Patents, Technical Standards and Firms' Global Social Network

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Contents

Chapter1. Introduction

Patents, in general, are a popular academic research topic, especially with economists. Early work focused on how well patents protect an innovation in terms of time to imitate or on patent output in particular industries (e.g., Mansfield, Schwartz, and Wagner, 1981; Scherer, 1965). Some early studies of productivity established that patents are associated with added firm value (Griliches, 1995). Other studies have found that patents or patent citations can also increase the market value of a firm (Hall et al. 2005 and Hanel, 2006). Patent statistics are also now commonly utilized in other disciplines, such as finance and strategic management. (Martin, 2009). On the other hand, patents covering technical standards have taken on increasing importance in global trade, business negotiations and relationships among firms. (Contreras, 2016). Recent studies have shown that technology standards contribute strongly to economic growth and development (Ernst et al. 2014). Technological standards are a central component of the modern network economy and can have significant welfare effects. As a consequence, mechanisms behind standard development and implementation represent a major policy concern. (Lerner, 2016).

While there are many patent classifications developed by International patent classification (IPC), the European Classification system (ECLA), Japanese File Index (F-Index), etc.(Varma, 2014), some literature focus on particular field of the patents, such as the patents of business method software. In 1998, the US Court of Appeals of the Federal Circuit (CAFC) issued a decision that is widely viewed as having opened the door to widespread business method patenting, especially financial methods, in the State Street Bank and Trust vs Signature Financial Corporation case (Hall, 2009). Since then, there has existed explosion in business method patent applications and grants around the world.

In this paper, I pay more attention on some important topics which refer to the business method patents and the technology standards and attempt to employ social network analysis on these empirical studies.

1.1 Developments of Software Patenting

As legal changes in many countries including the United States and Japan, have made it easier to obtain patents on inventions. Recently, information technology and communications (ITC) patents, particularly, software patents have grown rapidly in number. The topic about the software have attracted many scholars. Hall and MacGarvie (2010) investigated the value creation or destruction associated with the introduction of software patents in the United States, by analyzing the stock market's reaction to legal decisions expending the patentability of software, and examining the relationship between Tobin' q and firms' software patent and patent citation stocks. As the same as did in Hall and MacGarvie (2010) for the case of the United States, Yamauchi and Onishi (2012) focused on Japanese intellectual property (IP) policy reform, especially on the revision of examination criteria in computer programs, and examined the impact of the expansion of the scope of software patent protection on R&D and patenting activities of firms. Furthermore, some studies such as Wen et al. (2013) paid attention on software patent strategy, i.e., patent commons, raised by software companies, and its relationship with the entry rate of start–up software firms.

Among the software, the business method software is especially developing rapidly. Business method software has increasingly become an important driver of commerce in the digital age.[1]

Given its global significance, inventors and developers of such software have sought to patent it to protect their financial interests. Two court decisions, i.e., the case of State Street Bank and Trust Co. vs. Signature Financial Group, Inc., and AT&T Corp. vs. Excel Communications, Inc. in the 1990s are widely viewed as having opened the door to a flood of business method software patents at the US Patent and Trademark Office (USPTO), have also impacted other patent offices around the world (Hall ,2009). The State Street Bank decision on the patentability of business method triggered an increase in the number of business method patents issued by the USPTO (Hunt ,2010). Before

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[1] Business method software deal with a broad spectrum of data processing applications.

the State Street Bank decision, the US Class 705 patents granted in a year since 1992 was 249; that number increased to 489 in 1998, and to 5902 in 2013.[2, 3]

In business method patents, those from financial firms and providers of consumer payment services account for less than one-tenth of the total (Hunt, 2010). However, a number of financial institutions, especially some big banks, have accumulated a dozen or more of these patents and a significant number of applications are pending. As indicated by La Belle and Schooner (2014), to the extent that the patent process involves a significant investment of resources, larger institutions (e.g., big banks) would be more likely to have significant patent activity. Given that large institutions are often industry leaders, if there has been a change in attitude toward the benefits of patents in the financial services industry, one might expect to see a change in larger financial institutions before smaller firms. Finally, and more generally, the political and economic power of large financial institutions means that their interest in patents may have a significant impact on patent practice and policy.

Although many scholars, both legal and economic, provide a fairly thorough analysis of individual cases and its implications, there is relatively little literature on the impact of business method patents based on a more broad-based or empirical approaches. Some literature has focused on the role of the business method patents in encouraging innovation and the consequences of low patent quality for the performance of the system (Wagner 2008, Hall et al. 2009 and Hunt 2010). Hall (2009) argued that, allowing business method patents will cause an increase in the patenting of business methods. This increase in patenting, especially one that introduces patents of less certain quality, comes at an increase in litigation, raising the costs of the system as a whole. At the same time, Hunt (2010) constructed new indicators of R&D to see if the business method patents increase innovation in US financial services sector, and pointed out that there does not appear to be an obvious effect from business method patents on the sector's R&D intensity.

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[2] U.S. Patent & Trademark Office, USPTO Patent Statistics, Patent Counts by Class by Year Report.

[3] Although the US Supreme Court decision in Alice Corporation Pty. Ltd. v. CLS Bank International, decided on 19 June 2014, has had a significant impact in the field of "software patents", particularly those covering financial and business related processes, it is still observed that significant numbers of the business method patents continue to be applied for in the USPTO or jurisdictions outside the US.

1.2 Developments of Technology Standards and Standard Setting Organizations

On the other hand, industry institutions play important roles in ensuring the protection of intellectual property protection and maintaining a level competitive field for their members. Certifications or validations by industry organizations can also impact firms' conduct (Goel and Nelson, 2019), whereas standards lower transactions costs by improving coordination and eliminating unnecessary duplication (Kindleberger, 1983). Among the numerous different industry institutions, Standard Setting Organizations (SSOs) or Standard Developing Organizations (SDOs) are responsible for international technology standards (https://definitions.uslegal.com/s/standard-setting-organization-sso/). There are two broad classes of SSOs – those dealing with quality standards (e.g., ISO 9000), and those dealing with interoperability (e.g., MP3 format or USB). Examples of SSOs include The International Organization for Standardization (ISO), The International Electrotechnical Commission (IEC), The International Telecommunication Union (ITU), etc. (https://www.electronicdesign.com/communications/10-standards-organizations-affect-you-whether-you-know-it-or-not). Without standards, it would be nearly impossible for firms to exploit economies of scale, as there would be barriers to mass production and mass communication.

While there are multiple ways to categorize these institutions, three categories are often utilized, i.e., (1) formally recognized standards bodies; (2) quasi-formal standards bodies and (3) standardization consortia. Whatever the category, it is usually stakeholders that work together on a voluntary basis to produce standards (Contreras, 2019). Thus, SSO incorporate all variants of groups that develop standards, including Special Interest Groups (SIGs), standards-development organizations, consortia, and other entities.

Technology standards can prescribe methods which are protected by patents. If a standard cannot be implemented without infringing a patent, this patent is called a standard essential patent (SEP). Patented methods may also be useful, but not essential, for implementing a standard. A patented method is called commercially essential if they are considered to be indispensable in order to make any product that complies with the standard, or if for implementing a standard, existing alternative methods are technologically inferior or not accessible on commercially viable terms (Bekkers and Martinelli 2012, and Baron and Pohlmann 2015).

Some recent literature focused on the values or knowledge positions of the SEPs. Baron and Pohlmann (2015) argued that, many patented inventions are made in the process of standard development (e.g. address a specific need or problem in a standardized technology), but not included in the standard. This is because many different firms make contributions to standards under development, and contributions are subject to vote by SSO members. In their recent study, Bekkers and Martinelli (2012) indicated that claims of essentiality are the results of strategic behavior of the patent's owner instead of the actual technical relevance.

What's more, every SSO needs a set of rules that address the intellectual property rights (IPR) in order to ensure that the SSO owns its work product upon completion, and to decrease the risk, or mitigate the hold-up problem that its completed standards will encounter IPR-based impediments to broad implementation (Farrell et al. 2007, Bekkers and Updegrove 2013).

Membership in SSOs is voluntary and a firm can potentially belong to several SSOs (Baron and Pohlmann, 2013). This affects how the firm/industry grows and technological change takes place. However, little is formally known about the drivers of membership in SSOs and this paper attempts to contribute in this regard. What induces firms to join particular SSOs? Is it the market power or IPR rules? To motivate this thought, one could think of the electric vehicle industry as an example. Given the newness of the technology with firms at different stages of development, widely accepted technical standards do not seem to have developed. A firm might decide between joining future SSOs dealing with battery life, battery size or standardization of charging outlets (or might join them all). Any decision will have implications for firm/industry growth. However, will early entrants (e.g., Tesla in the United States) have an interest in joining SSOs when they have market power not only with regard to market share but also with regard to the network of charging stations?

These rules that are also called as bylaws or constitutions etc. are often related to the procedures for setting standards and related to the policies applicable to standard essential patents (SEPs) (Barron and Spulber, 2018). The latter mandates some form of disclosure and the licensing of these SEPs. The most common IPR policy was a requirement to grant licenses on “Fair Reasonable and Non-Discriminatory” terms, often called a FRAND policy (Epstein and Kappos, 2013). Some standards organizations require royalty-free licenses. Other organizations offer a list of options, which may also include voluntary disclosure of the most restrictive licensing terms (Bekker et al., 2011). All these have implications for competitiveness and profitability that would affect incentives of firms to join SSOs.

Although SSOs developed many rules regarding procedures for setting standards or the IPR policies for the SEPs, as indicated by Chiao et al. (2007), few statistical studies have examined the relationship between the rules and operations of different SSOs. The focus on SSO membership is important as these private institutions can somewhat substitute for or complement government institutions. To tie this research to the related body of knowledge, Lerner and Tirole (2006) discussed theoretically forum shopping on the SSOs activities and suggesting that the sponsors of an attractive technology can afford to make few concessions such as royalty-free licensing to prospective users and to choose an SSO that is relatively friendly to its cause. To test their theoretical work, Chiao et al. (2007) empirically explored SSOs’ policy choices. They found a negative relationship between the extent to which an SSO is oriented to technology sponsors and the concession level required of sponsors.

On the other hand, relationships with the IPR rules and firms with SEPs may be investigated by the social networks where firms choose different SSOs and identify which SSOs may be friendly to them.[4]

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[4] IPR protection is a problem, even in developed nations (see Goel, 2019).

1.3 Developments of the Social Network analysis on Global Knowledge Network

Recent development in the field of social network analysis brought up several software tools that facilitate visualization, analysis and interpretation of patent statistics, i.e., patent applications, patent citations or joint patent applications (Clarkson 2004, Leydesdorff and Vaughan 2006, and Bartkowski et al. 2008). The social network analysis is becoming a useful analysis tool along with statistics.

Yang et al. (2011) examined how firms' alliance learning approaches (exploration versus exploitation), and their joint and relative embeddedness in alliance networks (*relative centrality*) can interact to drive subsequent acquisitions of alliance partners. Minns (2014) employed the data of the US ICT companies and social network analysis technique to investigate the relationship between the embeddedness in the companies' alliance networks and their competitiveness. through the lines in the R&D alliance network, we also test the relationships between the positions and knowledge transfer, to investigate if it helps to build relationships and networks for sharing existing research and ideas and stimulating new R&D activity among the firms engaging in the business method software development.

Network-based techniques such as the "*main path analysis*" were pioneered by Hummond and Doreian (1989). In the recent past, number of papers employed this approach for mapping technological trajectories (Mina et al. 2007, Fontana et al. 2009 and Barbera-Tomas et al. 2010). Specific algorithms can be used to identify the "main flow of knowledge" within the patent citation network. This main flow of knowledge is a set of connected patents and citations linking the largest number of patents of the network and therefore cumulating the largest amount of knowledge flowing through citations. This path represents therefore a local and cumulative chain of innovations consistent with the definition of technological trajectory.

Given the success of this approach in understanding the main flow and the development of patented knowledge, it might be promising for providing insight into the knowledge position of the firms that own those patents. As indicated in Bekkers and Martinelli (2012), however, the granularity of this method might restrict it usability in this context: even if the full network comprises thousands or even ten thousand of patents, the identified *main path* of knowledge often comprises few dozen of patents or even less. This "over selective" problem may result in serious limitations and led to misunderstanding the knowledge positions of the SEPs.

Gould and Fernandez (1989) proposed a knowledge broker typology framework. The advantage of the broker position in a network is that the participants who are positioned an information brokers between groups with different information backgrounds benefit from information flows, and have a positive influence on their quantitative and qualitative output, and even can induce competition or conflict between neighbors who are not linked directly. Thus, the approach to brokerage and affiliations may help us to understand more the roles of patents that dominate a transactional or exchange of knowledge network. The roles of the actor in the network could be quite divergent, and categorized such as "itinerant", "representative", "gatekeeper", and "liaison". I will introduce them detailly in next chapter.

Above all, the approaches talked about are in one-mode network, say, all the actors (nodes) are in one set. In social network analysis, two-mode data refers to data recording ties between two sets of entities. In this context, the term "mode" refers to a class of entities – typically called actors, nodes or vertices – whose members have social ties with other members (in the one- mode case) or with members of another class (in the two-mode case).

Most social network analysis is concerned with the one-mode case, as the patent-citations network or joint-patent- applications network which are just mentioned. The two-mode case arises when collect relations between the participants (firms with SEPs) and SSOs. Although it would be a mistake to think of two-mode data as an advance over one-mode data, it is important to note that there are many cases were extending network analysis methodology to more than two modes are desirable (Borgatti, 2009), like the case in this chapter. Through the two-mode network, we can easily figure out like how many SSOs a company is involved in, which firms are alliance members because they participate in the same SSO, which firms play a leader role as they are active in many SSOs.

1.4 Organizations of the Paper

My paper is organized as following: in the second chapter, I implement comparison about the competitiveness of companies engaged in software development, by using the software patent data in firm level. I attempt to employ the most important methods of exploring social networks, emphasizing visual exploration on the comparison analysis of software development sector and highlight some important characteristics, e.g., *betweenness centrality, degree,* or *brokerage roles*, etc., in the joint patent application network.

In the third chapter, I attempt empirical analysis for business method software patents from a different perspective. I focus on the competitiveness of firms that engage in business method software development and employ social network analysis technique to determine the characteristics of the social network about firms in their R&D alliance networks. This approach enables us to examine the determinants of knowledge transfer, as signified by patent citations, in the business method software development sector. For the purpose of this study, I identified 19,385 software patents, among which are 4,095 joint applications applied for by 37 countries over the period 1995-2012.

In the 4th chapter, I would like to introduce some important definitions about technical standard, Standard Setting Organization (SSO) and some recent topics about standard and SSOs.

In the 5th chapter, I attempt to investigate the relationship between whether the patent is claimed by its owner to be essential and the knowledge position of the patents in the patent citation network. I focus on the knowledge positions not only in "*main path*" discussed in the earlier literature, but also in *brokerage roles* processes. I pay attention on essential patents declared by member firms in JTC1, a standard setting organization (SSO) that provides a standards development environment related to develop worldwide Information and Communication Technology (ICT) standards for business and consumer applications. I also build a dataset for the citation relationships between the patents, which involves more than 15000 pairs of citations between the essential patents and between the essential patents and other patents held by the member firms. Furthermore, I implement regression analyses for the determinants of strategies of the SSOs members related to the declaration of essential patents by employing the timing for cooperation and entry into an industry SSO, and patent portfolio of the SSOs members.

In chapter 6, I use data on more than 1060 member firms as participants in 28 SSOs, I'm able to uniquely graph the membership of firms in SSOs by highlighting some important characteristics, e.g., *betweenness centrality*, *modularity*. And a multinomial logit regression analysis studies the propensities of firms to belong to four communities (calculated according to modularity).

My Analysis in the paper is based on the Searle Center Database (SCDB), a database recently developed for the analysis on the SSOs activities. I also use PATSTAT, a patent data set, to collect the information for the companies' patent applications and patent classifications in the United States Patent and Trademark Office (USPTO).

Chapter 2. Software Patents and Joint-application Patent

According to World Economic Forum (WEF), although Japan placed eighth in the world in 2005 in an annual ICT competitiveness ranking, after then, Japan has been languished between 15th and 20th in more recent years, placing 16th in 2014, while Western European countries, the USA, Korea and Singapore have dominated the top positions (http://reports.weforum.org/global-information-technology-report-2015/). At the same time, some literature also indicated that, the Japanese ICT sector increasingly lags the U.S. IT sector in software innovation and that this underlies Japan's weakening competitive performance vis-à-vis U.S. ICT (Cole and Nakata 2014).

Thus, how to increase the competitiveness in Japanese ICT sectors, especially in software development sectors is considered an important topic not only for industrial world but also for academic world. This chapter attempt to make a comparison with some other countries to investigate the Japanese competitiveness in software development through studying the software patenting and its joint application network.

2.1. Defining of Software Patents

As indicated by Hall and MacGarvie (2010), one difficulty that all researchers encounter in the area related to software patent, is that the definition of a software patent is rather unclear. Although all patents are classified into a number of technology classes by different patent classification systems, i.e., the International Patent Classification (IPC), the United States Patent Classification (US Class), or the Cooperative Patent Classification (CPC), it is unfortunate truth that the relevant classes are broad enough to contain both software and hardware patents, and some software patents end up classified in classes that do not appear to have anything to do with software patents at first glance. Thus, many researchers suggested definition methods to identify software patents. However, the accuracy of these various definitions is needed to check carefully depending on different purpose of the research, there is not a practical and standard way to choose a particular set of software patents out of a mass patent data set.

Bessen and Hunt (2007) used a modification of the technique of reading and classifying individual patents. They began by reading a random sample of patents, classifying them according to the definition of software, and identified some common features of these patents. They developed an algorithm to perform a keyword search of the U.S. Patent Office database, which identified 130,650 software patents granted in the year 1976 to 1999. Next, to validate the accuracy of this algorithm, they also compared results to samples and statistics generated by other researchers. Particularly, Bessen and Hunt define software patents as those that include the word “software”, or the words “computer” and “program” in the description and/or specification in the title and abstract of the patent documents. Patents that meet the criteria containing the words “semiconductor”, “chip”, “circuit”, “circuitry” or “bus” in the documents are excluded, as they are believed to refer to the technology used to execute software rather than the software itself. Patents containing “antigen”, “antigenic”, or “chromatography” in the description/specification are also excluded. Graham and Mowery (2003) identify as software patents those that fall in certain International Patent Classification (IPC) class/subclass/groups. Particularly, the class/subclasses are “Electric Digital Data Processing” (G06F), “Recognition of Data; Presentation of Data; Record Carriers; Handing Carriers” (G06K), and “Electric Communication Technique” (H04L). Graham and Mowery selected these classes after examining the patents of the six largest producers of software in the U.S. (based on 1995 revenues) between 1984 and 1995.

