inter-field. Their longer TCT meant that their technology had a low speed of innovation.
- **Patents with Intra-field Mobilised Code**: They tended to have low novelty and a small innovative scope; therefore, their codes assigned were mobilised intra-field.
- **Patents with Abolished Code**: They were mainly granted prior to 2000. Patens of this type and patents with Original Code performed similarly – their values of patent indicators were low.

Technological evolution from the perspective of the USPC reclassification

This study investigated different groups of patents based on the USPC reclassification. Statistical analysis was conducted on the technology codes and comparisons were made between two ten-year periods. Based on the results derived, different types of technological evolution were found.

- **Emerging technologies in Class 001:** In both periods, a large portion of the emerging technologies were about "Data processing: database and file management or data structures" in the C&C field. This reflects the uncertainty of the development of the emerging technology, and thus patents originally assigned to Class 707 needed to be continually redefined and reassigned with specific technology codes.
- **Technological transition in Inter-field Mobilised Code:** Technologies from the E&E and Mechanical fields tended to be transferred and applied to the C&C field. Technologies about "Television" in E&E was transferred and applied to "Pulse or digital communications" in the C&C field. Technologies about "Recorders" in E&E were also transferred and applied to "Thermal measuring and testing" in the C&C field. In the Mechanical field, technologies related to "Optical: systems and elements" were transferred and applied to "Optical communications" in the C&C field in both periods.
- **Technological cohesion or spread in Intra-field Mobilised Code:** Technologies in this group tended to focus on the C&C and D&M fields. In the C&C field, technologies related to "Computer graphics processing and selective visual display systems" and "Data processing: database and file management or data structures" were combined together and applied to "Data processing: presentation processing of document, operator

interface processing, and screen saver display processing". Figure 3 shows not only technological cohesion but also technological spread. For example, technologies about "Data processing: database and file management or data structures (Class 707)" were spread to other technologies in different fields. Patents with original USPC 707 were reclassified to eight different codes in the first period, and then spread to other ten codes in the second period.

- **Technological substitution in Abolished Code:** Technologies in this group tended to occur in the first period. This indicates that the USPC scheme in the second period has been adapted to the recent technological development. In the first period, technologies of this kind mainly occurred to those related to "Semiconductor device manufacturing", which were reclassified to Class 438 with their original USPC 437 being abolished. Technologies related to "Error detection/correction and fault detection/recovery" which were reclassified to Class 714 with their original USPC 371 and 395 being abolished. This indicates that the mature technologies have caused the biggest impact on the USPC scheme.

It is suggested that future research extend the sample to patents with reclassified USPC subclasses or patents with reclassified secondary USPCs in order to observe recent intra-field technological changes in great detail. The Radical (Leaps) Innovation of technologies is only applied to the minority, but the majority of patents are embedded with Incremental Innovation. Incremental Innovation tends to occur inside fields. Through extending the patent sample to subclasses or secondary of USPC, it helps understand more technological evolution within a field. Besides, understanding the establishment, abolishment and movement of technology codes recorded in the Classification Orders Archival Report (USPTO, 2013) helps understand the trajectories of technological evolution more detail. Although this study focused on the reclassification of USPC schemes, it is argued that the same research model could be applied to trace the changes in the class schemes in International Patent Classification (IPC) or Cooperative Patent Classification (CPC) and changes in classification codes in their counterpart patents.

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