As a relatively recent paper, Hall and MacGarvie (2010) identified all the U.S. patent class subclass combinations in which fifteen software firms (Microsoft, Adobe, Novell, Autodesk, Symantec, Macromedia, Borland, Wall Data, Phoenix, Informix, Starfish, Oracle, Veritas, RSA Security, and Peoplesoft) patented and then categorized patents falling in these class-subclass combinations as “software”. They refer to this definition of software patents as the Hall-MacGarvie definition. Hall and MacGarvie then combined the definition with the union of the set of patents in all relevant IPC and US patent classes (including the union of Graham and Mowery), and intersected with the set of patents found using a keyword search of title and abstract such as did in Bessen and Hunt.

On the other hand, Yamauchi and Onishi (2012) employed the combination of keywords and technological classification methods to present an approach of definition of software patents for Japanese software companies. They add the IPC subgroups G06F17 and G06F19 to the definitions of Graham and Mowery (2003). They also included in the sample the game–related IPCs A63F13 and A63F9 which are considered to be important for Japanese game software companies.

In this chapter, I employ the approach that combines keywords and technological classification, say, Cooperative Patent Classification (CPC) to define software patents. To reflect dynamic changes in software development, I include the CPC classification related to management software and business model. My definition of software patents with the CPC class/subclass are summarized in Table 1, that could be divided into four main groups of software technologies, i.e., control software, management software and business model, image data processing software, and voice data processing software.

I also use keywords in the title of patent documents to exclude those may related to hardware. The search algorithm is summarized as the follows.

Search Algorithm The search query used is:

> *((“software”) OR (“methods” AND “program”)) AND (utility patent excluding reissues) ANDNOT (“chip” OR “semiconductor” OR “bus” OR “circuit” OR “circuitry” OR “device” OR “apparatus”).*

2.2. International Comparison of Software Patents

Table 1 presents the number of software patents applied for the USPTO from 20 selected countries and regions. The number of patents applied for by the US software companies is dominant, followed by those from Japanese software companies. Germany is the third most in my sample. In Asian region, besides Japan, the most of USPTO patents are applied for by software companies of Korea and Taiwan.

Table 1: Number of Software Patents for Selected Countries

Country	G06F7	G06F8	G06F11	G06F17/19	G06F21	G06Q	G06T3	G06T5	G06T9	G06T11	G06T15	G06T17	G10L15
USA	5043	14369	31241	102974	25632	125542	2438	3927	1770	5173	4489	2478	5767
Japan	1282	2133	7623	17859	6607	11967	1848	2927	1057	2336	1591	727	1389
Germany	367	971	1550	4941	1130	4557	141	372	67	555	300	171	398
Canada	239	913	827	4600	1190	5215	203	207	70	285	279	145	182
UK	351	598	1397	3925	1399	4702	111	163	97	251	300	135	276
Korea	299	407	891	2834	1326	2164	264	512	212	209	332	148	259
Taiwan	200	389	1366	2238	944	1678	204	324	57	130	218	66	187
France	325	313	679	2260	987	2116	95	256	120	205	98	153	110
Israel	244	339	1082	2456	895	2019	106	227	40	105	148	71	125
India	92	525	1133	2720	544	2247	38	65	33	70	27	17	81
China	46	323	775	2565	564	1316	69	138	29	122	134	76	136
Australis	72	128	144	1316	1058	2229	124	51	38	128	59	22	43
Netherlands	105	89	194	1194	466	882	104	199	53	235	122	64	105
Switzerland	29	101	155	902	264	1149	21	26	9	28	28	37	36
Finland	19	103	94	960	393	958	26	43	11	41	43	10	66
Sweden	48	165	173	688	278	831	31	58	36	51	56	26	45
Italy	44	106	181	467	137	511	25	50	20	27	36	14	26
Ireland	10	102	106	485	110	836	13	140	2	15	4	8	6
Singapore	18	59	151	369	281	424	18	35	5	14	26	12	24
Belgium	17	65	78	390	96	342	14	60	3	17	20	31	35

Almost all countries' patents are concentrated in the fields of G06Q (Data processing systems or methods for administrative, commercial, financial etc.) and G06F17/19(Digital computing or data processing equipment or methods) while there is relatively less in G10L (the field related to voice and audio software). However, Korea seems to be relatively stronger in the G10L.

Figure 1: Share of Patents for Japan and the USA

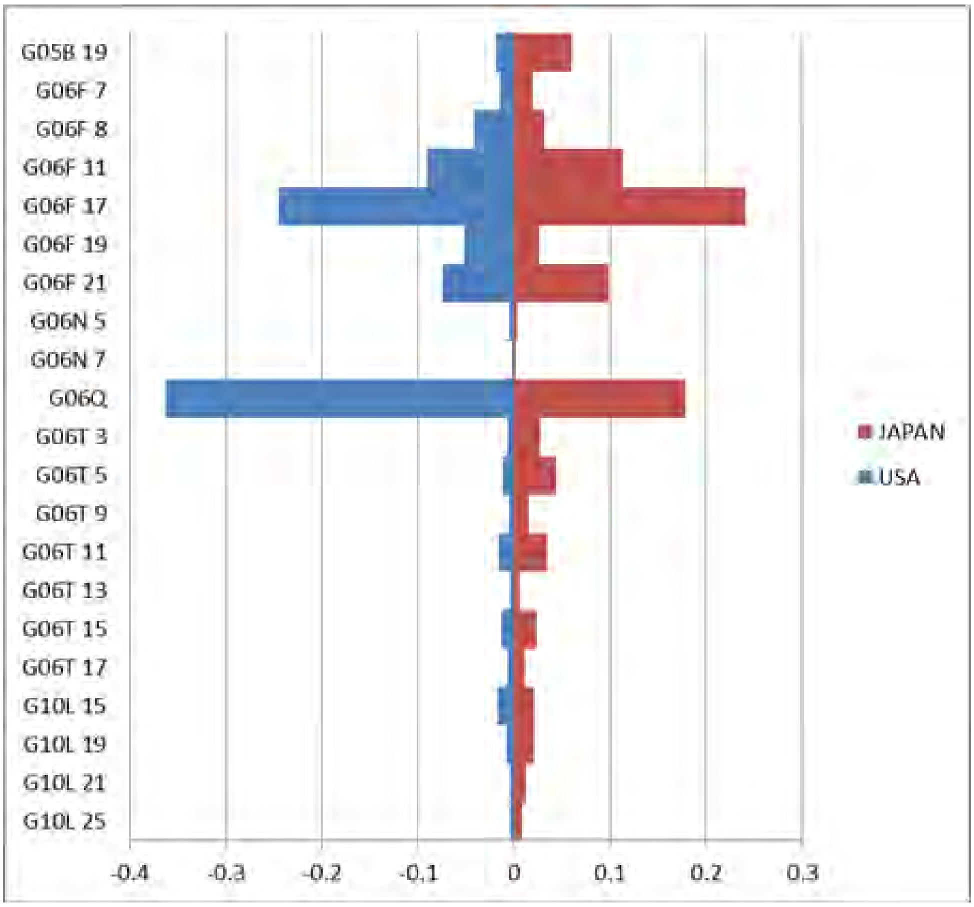
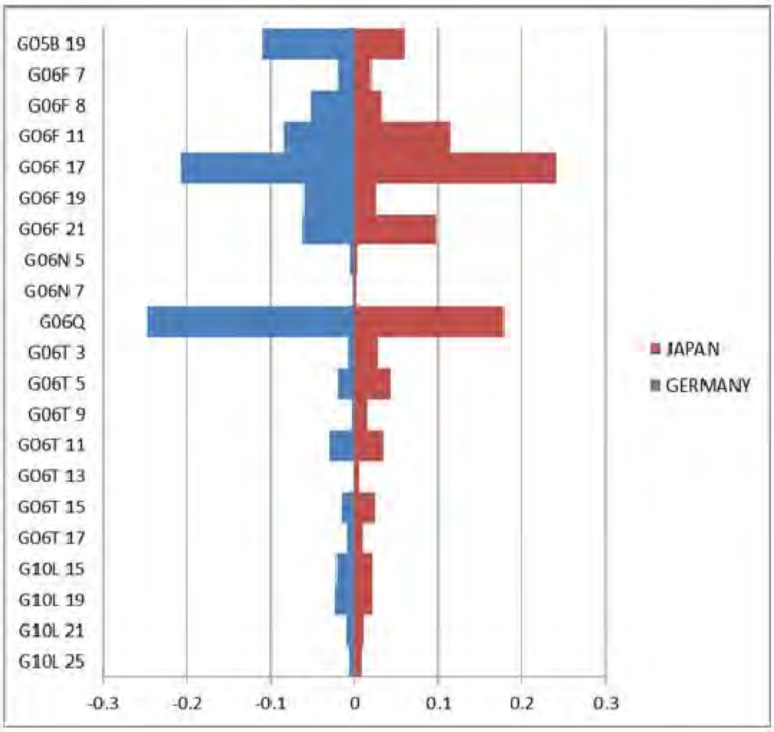


Figure 2: Share of Patents for Japan and Germany



I draw the pictures for the United States, Japan and Germany, using the share of their patents in each field to their total patents. based on these shares, it can be observed which field is stronger for the country. Figure 1 shows that, compared with those for the USA, Japanese companies seem to be relatively stronger in G05G19 (Programme-control systems), G06F11 (Error detection; Error correction; Monitoring), G06F21 (Security arrangements for protecting computers) and G06T (the fields related to imaging software), while the US companies applied for more patents in G06Q(Data processing systems or methods for administrative, commercial, financial etc.) and G06F19 (Digital computing or data processing equipment or methods).

Figure 2 presents the shares for Japan and Germany, which allows us to make a comparison for companies between of Japan and Germany. From the figure, we can understand that for the technology fields related to imaging and voice software (G06T and G10L), the shares of patents applied by Japanese and Germany companies are almost the same. But Germany is stronger in G06Q and G06F19, while Japan is stronger in G06F11 and G06F21.

2.3 Social Network Analysis

Social network analysis explores the relationships (‘‘ties’’, ‘‘arcs’’, or ‘‘edges’’) between the actors (‘‘nodes’’ or ‘‘vertices’’), i.e., firms that develop the business method in my case. The methodology employed in this section is based on recent developments in network analysis, which emphasizes the performance or competitiveness of actors (or firms) in the joint application network structure for business method software patents. Three network dimensions are considered. One is the centrality discussed in Granovetter (1985); another is the brokerage and structural holes advanced by Gould and Fernandez (1989) and Burt (1992); and the final one is related to the work of Friedkin (1998) that outlines the role of *structural equivalence* and its relationship to performance and behavior in the network.

3.2.1.1 Indices for *centrality*, *brokerage*, and *structural equivalence*

***Betweenness Centrality*:** I measure centrality by using *betweenness centrality* proposed by Freeman (1979). The *betweenness centrality* calculates the extent to which an actor (or firm) is located on the shorted path between any two nodes in its network. For actor i, its value of *betweenness centrality* can be measured by,

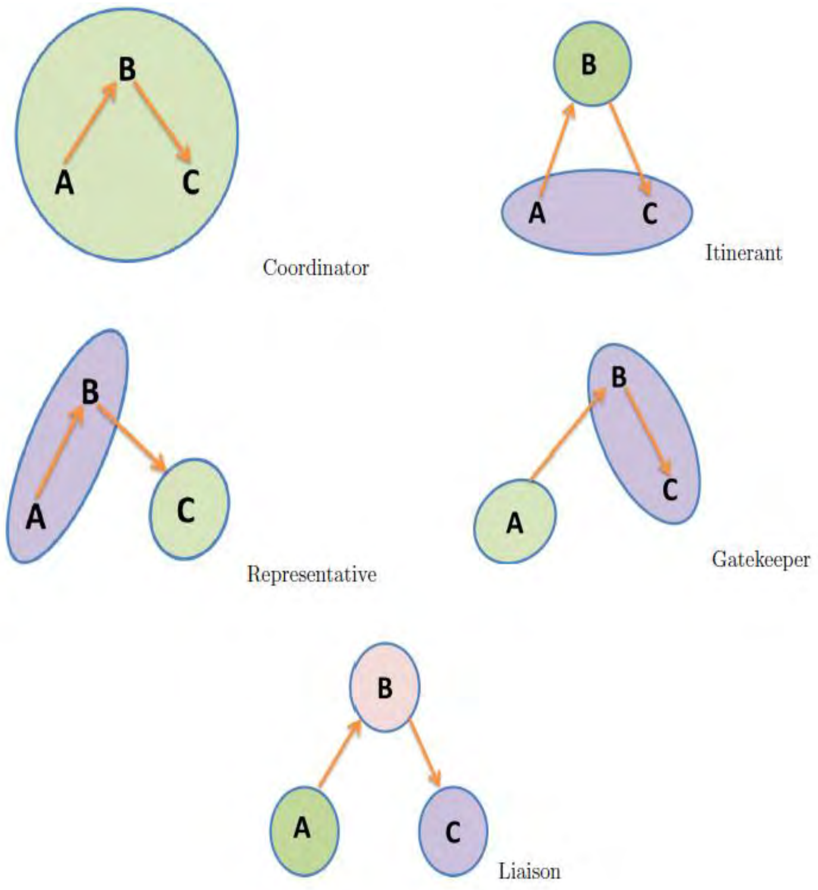
$$Betweenness\ Centrality_i = \sum_{j \neq k \neq i} \frac{g_{jk}(i)}{g_{jk}}$$

where $g_{jk}(i)$ denotes the number of shortest paths linking actors *j* and *k* that contain focal actor *i*, and $g_{jk}(i)$ is total number of shortest paths from actor *j* to actor *k*. The *betweenness centrality* captures both the centrality and the spanning of structural holes in the network.

***Brokerage Role*:** Brokerage is a state or situation in which an actor (or firm) connects otherwise unconnected actors or fills gaps or network holes in the network structure (Gould and Fernandez 1989, Burt 1992). Research into *brokerage roles* is concerned with describing the types of *brokerage roles* that dominate a transactional or exchange network. In addition, individual positions within the network may be characterized by the dominant type of brokerage role, and hypotheses may be tested about the personal characteristics of firms with certain types of *brokerage roles*.

Gould and Fernandez (1989) proposed a knowledge broker typology framework, in which the brokers’ role could be categorized as “coordinator”, “itinerant”, “representative”, “gatekeeper”, and “liaison”.

Figure 3: Five Types of Brokerage Relations among Firms


Coordinator

Itinerant

Representative

Gatekeeper

Liaison

Figure 3 depicts the categories, where the triad in which actor B mediates transactions between actor A and actor C can display five different patterns of group affiliations.

- In the triad of “coordinator”, all actors including the broker B and the source of knowledge are in the same cluster.
- In the “itinerant” framework, the broker B mediates between actor A and C that are in the same cluster, but the broker B is not part of this cluster.
- “Representative” role is given if a cluster delegates the brokering role of external knowledge to someone in the other cluster.
- “Gatekeeper " screens external knowledge to distribute it within their own cluster.
- “Liaison” is when they knowledge is brokered across different clusters, neither of which the broker B is member of.

In this section I focus on three types of these interactions: *itinerant brokerage, gatekeeper brokerage and Representative brokerage.* Since in my case, there is no direction in the network of joint patent application, gatekeeper brokerage works in the same qualitative manner as *Representative* brokerage. Thus, I combine the two types of concepts of brokerage typology into one type as *“gatekeeper/Representative”*.

***Structural Equivalence*:** The concept of *structural equivalence* is associated with a group or cluster of firms, that have similar relationships with themselves, each other, and all other firms in the network (Newman 2010, p.212). In this context, structural similarity may stimulate a competitive orientation in which firms are attentive to each other’s statues and interests (Burt 1987). Accordingly, the strategy for firms in the same group or cluster may be initially identified as following a joint policy of innovativeness because their networks are structural equivalent (Seaman et al. 2017).

To implement the network analysis, I use *Pajek*, a software tool for analyzing social networks to measure the *betweenness centrality*, three types of brokerage and structural equivalent for each firm of the joint applications for the business method software patents.[5]

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[5] There is a variety of software tools that have been developed for social network analysis. The most popular software packages include Pajek, UCINET 6, NetDraw, Gephi, E-Net, KeyPlayer 1, StOCNET and Automap. I employ Pajek in this study because it has efficient algorithms for analyzing large networks in addition to its powerful visualization function. See Apostolato (2013) for an overview of software applications for social network analysis.

2.4. Social Network Analysis on Joint Patent Application Network

Many software companies these days, are forced by increasing international competition and an unstable economy and are opting to specialize rather than generalize as a way of maintaining their competitiveness. Consequently, firms cannot rely solely on themselves, but must cooperate by combining their advantages. In this section, I employ the social network analysis techniques discussed in the last section on the patent joint application networks, to explore the characteristics of the network, and the competitiveness of the firms compared with their competitors and partners in the knowledge learning, knowledge transfers or technology spillovers.

2.4.1. Joint Patent Application

I gather the information for joint patent application to the USPTO from Thomson Reuters, a database that concludes all names of inventors and applicants for the USPTO patents. In some cases, the name of applicants can be directly linked to the name of company where the inventors belong to. I use the names of applicants (firms) to build a joint patent application network. I collect all names of applicants based on USPTO patent number and combine them with the data obtained from the PATSTAT. I identify 1529 companies that applied for 387,905 software patents to the USPTO during the period of 1990–2012. Most of patent applications have only a single applicant, that cover 47% of the patent applications in sample. The applications with co–applicants between 2 and 6 companies share approximately 40%.

2.4.2. Visualization Analysis

I utilize *Pajek* to implement visualization analysis on the joint patent application network. Here, I focus on *betweenness centrality* position and *brokerage roles* of the applicants, say, software companies in the network[6].

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[6] Since in joint patent application network, the relation between the co–applicants have no direction, it is impossible to make distinction of "representative" and "gatekeeper". Thus I focus on only one of the two types of *brokerage roles*, say, "gatekeeper" in analysis.

2.4.2.1. Visualization Analysis on *Betweenness Centrality*

Figure 4: *Betweenness Centrality* for Management and Business Model Group

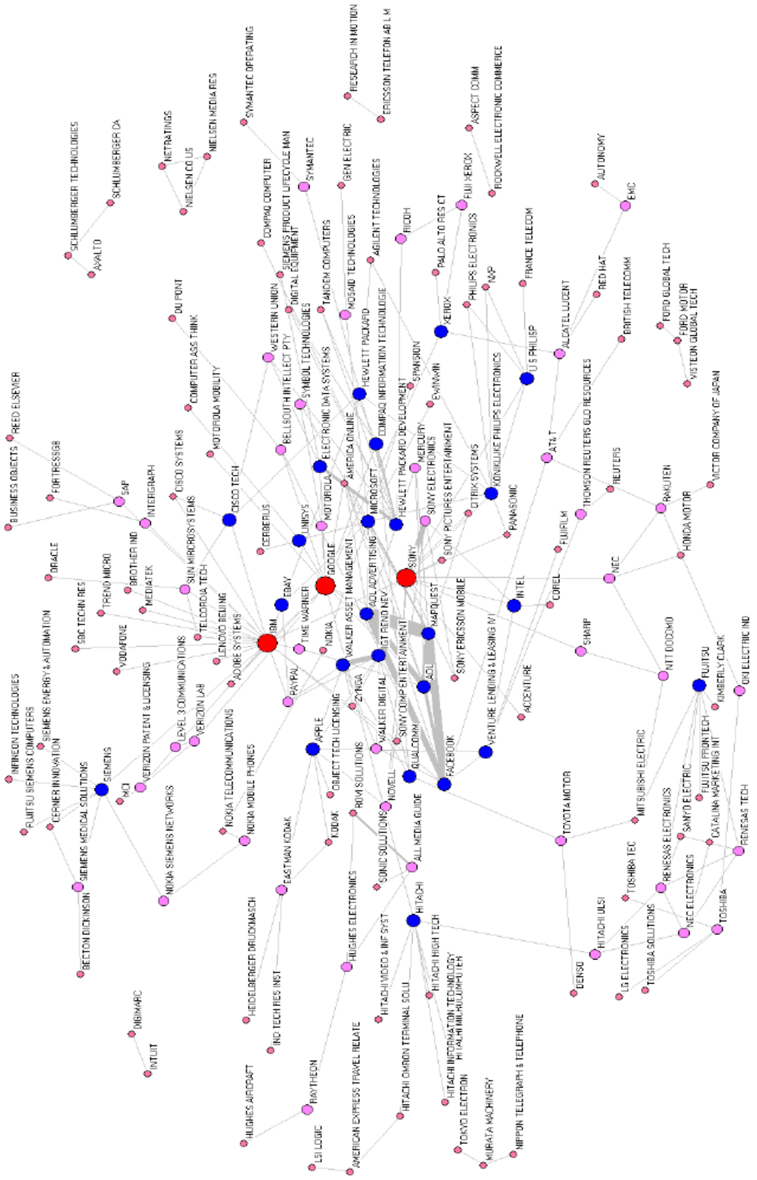


Figure 5: *Betweenness Centrality* for Management and Business Model Group

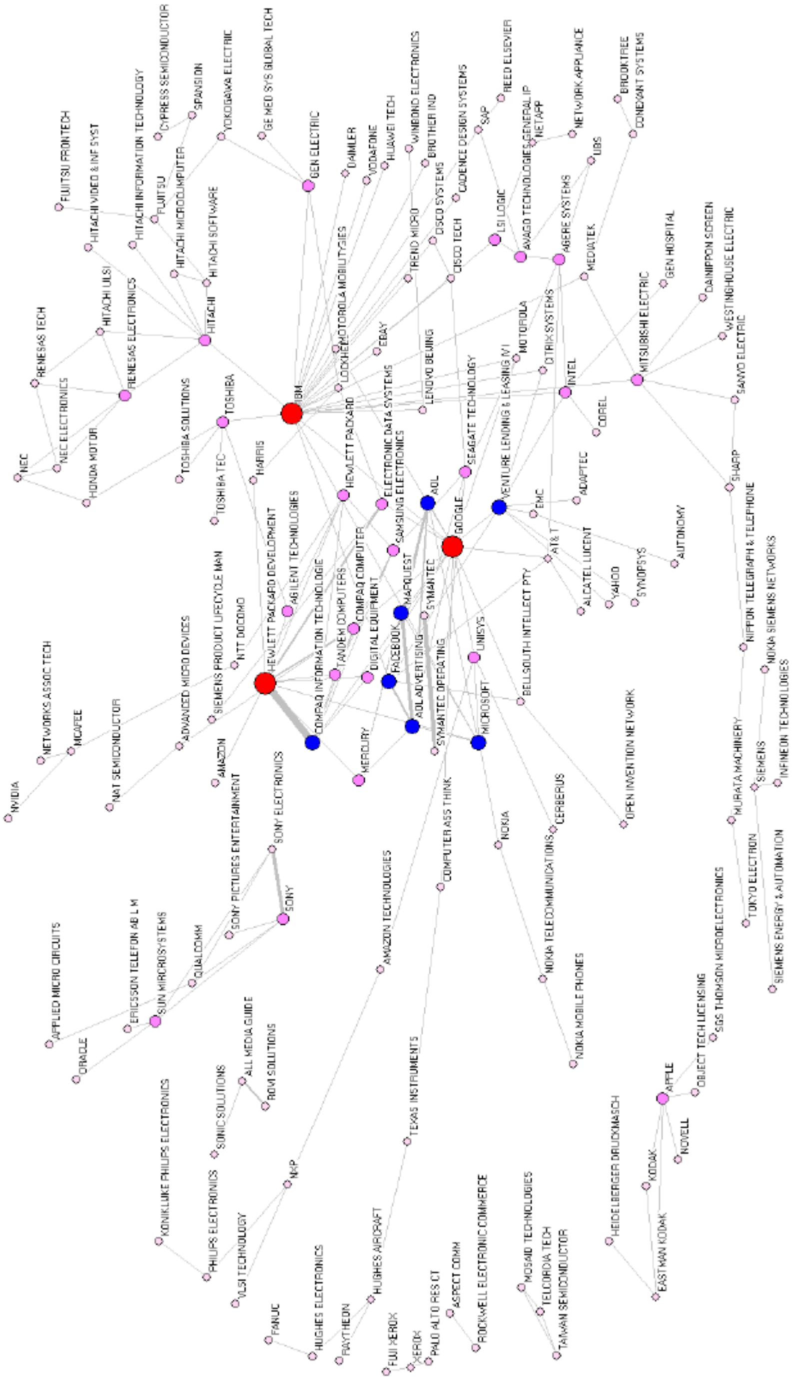


Figure 6: *Betweenness Centrality* for Management and Business Model Group

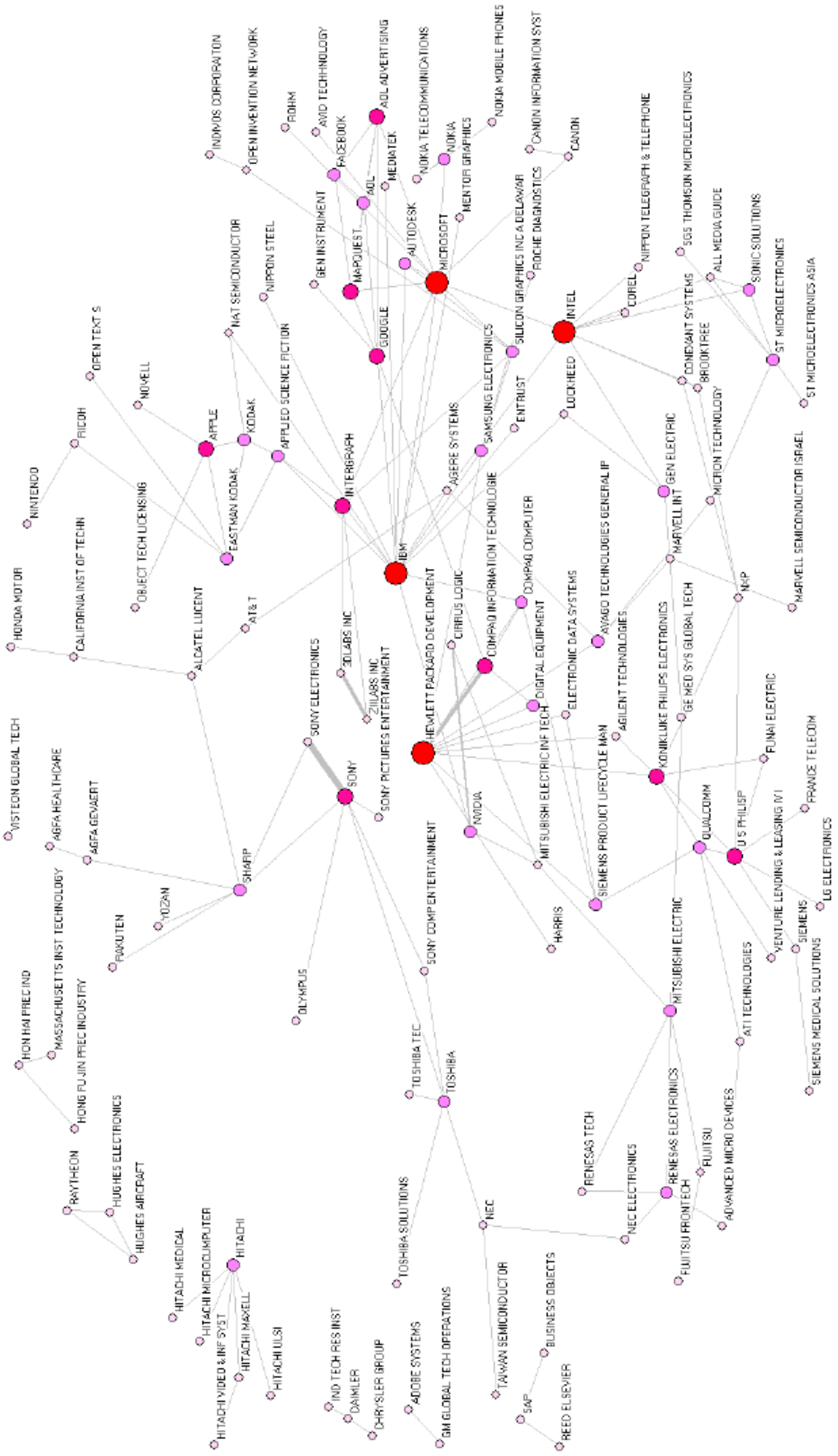


Figure 7: Betweenness Centrality for Management and Business Model Group

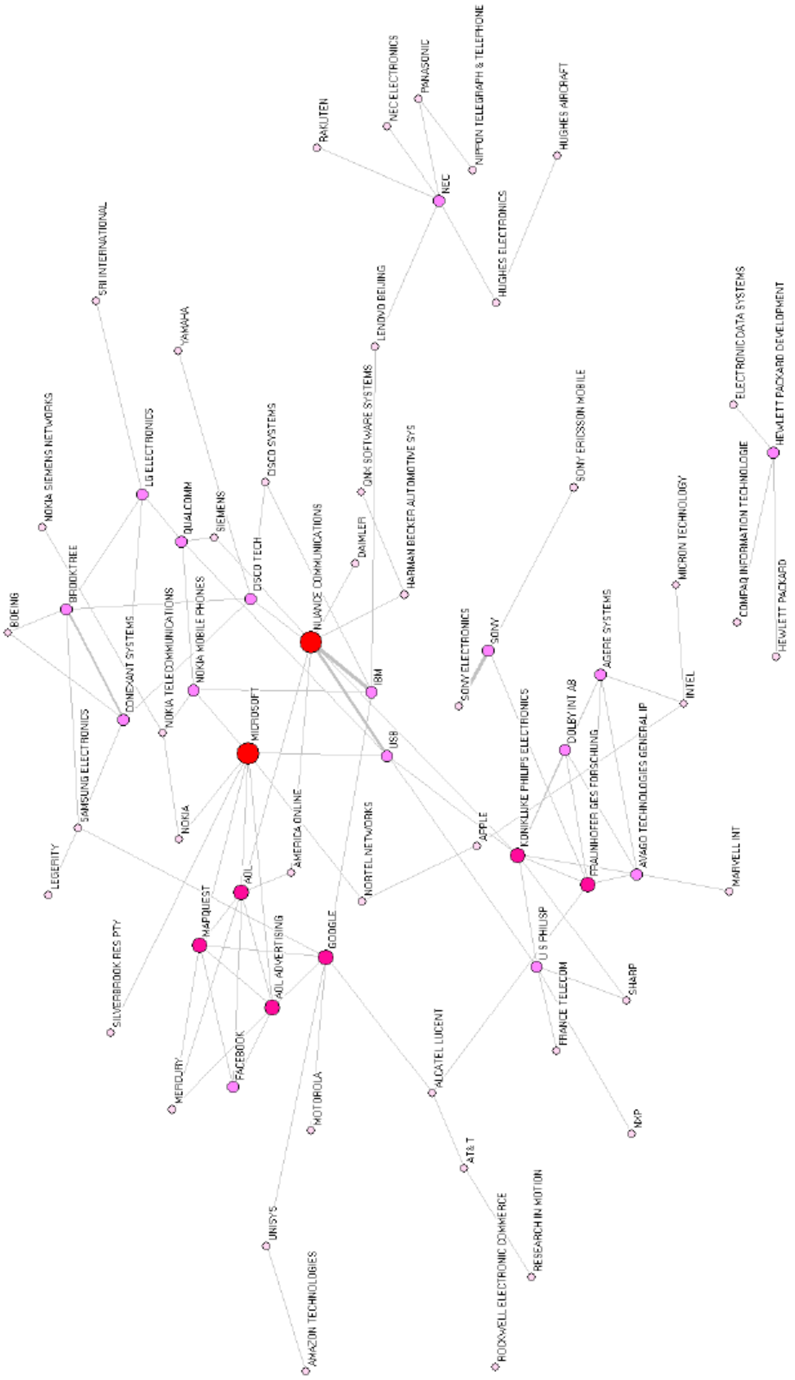


Figure 4, 5, 6 and 7 depict the "*betweenness centrality*" for the four groups. The vertex (of the companies) sizes show their values of "*betweenness centrality*". The width of lines between the vertexes represent the scale of joint patent applications made between the two companies, and the positions of the vertexes (of the companies) in the networks are determined with the *Kamada-Kawai* energy command, , which makes the vertexes with high values of the *betweenness centrality* occupy the central position, (inversely, vertexes with low values of the *betweenness centrality* situate peripherally).

As shown in Figure 4 for the group of management software and business model, IBM, GOOGLE and SONY are located in the center of the network with biggest size of the vertexes. Around these companies, there are ADL (an international management consulting firm), UNISYS, EBAY, MICROSOFT, MAPQUEST (an online web mapping service firm), FACEBOOK, INTEL and several computer manufacturers, i.e., HEWLETT PACKARD, COMPAQ and APPLE. Besides SONY, Japanese companies such as FUJITSU, and HITACHI also have relatively larger values of the "*betweenness centrality*". However, they are located peripherally, and connect only with their affiliates or other Japanese companies. These firms form several clusters in which there exist cooperations in R&D activities mainly among Japanese companies for software development. That is also the case for Germany company, SIEMENS.

Then turn to Figure 5, 6 and 7. Compared with the group of voice data processing software, in which main players seem to be European companies such as NOKIA, SIEMENS, and KONINKLIJKE PHILIPS besides the US companies, many Japanese companies are active in the groups of control software, and image data processing software in the joint patent applications to the USPTO. For example, in the group of image data processing software, it can be observed that there are several clusters where SONY, SHARP, HITACHI, TOSHIBA, RENESAS ELECTRONICS and MITSUBISHI ELECTRONIC are located the center position of their own clusters respectively. However, the positions in the network for these Japanese companies are quite peripheral, compared with the US companies and even compared with SAMSUNG ELECTRONICS, a Korea company. Furthermore, in the group of image data processing software, the cluster of HITACHI and its affiliates or group companies is even isolated to any other cluster.

2.4.2.2. Visualization Analysis on Brokerage Roles

Figure 8: Itinerant for Management and Business Model Group

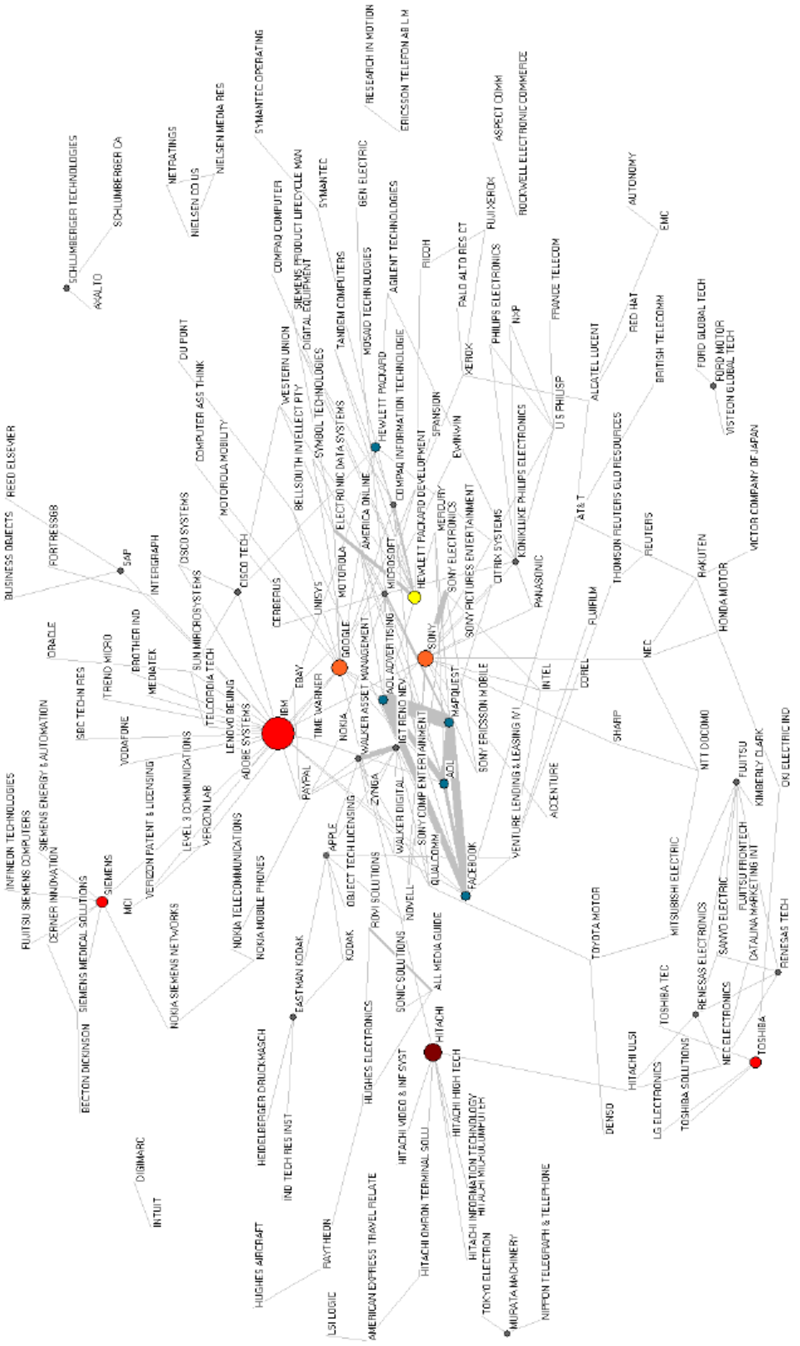


Figure 9: Gatekeeper for Management and Business Model Group

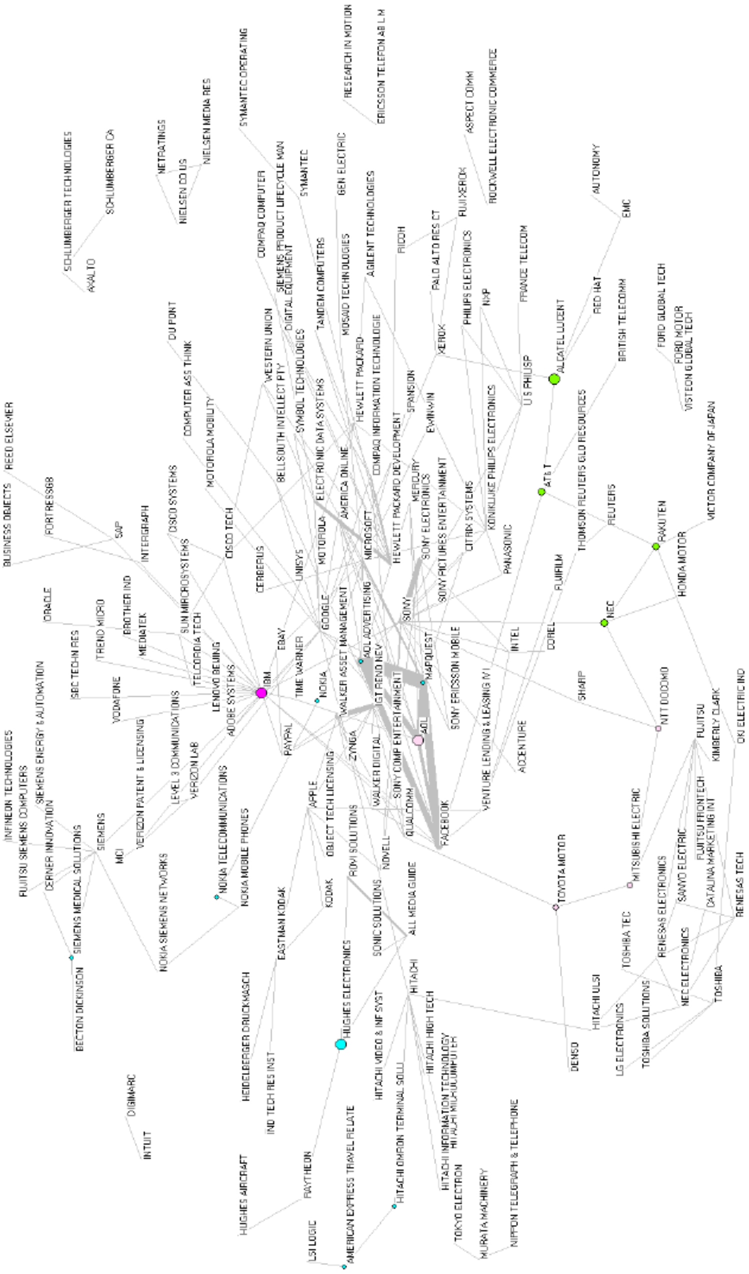


Figure 10: Liaison for Management and Business Model Group

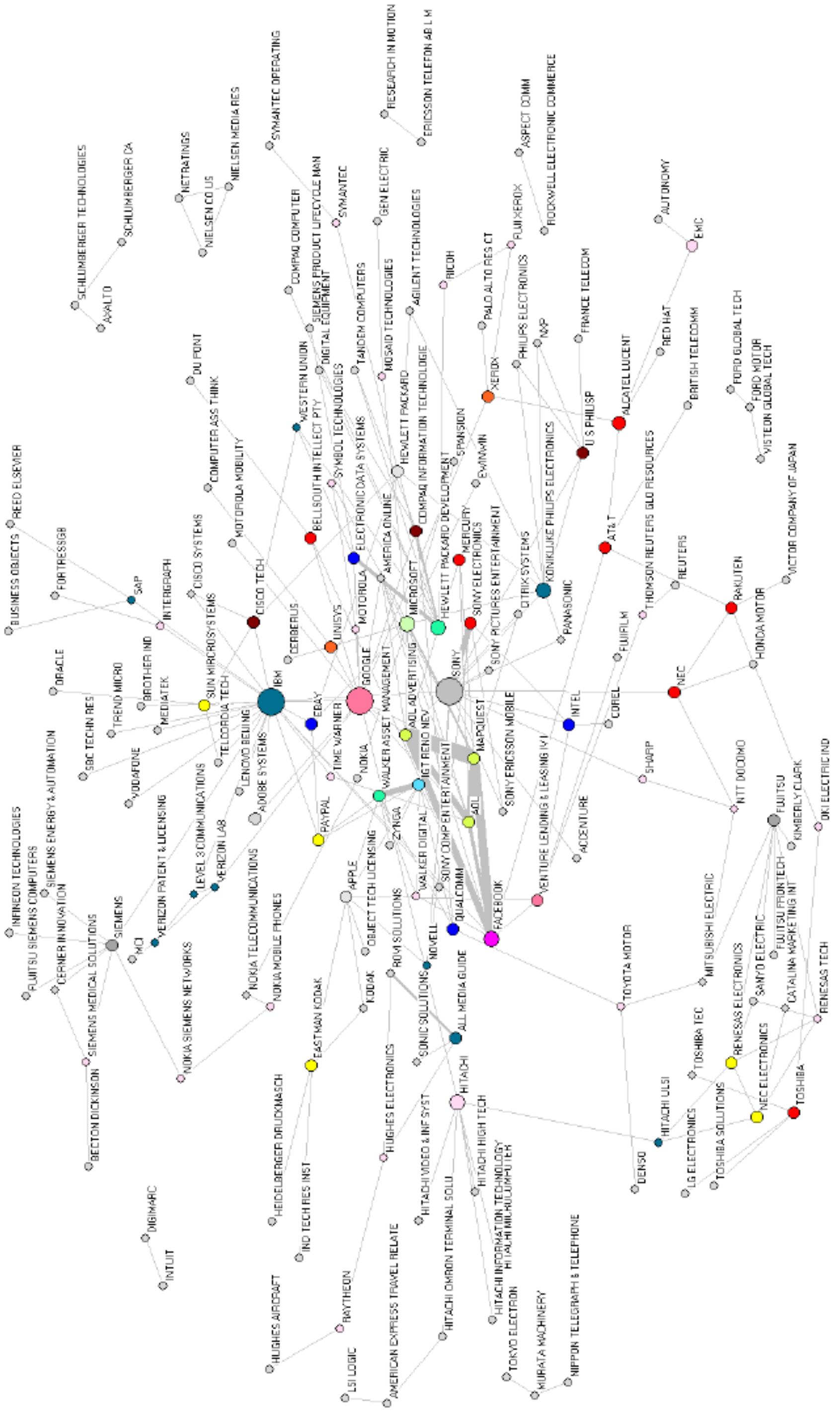


Figure 8, 9 and 10 reveal several *brokerage roles*, i.e., “itinerant”, “gatekeeper” and “liaison” for the group of management software and business model. First, let us have a closer look at IBM, that combines several types of *brokerage roles*. As an itinerant broker, it has ties with two or more members of other clusters. And for information flowing toward members of its cluster, it is a gatekeeper. Finally, it may mediate between other clusters, in this role, IBM is a liaison. SONY is also an itinerant as well as a liaison in the network. However, unlike IBM, SONY is not a gatekeeper.

Then, I pay attention to TOSHIBA and HITACHI, they are the bridges between the clusters that consists mainly of Japanese companies, so they are itinerants and liaisons. Besides these two companies, as Japanese companies, NEC and RAKUTRN play important roles to screen external knowledge from the US company clusters to distribute it within their own Japanese company clusters. So they are gatekeepers.

Figure 11: Itinerant for Control Software

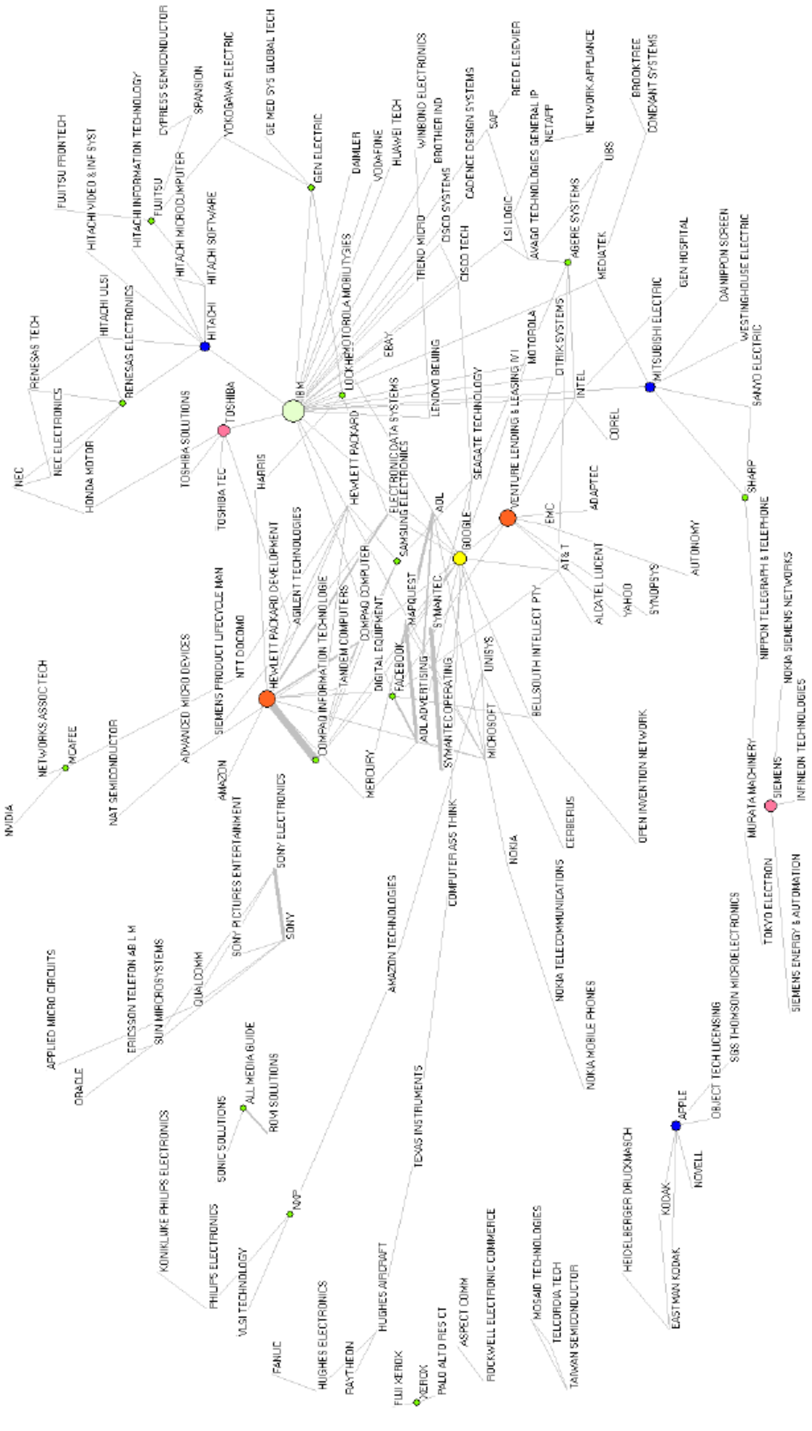


Figure 12: Gatekeeper for Control Software

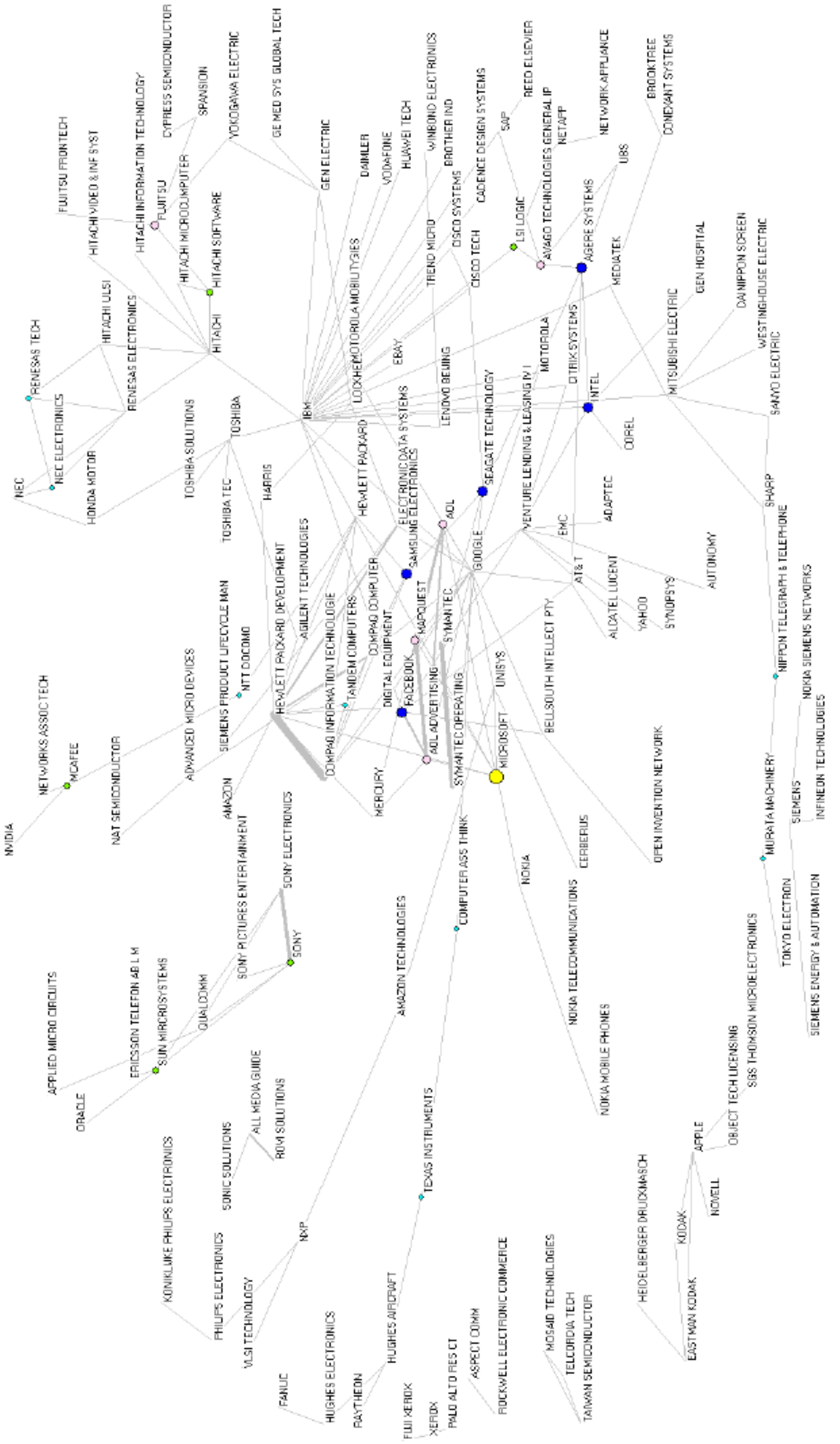
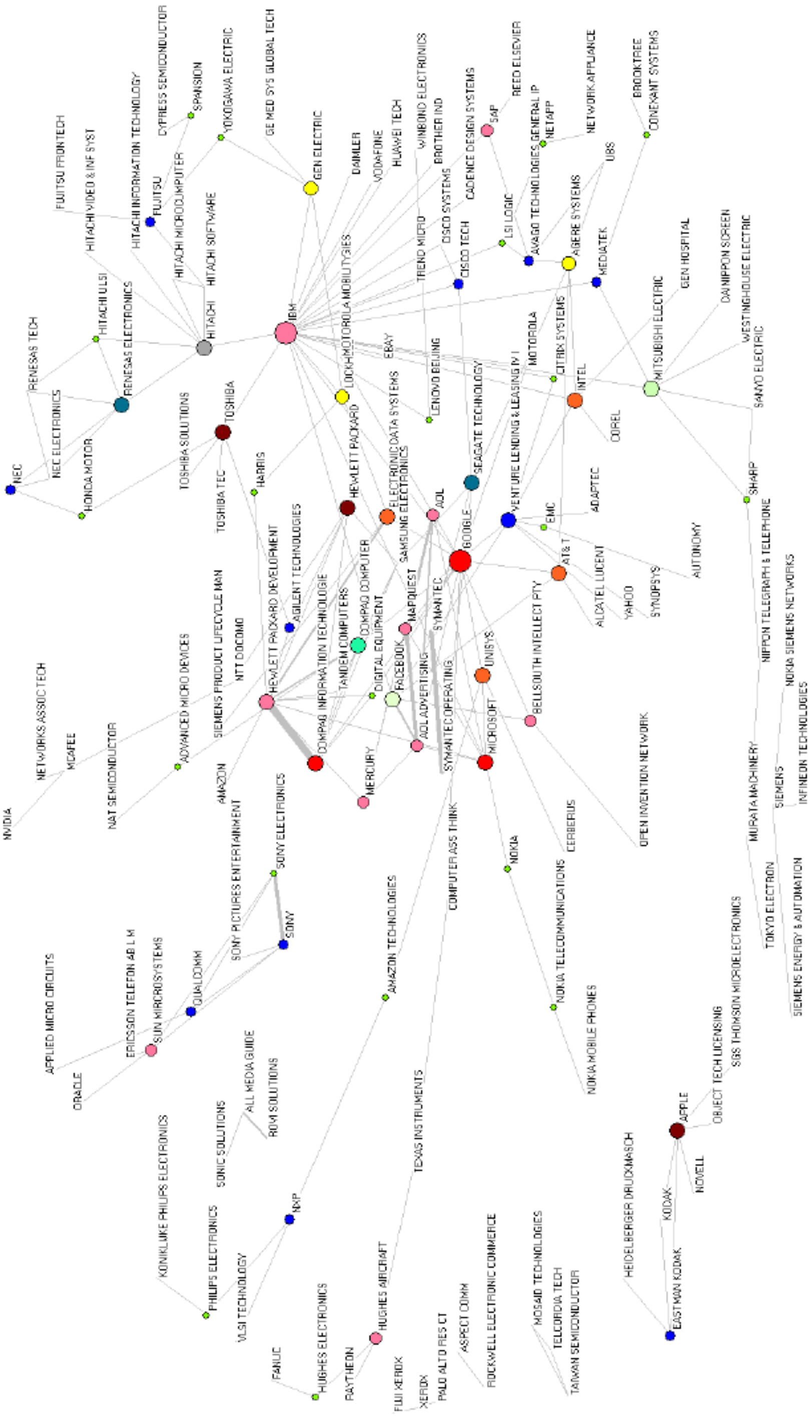


Figure 13: Liaison for Control Software



Let us move to group of control software. MITSUBISHI ELECTRIC, HITACHI and IBM, the three companies form an interesting triangle, two angles related with the Japanese companies groups in the “northeast” and “southeast”, and the other angel related to the US companies group in the center. So MITSUBISHI ELECTRIC and HITACHI are all liaisons that mediates knowledge transactions between the US company clusters and Japanese company clusters. But as for itinerant broker, HITACHI and MITSUBISHI ELECTRIC have no ties with two or more members of any cluster other than their own, so they are not competent in this role. In this group, NEC does not play as a gatekeeper as it does in the group of management software and business model.

Figure 14: Itinerant for Image Software

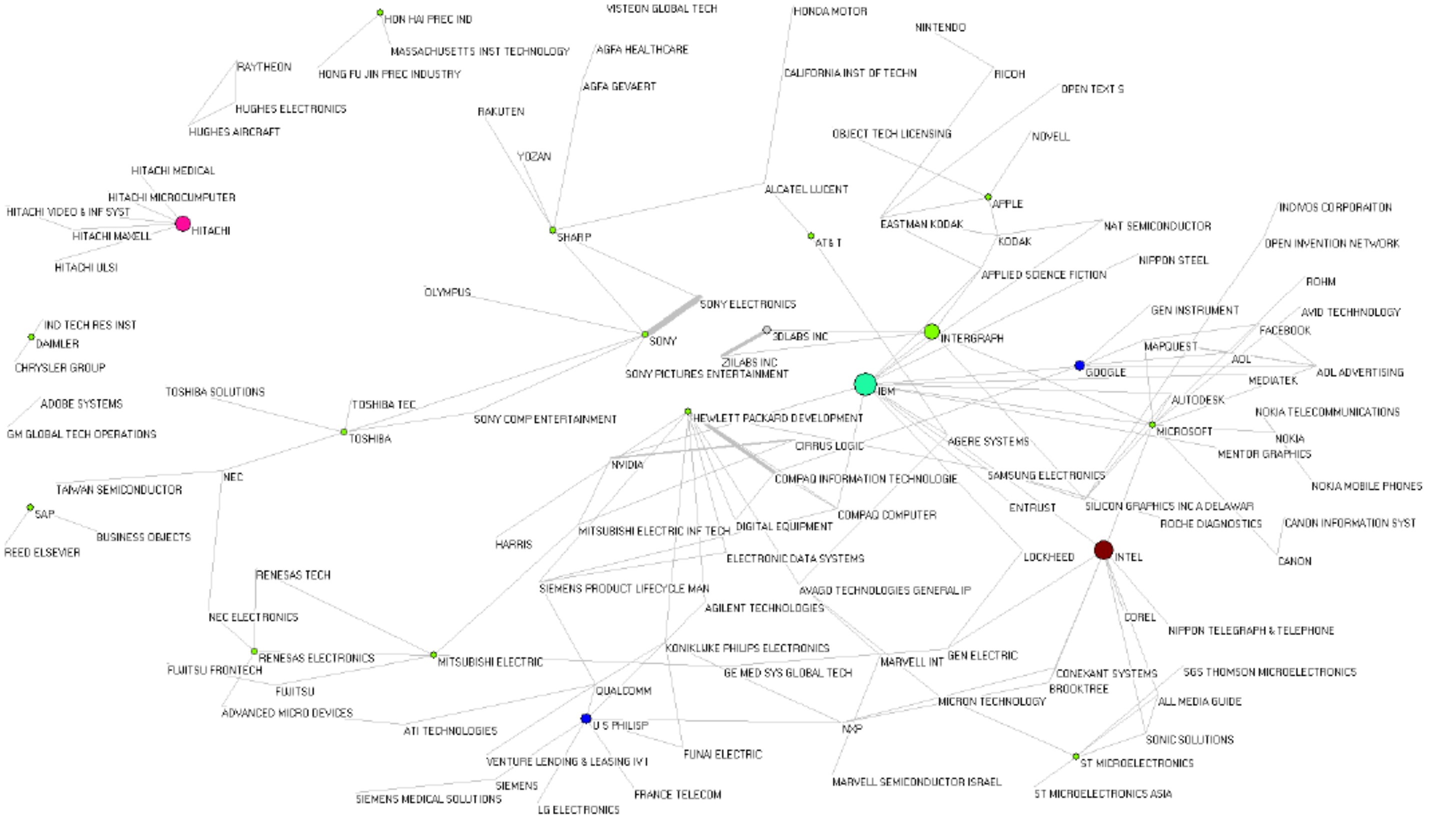


Figure 15: Gatekeeper for Image Software

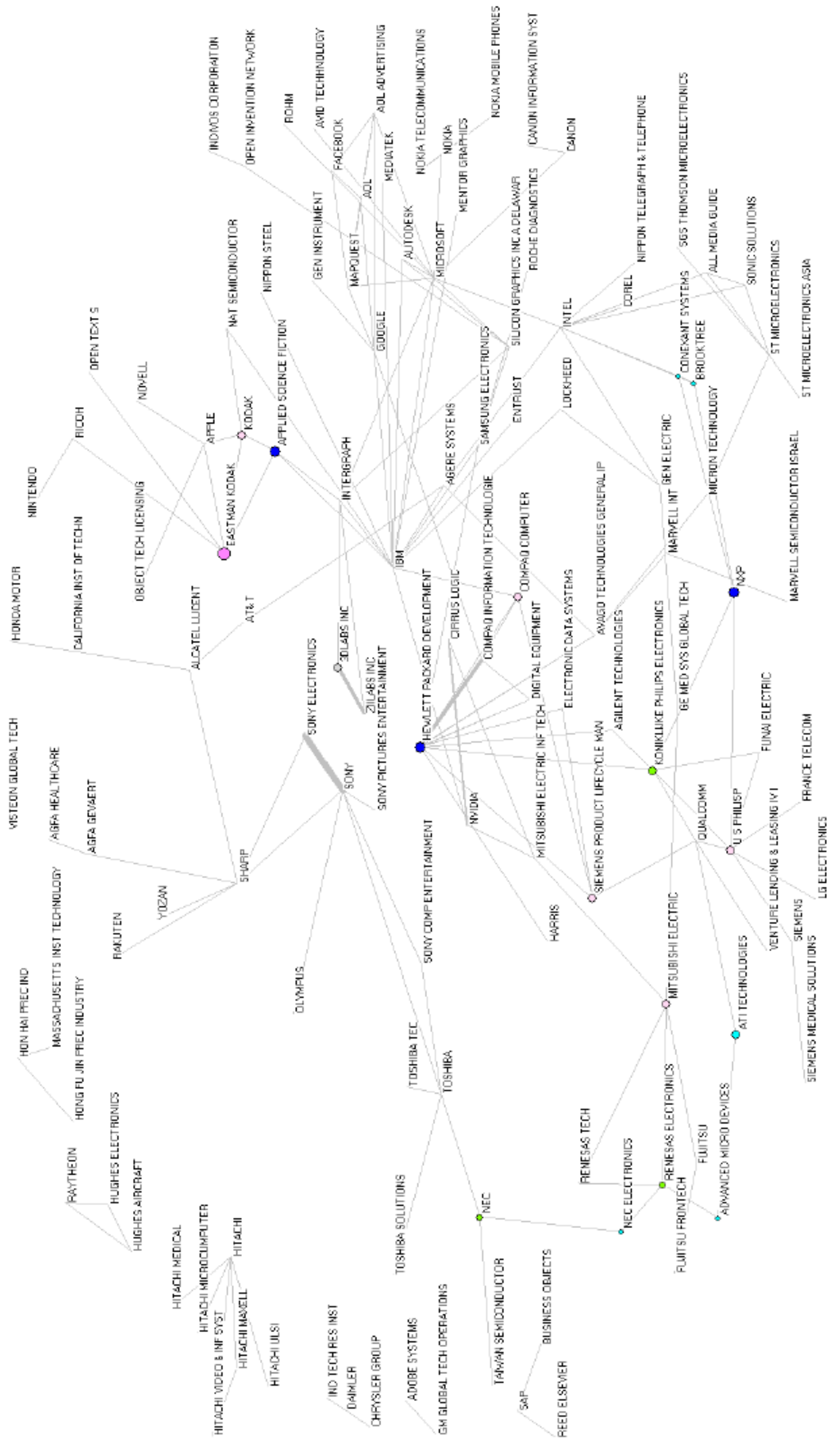


Figure 16: Liaison for Image Software

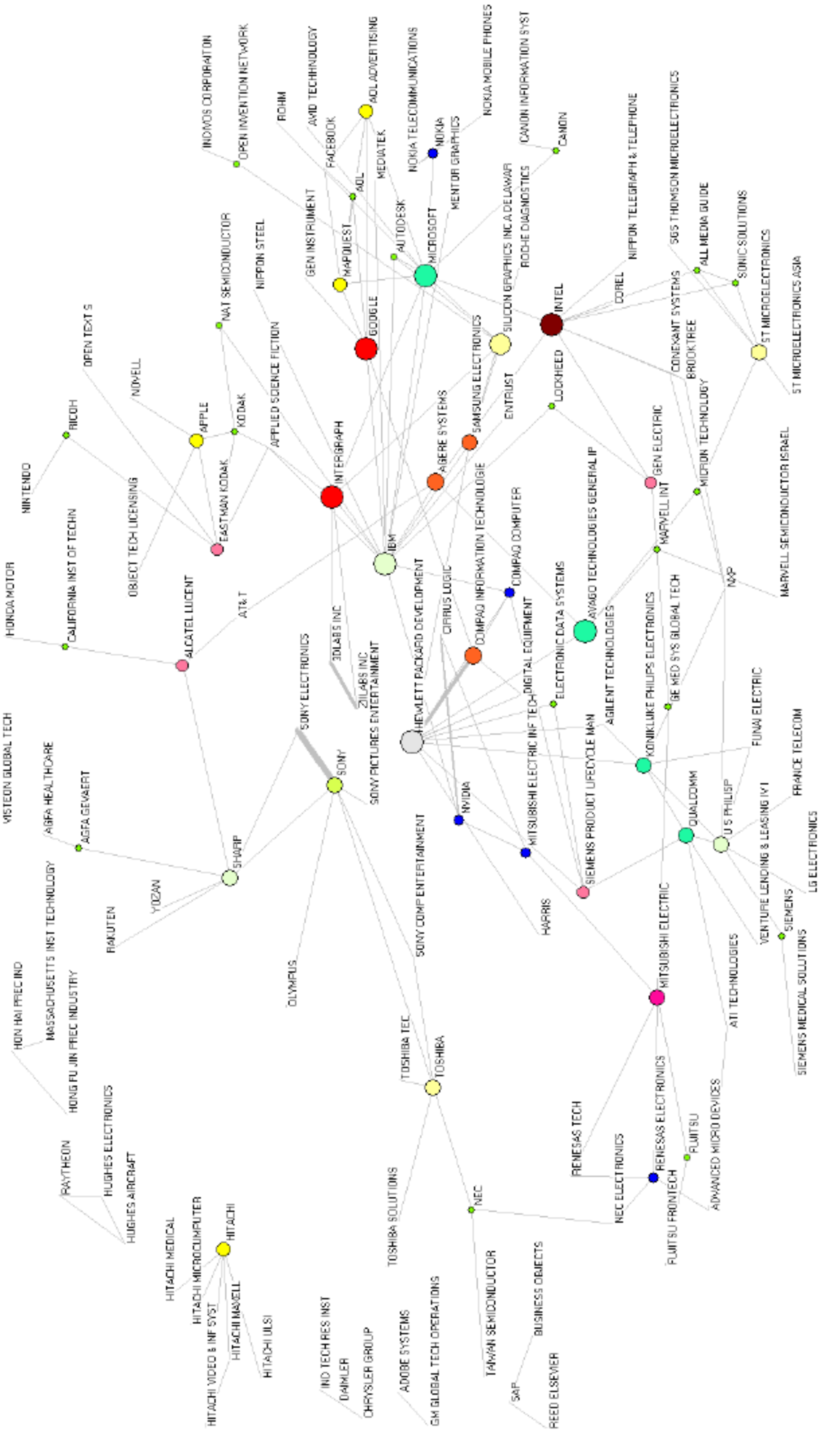


Figure 17: Itinerant for Voice Software

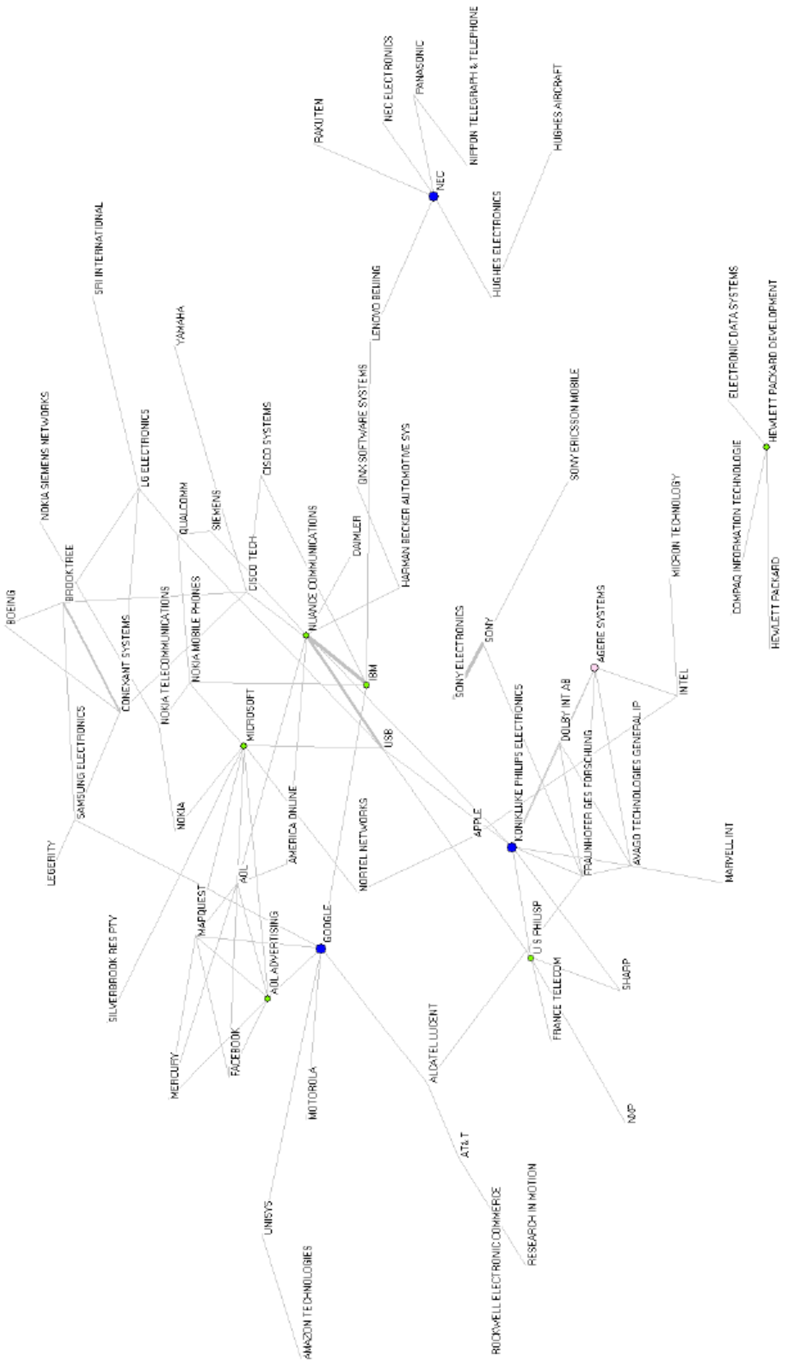


Figure 18: Gatekeeper for Voice Software

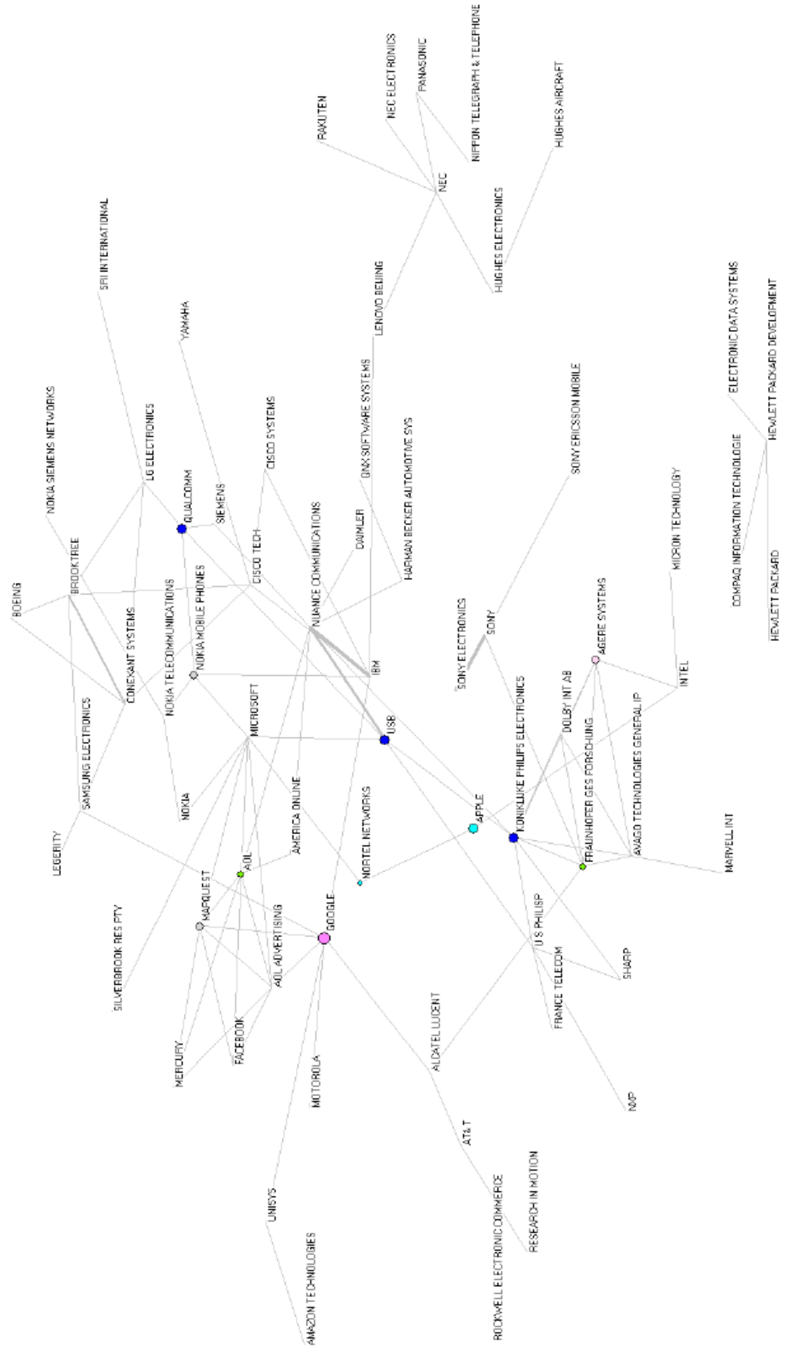
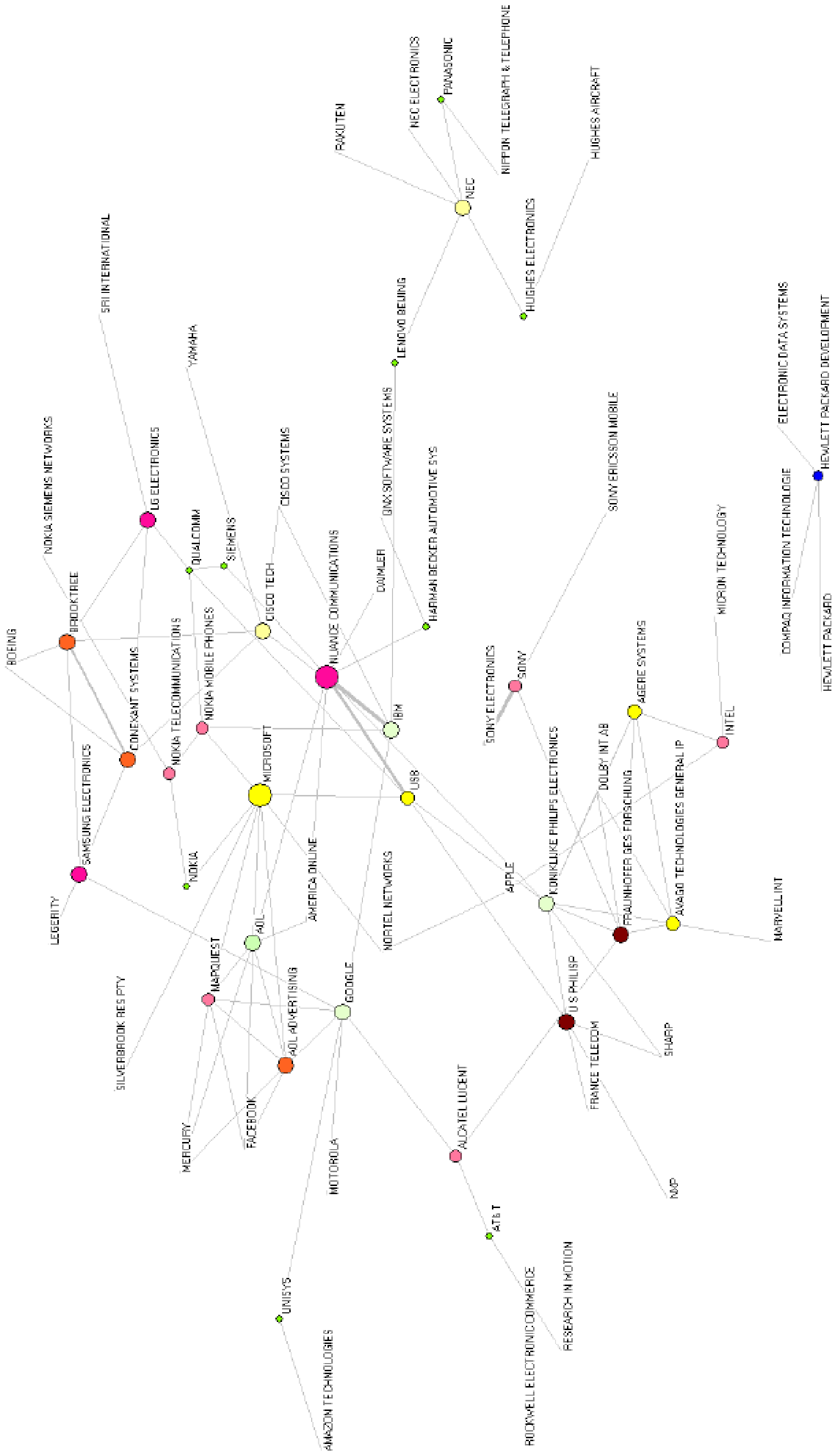


Figure 19: Liaison for Voice Software



The Figure 14–19 present the *brokerage roles* in cooperation network of the groups of image and voice data processing software. In the group of image data processing group, the US companies are still dominant, they frequently occur with large values of the *brokerage roles* and draw most of the other companies into a star-shaped network. For example, HEWLETT-PACKARD processes a center role regarding cooperation with other active players, particular CAMPAQ-INFORMATION-TECHNOLOGY. It also can be seen that IBM, being engaged with such a broad number of partners put him into a bridge-position between two large subnets. SONY, SHARP and TOSHIBA are important liaisons mediating knowledge transactions between the US company clusters and Japanese company clusters. HITACHI also acts as a bridge among the clusters. However, the member of the clusters for HITACHI are limited and isolated to the main clusters including the US and other Japanese companies. Looking at the group of voice data processing software, LENOVO BEIJING, a Chinese company, seems to play another interesting role since it serves an interface or link between the groups of NEC and IBM. Applicants bridging different clusters are interesting because they have easier access to knowledge from both clusters. It is also worth mentioning the subnet NUANCE COMMUNICATIONS located in. That has strong 18 cooperation relationship with IBM and USB and was founded as a broker between IBM and USB, bundling the patents of both applicants. The position GOOGLE situated is meaningful because GOOGLE combines *brokerage roles* of itinerant, gatekeeper and liaison.

2.4.3 Dynamic Changes in *betweenness centrality* for Management Software and Business Model

<u>Figure 20: *Betweenness Centrality* in 1990–2000 for Management Software and Business Model</u>

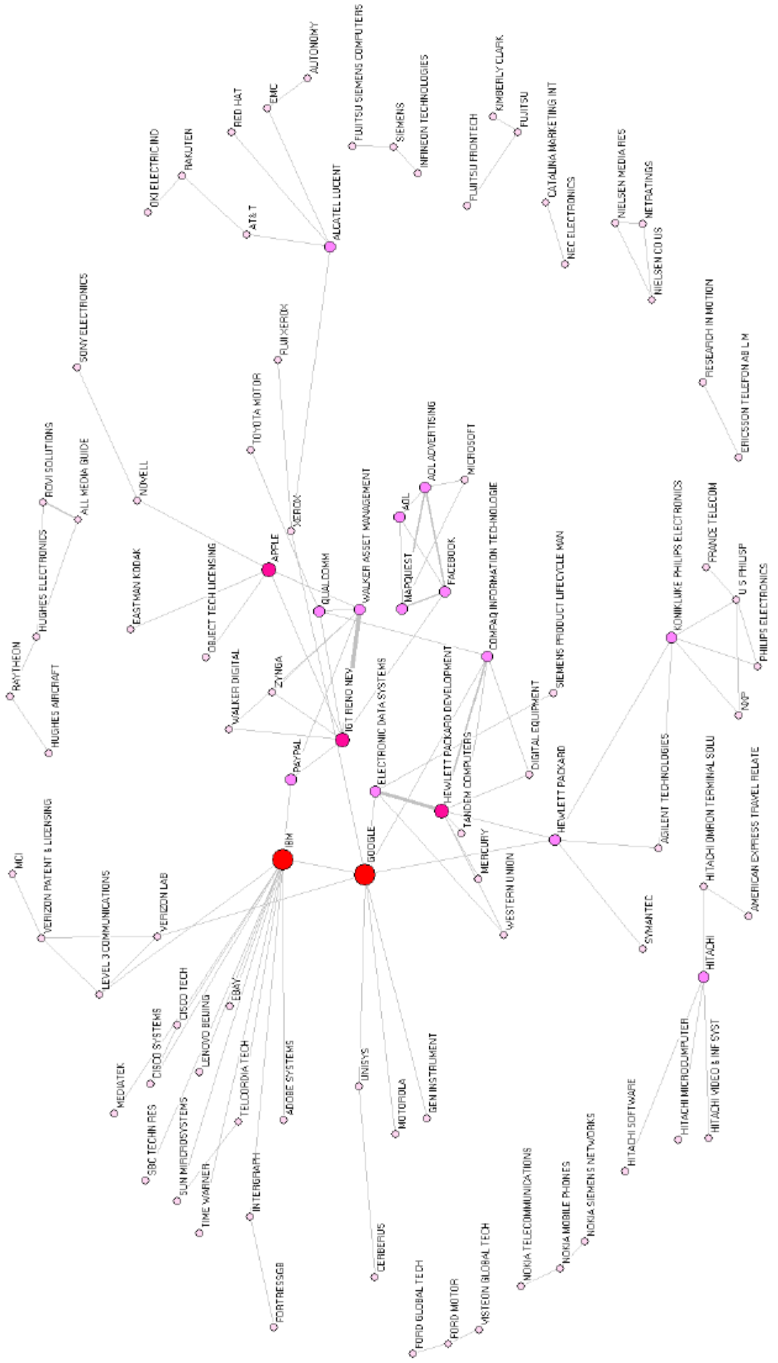


Figure 21: *Betweenness Centrality* in 2001–2012 for Management Software and Business Model

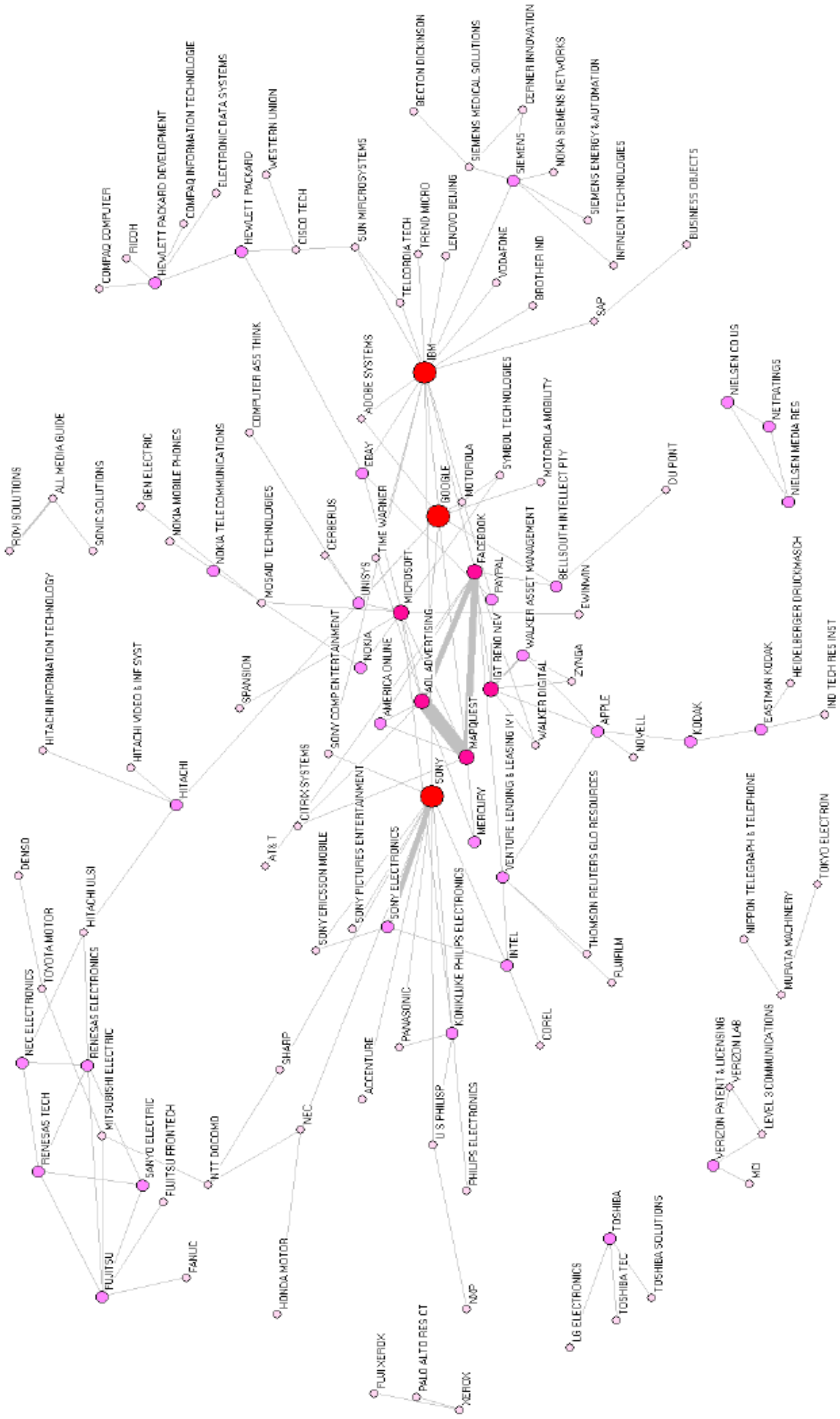


Figure 20 and 21 show extracted network about the dynamic changes of "*betweenness centrality*" for the group of management software and business model from 1990–2000 to 2001–2012. Figure 21 refers the period of 1990–2000, while Figure 22 is about the period of 2000–2012.

We can see from the figures, the network formed from active applicants becomes stronger and the tendency that applicants connected with a core applicant grew. As a result, the star-structure network established of core applicants is forming. The active applicants increased from 96 to 120, while the core applicants, were only the most famous company IBM and GOOLE in early years, but in the later period, more and more company grew up to core applicants such as SONY, AOL, and MICROSOFT. And what is worth mentioning is that, besides some US companies such as EBAY, UNISYS, APPLE, INTEL and PAYPAL, the companies from Japan and European countries, such as HITACHI, TOSHIBA, SIEMENS, NOKIA and KONINKLIJKE PHILIPS, grow up quickly, and cooperate frequently, hence form a subnetwork. However, not only the core applicants but also the bridge applicants are still almost the US companies.

2.5 Summary

In second chapter, I implemented empirical analysis about the competitiveness of Japanese companies engaged in software development, by using the patent data in firm level. I utilized social network technique to find out the characteristic, i.e., "betweenness centrality" and brokerage roles in software patent joint application network., and then carried out international comparison about software companies.

Main results can be concluded as the follows.

1. Since the definition of software patent is unclear, I tried to define "what is a software patent" using patent classification Cooperative Patent Classification (CPC) where performing reference of Graham and Mowery (2003) and Yamauchi and Onishi (2012). Then, I refined sample of software patents by searching keyword in the title of the patent document, e.g., software, program, computer, such as did in Bessen and Hunt

(2003) and Hall and MacGarvie (2006). As result, I identify 1,301,654 software patents applied for to the USPTO by 66 countries and regions during the period of 1990–2012.

2. I utilized the information of joint application for software patent to build a social network where the object of complicated network is linked vertexes and lines, and regard a company as a vertex, the joint application between the companies as a line. In visualization analysis, I use two kinds of indexes to measure the positions of firms. They are “betweenness centrality” and “brokerage roles”. Results of the visualization analysis suggested that, in sample period, Japanese software companies grow up quickly, and cooperate with others frequently. They became important players in the network and formed many own subnetworks. However, most Japanese companies are located peripherally compared with the US companies that situated almost in the center of the network. Visualization analysis on brokerage roles shown not only the core applicants but also the bridge applicants are still almost the US companies. Next chapter I pay attention on the business method software.

Chapter 3. Business Method Software Patents

As indicated by Spulber (2011), business method inventions contribute to the establishment of new types of firms, development of new industries, and improvement in the productivity and performance of established firms. A business method invention often involves the creation and application of economic and business knowledge. A business method invention can encompass scientific and technological discoveries that implement the commercial technique.

After discussion about generalized software patents in last chapter, I merely focus on business method patents in this section. In this chapter, I utilize the information of joint application for business method software patent to build a patent social network, in which I use several kinds of indexes, i.e., relative centrality, structural equivalence and brokerage roles to measure the positions of firms that engage in business method software development. Then I employ patent citations as a dependent variable to represent the knowledge flows or knowledge transfers and investigate the relationship between the network positions of firms and the knowledge flows.

3.1. Definition of Business Method

There is no precise definition of a business method patents. As pointed out by Hall (2009), for the purpose of examination, the USPTO defines a business method patent fairly narrowly, as a patent classified in US patent class 705, defined as "data processing: financial, business practice, management, or cost/price determination." However, the set of patents that could be classified as business method patents will change over time as the subject matter definitions used by the USPTO change, either in response to court rulings, or to other changes, including legislative. Hall (2009) argued that, patents reflecting these changes may be contained in two main patent classes, i.e., Class 705 (data processing: financial, business practice, management, or cost/price determination) and Class 902 (electronic funds transfer). In his empirical analysis, Lerner (2008) employed all patents as the business method patents with a primary assignment to subclasses 705/4, 705/35 through 705/45, and 902/1 through 902/41.

On the other hand, Hunt (2010) focused on "soft" business method patents that also qualify as software patents as well. Hunt (2010) defined the business method patents that fall into subclasses of Class 705, which include 1, 4, 7, 10, 16, 26, 30, 33, 45, 53, and 64–80. These exclude many of the patents primarily dealing with cryptography, postage metering, and other technologies less closely related to the provision of financial services.

In this chapter, I follow the definition of Hunt (2010), and employ the approach that combines keywords search and US classification, say, patents or applications that fall into the subclasses of Class 705 to define business method patents. I also check keywords in the title of patent documents to exclude those may related to hardware. The search algorithm is almost the same with the way of searching for software which I talked about in last chapter, so no more repeat in this chapter.

3.2. Social Network Analysis of Joint Patent Applications for Business Method Software Patents

This section highlights some characteristics of analysis of cooperation in business method patent applications by employing methodologies currently developed in practice. This type of network analysis allows identification of important players in business method development or in financial markets. In addition, their connectedness can be used in the analysis of competitiveness or for identifying partners for joint development projects for business method software.

3.2.1. Data Descriptive

I collect the business method patents applied for in the United States Patent and Trademark Office (USPTO) between 1995 and 2012. The data of the USPTO are derived from patent data set, PATSTAT ver. Oct. 2016,[7] which includes the US publication number of patents, patent application date, name of applicants (name of firms), US patent classification, patent citation, and name of applicants' country. Information on the US patent joint applications is obtained from the dataset leased by the Thomson Reuters, which includes the name of applicants and the US publication

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[7] PATSTAT, also known as the EPO Worldwide Patent Statistical Database, is snapshot of the EPO master documentation database (DOCDB) with worldwide coverage, covering more than 20 tables with bibliographic data of about 70 million for the patents issued by the most of patent institutes in the world. See the website: http://www.epo.org/searching/subscription/raw/product-14-24.html.

number of patents. Matching two datasets using the US publication number of patents, I identify 19,385 business method patents applied for by 3,160 firms around 37 countries and regions. I further identify 1,104 firms that jointly applied for 4,095 patents to the USPTO. Thus, most of the business method patents have only a single applicant that covers 78.9% of total business method patents in sample, and patents with co-applicants between 2 and 6 firms are approximately 19.4%. This large sample enables to uniquely examine the evaluation of knowledge flows using network analysis.

3.2.2. Social Network Analysis of Joint Business Software Patent Application Network

This section I utilize some social network indices which were talked about in last chapter. So, I would like just to show my analysis results.

3.2.2.1 Results of *betweenness centrality* and *brokerage roles*

Table 2 shows the results for the values of the *betweenness centrality*, *itinerant* and *gatekeeper/Representative* measured by the software *Pajek*.[8]

---

[8] To save space, I only list top 30 firms with the highest values for the *betweenness centrality*, *itinerant* and *gatekeeper/representative*, respectively. The values for the full sample are available upon request.

Table 2: Top 30 Firms with High Values of *Betweenness Centrality*, *Itinerant* and *Representative* Indices

Company	Betweenness Centrality	Company	Itinerant	Company	Representative
JP MORGAN CHASE BANK	0.180	JP MORGAN CHASE BANK	1174	WELLS FARGO BANK	33
BANK OF AMERICA	0.142	BANK OF AMERICA	932	CREDIT SUISSE	33
WELLS FARGO FOOTHILL	0.057	WELLS FARGO FOOTHILL	248	MICROSOFT	24
CITICORP	0.054	CITICORP	120	DEUTSCHE BANK TRUST COMPANY US	16
IBM	0.045	SILICON VALLEY BANK	110	LIGHTNINGCAST	15
SILICON VALLEY BANK	0.037	PNC BANK	84	GOING	15
WELLS FARGO BANK	0.036	WELLS FARGO BANK	80	GE CAPITAL	14
CREDIT SUISSE	0.035	CREDIT SUISSE	70	MORGAN STANLEY	13
WILMINGTON TRUST	0.027	COMERICA BANK	68	MORGAN STANLEY SENIOR FUNDING	12
PNC BANK	0.022	IBM	56	AMEDITECH	10
COMERICA BANK	0.020	LEHMAN COMMERCIAL PAPER	50	AOL	10
GEN ELECTRIC CAPITAL	0.019	CREDIT SUISSE	46	ROYAL BANK OF CANADA	10
BANK OF MONTREAL	0.018	WILMINGTON TRUST	32	JEFFERIES FINANCE	10
FIFTH THIRD BANK	0.017	FRONTSTEP	28	APPLIED BIOTECH	9
GE CAPITAL	0.017	ACCENTURE GLOBAL SERVICES	20	KODAK IMAGING NETWORK	9
CREDIT SUISSE	0.016	MICROSOFT	20	KODAK PORTUGUESA	8
GOOGLE	0.014	WELLS FARGO CAPITAL FINANCE	18	NPEC	8
MORGAN STANLEY SENIOR FUNDING	0.014	WACHOVIA BANK	18	DEG ACQUISITIONS	8
MICROSOFT	0.013	AT SYSTEMS	16	DRESSER RUSSIA	8
INFOR GLOBAL SOLUTIONS	0.012	FPC	16	FRONTSTEP (UK)	7
DEUTSCHE BANK TRUST COMPANY US	0.012	IGT	16	DRESSER RE	7
FLEET NATIONAL BANK	0.012	INTERGRAPH	14	INTERGRAPH PP & M US HOLDING	7
HEWLETT PACKARD DEVELOPMENT	0.011	INFOR	14	DRESSER ENTECH	7
WACHOVIA BANK	0.011	INFOR GLOBAL SOLUTIONS	12	INTERGRAPH TECHNOLOGIES	7
LEHMAN COMMERCIAL PAPER	0.010	EBAY	12	ISCHEMIA TECH	7
US BANK NATIONAL ASSOCIATION	0.009	DEUTSCHE BANK TRUST COMPANY US	12	INSTANT TECHNOLOGIES	7
MATRIA HEALTHCARE	0.009	US BANK NATIONAL ASSOCIATION	12	BINAX	7
ALCATEL LUCENT USA	0.009	AT&T	10	KODAK (NEAR EAST)	7
ACCENTURE GLOBAL SERVICES	0.008	KODAK AMERICAS	10	KODAK REALTY	6
WELLS FARGO CAPITAL FINANCE	0.008	HARRIS TRUST & SAVINGS BANK	10	ADERANT LEGAL HOLDINGS	6

Table 2 shows the results for the values of the *betweenness centrality*, itinerant and gatekeeper/representative measured by the *Pajek*.

The first and second columns in Table 2 reveal top 30 firms with largest values of *betweenness centrality*. Among these, only 6 firms are high tech, like IBM, GOOGLE, MICROSOFT, etc., while the rest are all banks or financial institutions.

The extent to which a firm controls the flow of information in R&D alliances depends on its position in the network. Although financial firms and providers of consumer payment services account for less than one-tenth of the total business method patents (Hunt (2010)), banks and financial institutions have accumulated a significant number of joint patents. Thus, compared to other types of firms, banks and financial institutes play a dominant role in terms of the *betweenness centrality* in the network of joint patent application.

The remaining columns show 30 firms with largest values of the *itinerant* and *gatekeeper/representative*, respectively. The values for the *itinerant* and *gatekeeper/representative* illustrate the number of clusters associated with each company, suggesting the number of the *itinerant* or *gatekeeper/representative* role the firm plays. Contrast to those of the *itinerant*, where banks and financial institutes act mostly as a consultant to both unconnected firms of same cluster, there seem to be more high-tech firms have the *gatekeeper/representative* roles in the R&D alliances. These high-tech firms seem to control incoming or outgoing information/resources to their group and make decisions about whether or not the unconnected actors in the group have access to information or resources. This tendency likely results from tech–tech firms generally being information intensive.

In my sample, only 133 firms engage in the role of the *itinerant* while these for *gatekeeper/representative* are 145. Majority of my sample firms are neither the *itinerant* nor *gatekeeper/representative*.

3.2.2.2. Visualization Analysis of *Betweenness Centrality* and *Brokerage Roles*

Here I choose the top 120 firms with the highest values of *betweenness centrality* to give readers an image of network visualization.

Figure 22: ***Betweenness Centrality*** **of Selected Firms**

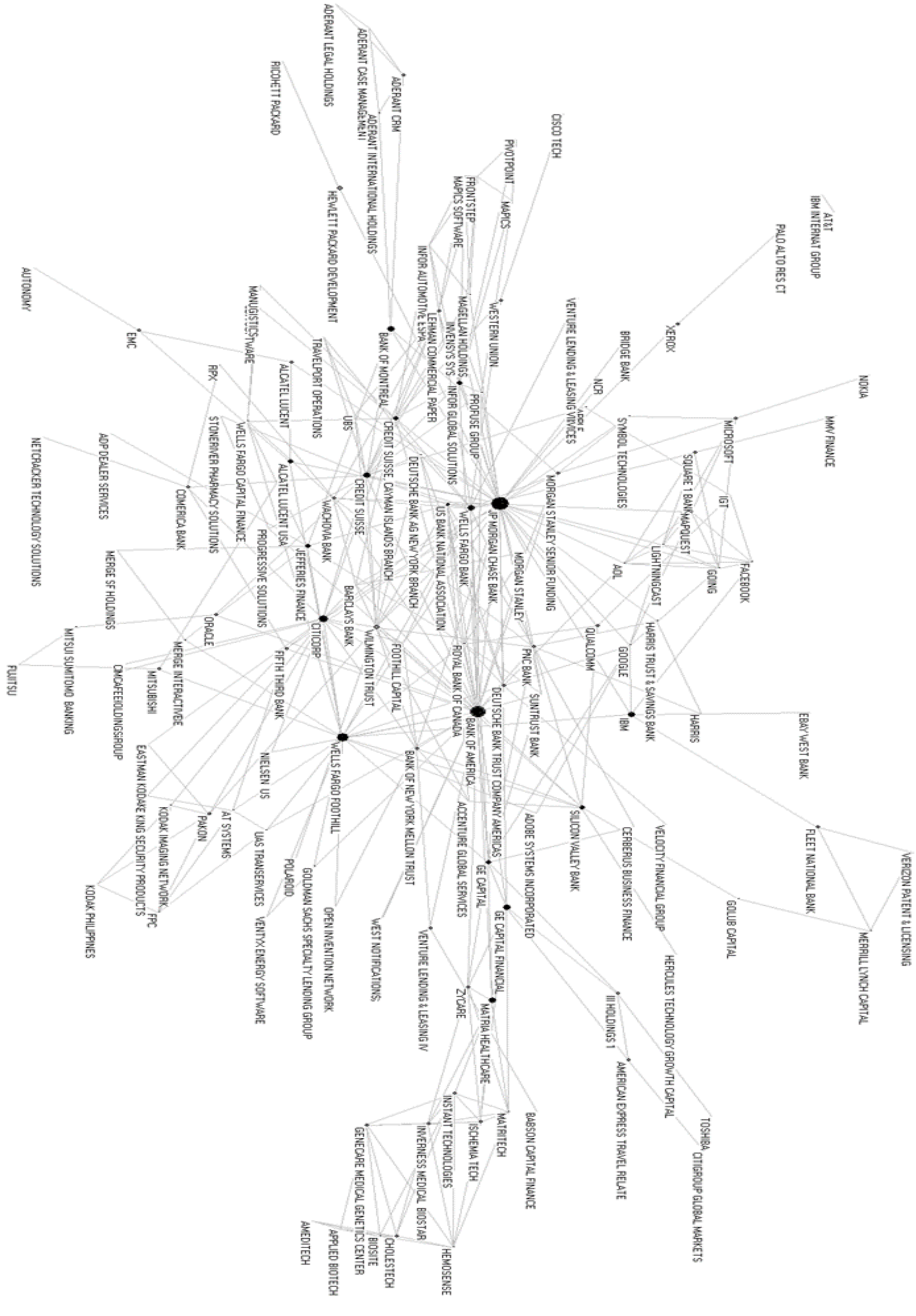


Figure 22 depicts *betweenness centrality* for selected firms. As shown in this figure, JP MORGAN CHASE BANK locates in the center of the network with biggest size of the vertex, and there are some firms with relative high value of the *betweenness centrality* around the central firm, such as BANK OF AMERICA, CITICORP, WELLS FARGO, and WELLS FARGO BANK. Figure 22 shows that big banks are major players in the network of joint application of the business method patents, as discussed above.

What's more, we can clearly observe that, joint applications are more prevalent in group companies. In Figure 22, there are some group firms like ADERANT INTERNATIONAL HOLDINGS, ADERANT LEGAL HOLDINGS, ADERANT CASE MANAGEMENT, ADERANT COMPULAW, ADERANT CRM, that scatter on the left side of the figure, while EASTMAN KODAK, KODAK IMAGING NETWORK, KODAK PHILIPPINES are distributed on the lower right side, where we can find that parent corporations tend to apply patents together with their subsidiary corporations. This may be attributed to internal structures of the firm and with division of labor.

Finally, we can perceive the edges among these big banks are denser than edges among peripheral firms. So that we can conclude that big banks tend to apply for a patent together with other big bank rather than a small company. This may be due to greater research capabilities of large firms, large firms having greater longevity and stability or due to other strategic considerations.

3.2.2.3. Visualization Analysis of *Brokerage Roles*

Figure 23: *Itinerant*s of Selected Firms

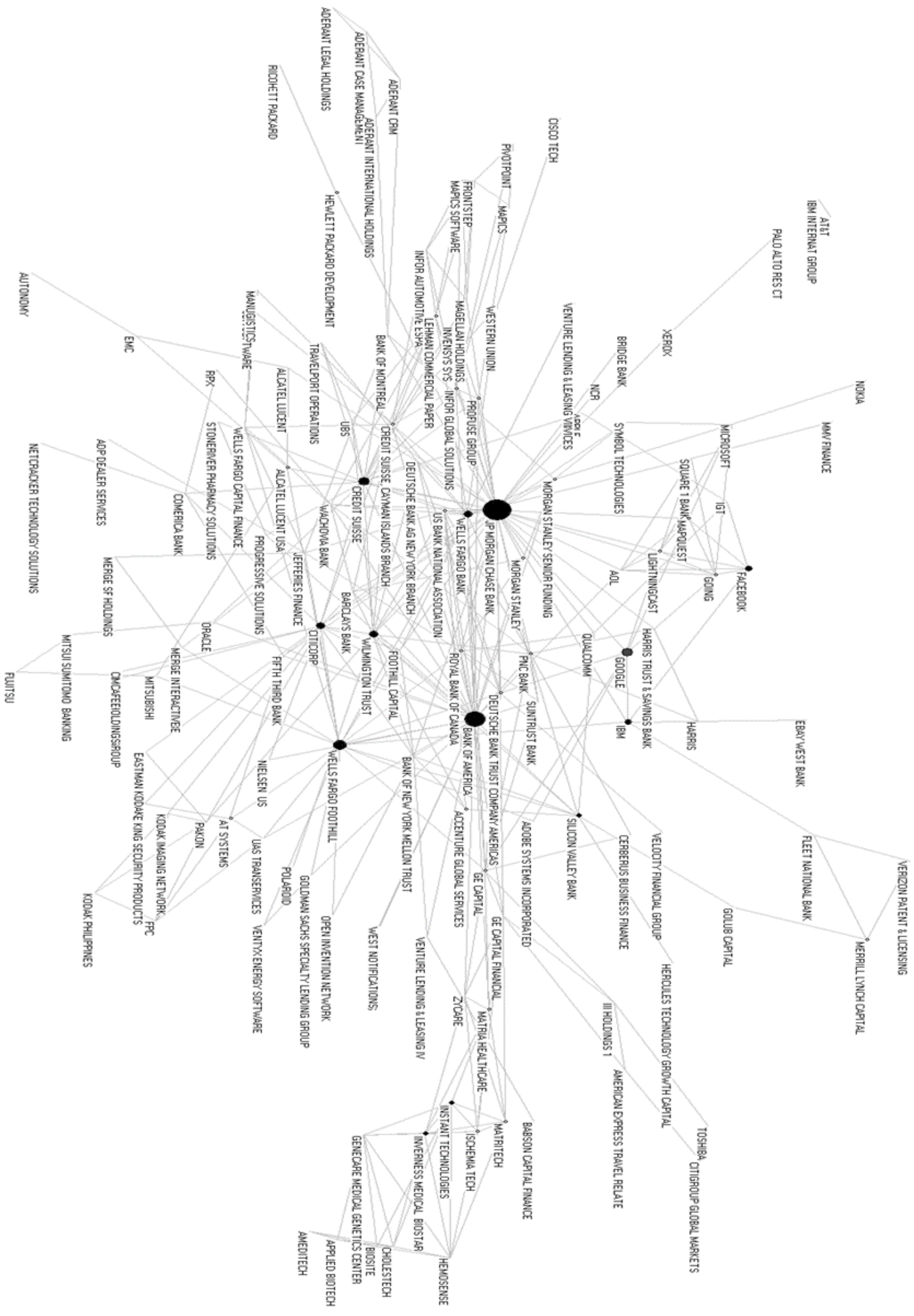
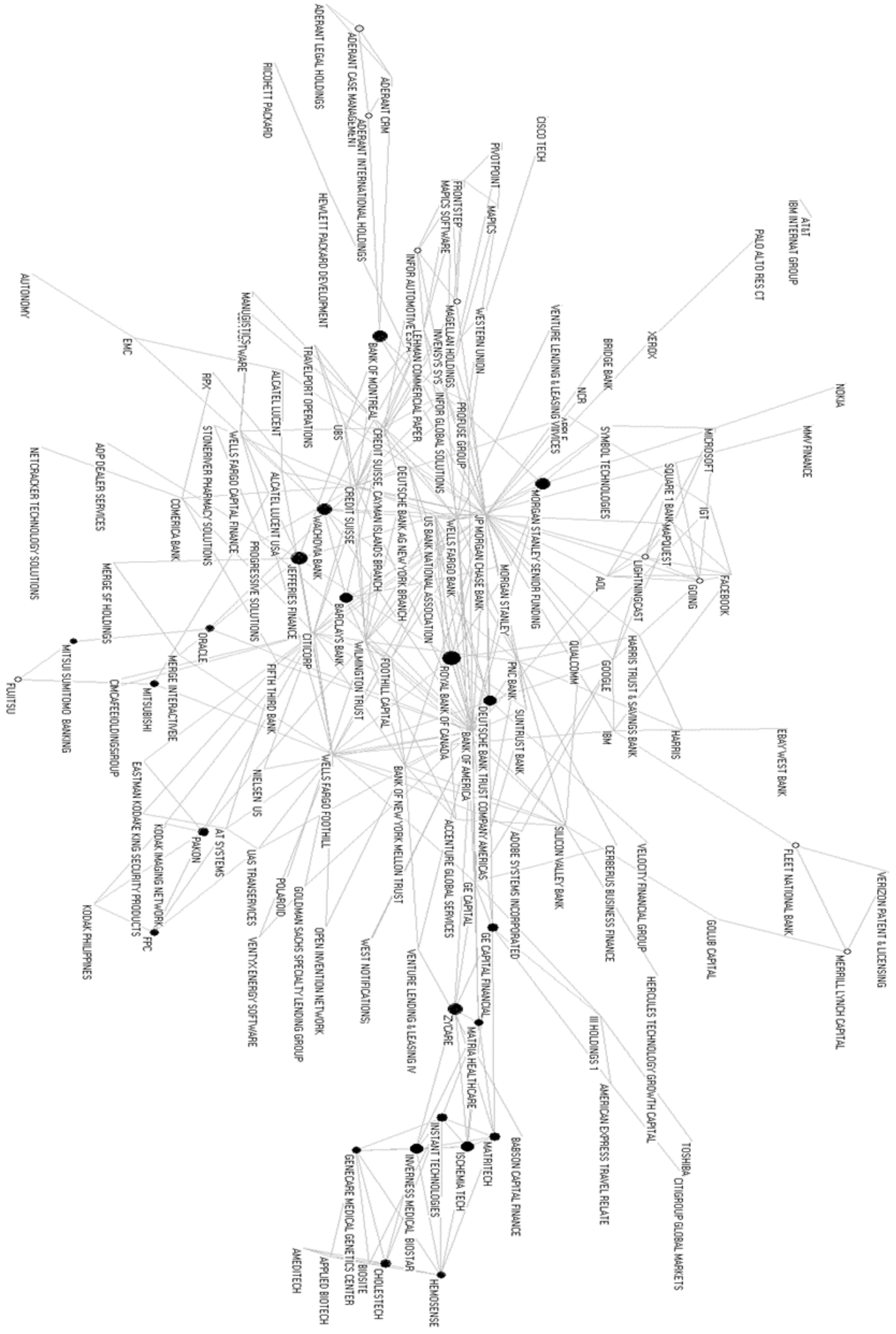


Figure 24: *Gatekeeper/Representatives of* Selected Firms



Figures 23 and 24 reveal *brokerage roles* of the *itinerant* and *gatekeeper/representative* for the network of joint application of the business method patents.

First, let’s have a look at the *itinerant*. In the *itinerant* framework, the *itinerant* broker B mediates between firms A and C that are in the same cluster, but the *itinerant* broker B is not part of this cluster. So, the *itinerant* broker is also called a consultant brokerage.

As shown in Figure 23, vertexes with bigger size act as external brokers of other two clusters, but it’s hard to identify which cluster they belong to. Among these vertexes, BANK OF AMERICA, JP MORGAN CHASE BANK, and WELLS FARGO reveal strong feature of “consultant” to different clusters, while for non-financial institutes, we can only observe GOOGLE that mediate between several high-tech firms as *itinerant* broker.

Next, pay attention to Figure 24 about the *gatekeeper/representative*. The *gatekeeper/representative* role is given if a broker delegates the brokering role of external knowledge to someone in the other cluster. This makes sense that the *gatekeeper/representative*s are inner brokers of one cluster, like ZYCARE and GE CAPITAL FINANCIAL. If we remove them from the clusters they belong to, information cannot input to or output from their clusters.

Finally, from what have been discussed earlier, can arrive at a conclusion that, although one firm can act in two or more *brokerage roles*, they are not necessarily actors with high *betweenness centrality*. Firms such as JP MORGAN CHASE BANK, it is a big bank both with highest values of *betweenness centrality* and *itinerant*, but it is not competent for the *gatekeeper/representative* role. Inversely, INSTANT TECHNOLOGIES acts both as an *itinerant* and *representative*; however, due to the relatively small value of *betweenness centrality*, it situates peripherally in Figure 6. The visualization of *brokerage roles* puts the analysis in perspective that I will further verify via regression analysis.

3.3. Empirical Analysis of Impacts of Network Positions on Knowledge Transfer

3.3.1. Technology Knowledge Flows and Patent Citations

In the literature, patent citations are informative of links between patented innovations, as innovation is a cumulative process ("standing on the shoulders of giants"). First, citations may constitute a "paper trail" for knowledge flows or knowledge spillovers between citing and cited firms. That depends on the fact that when patent B cites patent A may be indicative of knowledge flowing from A to B. There is a large body of papers utilizing patent citation data as a proxy for transfers or spillovers of technological knowledge (e.g. Jaffe and Trajtenberg (1999), MacGarvie (2006), and Goel et al. (2016)). Second, given that patents vary in quality, patent citations are indicative of the quality of patents or innovations.

In this section, I focus on the *relative centrality* of one firm with respect to another, types of *brokerage roles* and *structural equivalence* in the network of joint patent application, and their relationships with technology knowledge flows.

3.3.2. Hypotheses

As analyzed in the last section, inter-firm R&D alliances are a particularly appropriate context to examine how knowledge flows since one of the main reasons firms form alliances is to access technological information or know-how that facilitates innovation. Potential gains in the planned exchanges of knowledge resources which provide the information and learning benefits that lead to innovation and new product development, and consequently strength the competitiveness of the focal firm.

Central positions in R&D alliance networks provide the firm with a large catchment area for information. The presence of structural holes reduces information flow by eliminating the conduits that facilitate knowledge exchange. However, in dense local clusters with few structural holes, there is a high degree of redundancy in the information received (Burt (1992)). Therefore, maintaining the same number of ties, firms may derive more benefit from relative central positions that span structural holes since this relative central position provides greater access to novel and Distinctive information (Burt (1992), Ahuja (2000)).

Furthermore, when focusing on *relative centrality*, two of the most relevant embeddedness constructs for the study of alliance networks, Yang et al. (2011) argued that *relative centrality* reflects the degree of Distal information search and power dynamics within an alliance.

Thus, here I formulate a hypothesis,

***Hypothesis* 1**: A firm with relative central network position may make more patent citations from its counterpart firm.

That means that this firm may gain more in accessing technological information in the network. This may be due to greater familiarity with other firms in the network and with lower transactions costs associated with such interactions.

As discussed in the last section, there exist many "clusters", in which firms' behaviors are quite similar with regard to *structural equivalence* in the network of joint patent applications. *Structural equivalence* describes the way in which firms behave similarly with regard to their pattern in the R&D alliance network, even if they do not actually have ties with each other. Thus, this leads to an assumption that, structural equivalent actors tend to mimic each other, and tends to form similar tie structures that have influence on the innovation activities they engage in. Consequently, structurally equivalent actors tend to cite each other more in the network in joint patent applications. Again, this tendency might be tied to lower transactions costs and arrive at the second hypothesis.

***Hypothesis* 2**: Firms tend to cite more patents of each other if they are in the same cluster in the context of *structural equivalence*.

We understand knowledge brokers move knowledge around and create connections between different actors (firms in my case), and facilitate the creation, sharing, and use of knowledge. Additionally, as brokers of new knowledge resources, the control of information and the reliance of others on them could provide them with power (Burt (1992)). However, broker's functions are diverse, and not all actors in cluster networks have the capabilities or incentives for widespread interaction with other actors (Graf and Kruger (2011)). Furthermore, there are various costs and negative sides to the brokering of knowledge (Cumming and Cross (2003), Colazo (2010), Bercovitz and Feldman

(2011)). The costs of brokerage are that bottlenecks in information flow may form at the broker who risks being overloaded and stressed by others' reliance on it. In addition, actors, as broker in the network, may also bear the costs involved in maintaining and bridging ties (Long et al. (2013)). With this line of reasoning, I arrive at the last hypothesis as follows,

Hypothesis **3**: Different types of *brokerage roles* will likely have different impacts on knowledge transfers.

3.3.3. Empirical Methodology

To test the hypotheses outlined, I employ the specification widely used in international trade and technology spillovers (Maurseth and Verspagen (2002)) as the follows (here *i* and *j* denote firms, such that $i \neq j$),

$$C_{ij} = \exp\left(\alpha_1 log(P_i) + \alpha_2 log(P_j) + \alpha_3 Joint_{ij} + \beta_1 RelBetw_{ij} + \beta_2 DEqCluster_{ij}\right.$$
$$\left. + \beta_3 Itiner_i + \beta_4 Itiner_j + \beta_5 Gatek_i + \beta_6 Gatek_j + u_{ij}\right) \ldots (1)$$

Where C_{ij} is the number of backward patent citations made by firm *i* to firm j. This firm-specific dependent variable signifies the quality of patents and captures the flow of knowledge.

Turning to explanatory variables, P_i and P_j are, respectively, the number of patents applied for by firm *i* and firm *j* in the US patent class 705. $Joint_{ij}$ denotes a dummy variable that equals one if there is joint business method software patent application between firm *i* and firm *j*, and zero otherwise. Further, $RelBetw_{ij}$ is the *relative centrality* measured by the difference between the *betweenness centrality* of firm *i* and j, $DEqcluster_{ij}$ is a dummy variable for the *structural equivalence* cluster, which equals one if citing and cited firms are from the same *structural equivalence* cluster, and zero otherwise. As for the *brokerage roles*, r_i, $Itiner_j$, $Gatek_i$, and $Gatek_j$ mean the number of the *itinerant* or *gatekeeper/Representative* role the firm *i* and *j* play, respectively.

Additionally, I include dummies in the regression equation for the effect of the countries where the headquarters of focal firm *i* or firm *j* located, and dyadic dummies, *i*.e., $Comlan_{ij}$, for common official of primary language, g_{ij}, for border contiguity, and $Dist_{ij}$, for Distance between the countries of focal firm *i* and j. The border effects account for casual information flows via official and tourist visits, language similarity captures the transmission costs of knowledge (as does the headquarter location).

Table 3: Variable Definitions, Summary Statistics and Data Sources

Variable	Definition	Obs	Mean	Std.Dev.	Data Source
Cij	Number of backward patent citations made by firm *i* to firm *j*	16,876	3.218	6.64	PATSTAT ver. Oct. 2016
DEqCluster	Dummy variable for the structural equivalence cluster	16,876	0.322	0.467	measured by Pajek 4.05
ReBetw	*Relative centrality* measured by the difference between the *betweenness centrality* of firm *i* and *j*	16,866	-0.001	0.047	measured by the authors with Pajek 4.05
Itineri	Number of the *itinerant* role that the firm *i* play	16,866	0.045	0.187	measured by the authors with Pajek 4.05
Itinerj	Number of the *itinerant* role that the firm *j* play	16,872	0.052	0.201	measured by the authors with Pajek 4.05
Gateki	Number of *Gatekeeper/Representive* role that the firm *i* play	16,866	0.886	2.839	measured by the authors with Pajek 4.05
Gatekj	Number of the *Gatekeeper/Representive* role that the firm *j* play	16,872	0.92	2.838	measured by the authors with Pajek 4.05
log(Pi)	Number of patents applied for by firm *i* in the US patent class 705	16,876	75.996	168.228	PATSTAT ver. Oct. 2016
log(Pj)	Number of patents applied for by firm *j* in the US patent class 705	16,876	79.655	176.303	PATSTAT ver. Oct. 2016
DJoint	Dummy variable for joint application	16,876	0.041	0.198	Thomson Innovation Database (2015)
DContig	Dummy variable for border contiguity between the countries of focal firm *i* and *j*	16,077	0.788	0.409	CEPII database (2013)
DComlan	Dummy variable for common official of primary language between the countries of focal firm *i* and *j*	16,077	0.899	0.302	CEPII database (2013)
Dist	Distance between the countries of focal firm *i* and *j*	16,077	2383.1	2905.8	CEPII database (2013)

Table 4 Correlation Matrix of Selected Variables

	Cij	*DEqCluster*	*ReBetw*	*Itineri*	*Itinerj*	*Gateki*	*Gatekj*	*DJoint*
Cij	1.000							
DEqCluster	0.033	1.000						
ReBetw	0.028	0.005	1.000					
Itineri	0.102	-0.118	0.682	1.000				
Itinerj	0.064	-0.121	-0.733	-0.046	1.000			
Gateki	-0.016	0.074	-0.029	-0.067	-0.017	1.000		
Gatekj	-0.004	0.081	0.036	-0.021	-0.076	0.051	1.000	
DJoint	0.078	0.189	-0.012	0.041	0.056	0.029	0.021	1.000

Note: N= 16,866.

3.3.4 Statistics Descriptive

I gather the data for number of the business method patents and patent citations in the US Class 705 from Patstat ver. Oct. 2016 and merge the data with relative centrality, *structural equivalence* and *brokerage roles*. The sample include 16,876 pairs of citing and cited firm between which there is at least one patent citation made by firm i to firm j.

Table 3 shows the statistics descriptive for all co-variates and Table 4 reveals the correlation coefficients for these co-variates. From the tables we can find that the correlation coefficients are quite modest except for those between $RelBetw_{ij}$, $Itiner_i$ and $Itiner_j$, which are larger than 0.7.

3.4. Estimation Results

3.4.1. Baseline Results

Table 5: Network Positions as Drivers of Patent Citations: OLS Estimates

	Dependent Var.: Logarithm of Patent Citations LnC_{ij}						
	I	II	III	IV	V	VI	VII
DEqCluster	0.243***	0.239***	0.237***	0.239***	0.248***	0.241***	0.234***
	(16.62)	(16.38)	(16.32)	(16.41)	(16.95)	(16.56)	(16.06)
ReBetw	0.234	0.193	0.306				
	(0.29)	(0.96)	(1.55)				
*DEqCluster*ReBetw*	1.315**	1.340**		1.458***			
	(2.30)	(2.35)		(2.63)			
Itineri	0.024				0.112**	0.072	
	(0.18)				(2.34)	(1.54)	
Itinerj	0.048				0.033	-0.001	
	(0.37)				(0.82)	(-0.02)	
*Itineri*Itinerj*	3.516***					3.518***	3.641***
	(8.99)					(8.98)	(9.01)
Gateki	-0.012***				-0.009***	-0.012***	
	(-5.73)				(-4.54)	(-5.81)	
Gatekj	-0.006***				-0.003	-0.006**	
	(-2.64)				(-1.43)	(-2.54)	
*Gateki*Gatekj*	0.002***					0.002***	0.001*
	(4.18)					(4.18)	(1.72)
log(Pi)	0.125***	0.127***	0.127***	0.129***	0.127***	0.126***	0.128***
	(24.79)	(27.30)	(27.34)	(30.61)	(26.61)	(26.46)	(30.48)
log(Pj)	0.104***	0.108***	0.108***	0.106***	0.104***	0.103***	0.101***
	(19.84)	(22.44)	(22.36)	(25.35)	(21.82)	(21.66)	(24.70)
DJoint	0.253***	0.272***	0.270***	0.271***	0.262***	0.251***	0.255***
	(6.65)	(7.17)	(7.12)	(7.15)	(6.86)	(6.60)	(6.74)
DContig	0.082	0.085	0.085	0.085	0.084	0.082	0.083
	(0.99)	(1.03)	(1.03)	(1.03)	(1.02)	(0.99)	(1.00)
DComlan	0.129**	0.134**	0.134**	0.134**	0.131**	0.130**	0.135**
	(2.01)	(2.07)	(2.08)	(2.07)	(2.04)	(2.02)	(2.09)

Dist	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.23)	(0.21)	(0.22)	(0.21)	(0.23)	(0.23)	(0.22)
No. of Observations	16067	16067	16067	16067	16067	16067	16067
R^2	0.163	0.156	0.155	0.156	0.157	0.162	0.160

Note: (1) “***”, “**”, and “*” denote 1%, 5%, and 10% significance levels, respectively.

(2) Robust standard errors are used for t statistics in parentheses.

(3) The regressions include constant term and fixed effects of countries for citing and cited firms.

Table 5 presents the results of the OLS where the dependent variable is the logarithm of C_{ij}, the business method patent citations made by firm i to firm j. The estimations include country fixed effects of citing firm and cited firm that are not reported in the table to save space.[9]

As shown in the table, the coefficients of the log of the number of business method patents held by citing and cited firms, ($log(P_i)$ and $log(P_j)$), are positive and highly significant. This means that pairs of firms holding more patents experience higher technology flows between each other. Past patents signify familiarity with the patenting process as well as research experience and capability, all of which would make citations more likely.

The coefficient on joint patent applications (*Joint*) also has a positive and highly significant coefficient in all regressions. Thus, citations are more prevalent between the firms that have an experience in applying for joint patent application. This may be due to greater familiarity with partner's research. Lastly, the estimated results related to the effect of common official languages are significantly positive while those are insignificant either for the Distance or for border contiguity. The lack of relative significance of geographic factors make sense when one thinks of the underlying technology - software - that is easily transmitted via the internet, which reduces the significance of geographic borders.

Then turn to the estimated results concerning the impact of structural equivalent cluster, $DEqcluster_{ij}$. The coefficients are all positive and statistically significant. That is consistent with Hypothesis 2, suggesting more information or knowledge flows occur between citing and cited firms when they are in the same structural equivalent cluster.

On the other hand, coefficients for the *relative centrality*, $RelBetw_{ij}$, (columns I-III) fail to support *Hypothesis* 1. However, when use the interaction term between $RelBetw_{ij}$ and $DEqcluster_{ij}$, the coefficients turn to be strongly significant,

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[9] Since the correlation between *RelBetw_ij*, the relative centrality, and *Itiner_i* and *Itiner_j*, the itinerant of citing firm and cited firm is rather high (see Table 2), I conduct estimations separately from the column II to IV, and from the column V to VII to investigate the effects of the relative centrality and brokerage, respectively.

suggesting that the firm with higher *relative centrality* position will cite more patents from its counterpart firms that belong to the same structural equivalent cluster.

Table 5 also introduces considers results corresponding to *Hypothesis* 3. The coefficients of *itinerant* are not significant in most cases both for citing and cited firms, while those for the *gatekeeper/Representative* are significantly negative in all cases for citing firms and most cases for cited firms. When turn to the estimated results for interaction effects between citing and cited firms, $Itiner_i \times Itiner_j$, and $Gatek_i \times Gatek_j$, the coefficients are positively significant for the *itinerant*, as well as for *gatekeeper/Representative*. These results imply that, firms by acting as an *itinerant* or *gatekeeper/Representative* role may cite more patents between each other. On the other hand, patent citations may rarely occur between firms that act as *gatekeeper/Representative* role and firms that do not enact this kind of role.

3.4.2. Robustness check: alternate estimation method

Since the dependent variable, C_{ij}, is count data, the OLS estimates of the log-linearized model may be biased and inefficient. To deal with this issue, we estimate equation (1) using the Negative Binomial estimator and show corresponding results in Table 6.

These results are qualitatively quite similar to those of the OLS estimation. For instance, the coefficients of the log of the number of business method patents held by citing and cited firms, (*log(P_i)* and *log(P_j)*), are again positive and significant, as are the coefficients on joint patent applications (Joint).[10] Overall, the results are quite robust to the choice of the estimation technique.

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[10] An exception is the case for *Gatek_i*×*Gatek_j*, which is now significantly negative in column VII.

Table 6: Network Positions as Drivers of Patent Citations: Negative Binomial Estimates

	Dependent Var.: Patent Citations *Cij*						
	I	II	III	IV	V	VI	VII
DEqCluster	0.363***	0.351***	0.350***	0.351***	0.375***	0.362***	0.350***
	(14.91)	(14.21)	(14.17)	(14.19)	(15.23)	(14.87)	(13.99)
ReBetw	1.029	-0.195	-0.052				
	(0.86)	(-0.74)	(-0.20)				
*DEqCluster*ReBetw*	1.538***	1.646***		1.521***			
	(2.74)	(2.83)		(2.73)			
Itineri	-0.224				0.030	-0.049	
	(-1.18)				(0.45)	(-0.79)	
Itinerj	0.187				0.089	0.012	
	(1.02)				(1.50)	(0.22)	
*Itineri*Itinerj*	2.696***					2.689***	2.760***
	(7.22)					(7.28)	(7.05)
Gateki	-0.026***				-0.024***	-0.027***	
	(-9.20)				(-8.70)	(-9.23)	
Gatekj	-0.013***				-0.010***	-0.013***	
	(-4.49)				(-3.76)	(-4.43)	
*Gateki*Gatekj*	0.002***					0.002***	-0.001**
	(3.45)					(3.46)	(-2.35)
log(Pi)	0.214***	0.217***	0.217***	0.214***	0.219***	0.217***	0.210***
	(24.94)	(27.38)	(27.34)	(29.98)	(26.11)	(25.89)	(30.58)
log(Pj)	0.134***	0.135***	0.135***	0.138***	0.132***	0.131***	0.130***
	(15.34)	(16.92)	(16.96)	(19.59)	(16.44)	(16.29)	(19.33)
DJoint	0.366***	0.373***	0.370***	0.373***	0.365***	0.364***	0.365***
	(6.82)	(6.95)	(6.91)	(6.96)	(6.79)	(6.78)	(6.77)
DContig	0.196	0.193	0.193	0.193	0.196	0.196	0.191
	(1.28)	(1.27)	(1.27)	(1.27)	(1.29)	(1.29)	(1.25)
DComlan	0.201*	0.213*	0.214*	0.212*	0.205*	0.203*	0.216*
	(1.80)	(1.90)	(1.91)	(1.90)	(1.84)	(1.82)	(1.92)
Dist	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	(0.85)	(0.79)	(0.79)	(0.79)	(0.84)	(0.85)	(0.80)
No. of Observations	16067	16067	16067	16067	16067	16067	16067
R^2	0.075	0.072	0.072	0.072	0.073	0.074	0.073

Note: (1) “***”, “**”, and “*” denote 1%, 5%, and 10% significance levels, respectively.

(2) Robust standard errors are used for t statistics in parentheses.

(3) The regressions include constant term.

3.5 Summary

The third chapter implements empirical analysis about the competitiveness of firms engaged in business method software development, by using the patent data at the firm level. Using social network technique to find out the networking characteristic, i.e., relative centrality, structural equivalence and brokerage roles in patent joint application network, then carry out regression analysis of effects of these characteristics on knowledge transfers between patent citing and cited firms, the methodologies provide some unique insights. In this chapter, my main results are summarized as follows.

1. I identify a business method patent classified in US patent class 705, then refined sample of software patents by searching keyword in the title of the patent document, e.g., software, program, method, such as did in Bessen and Hunt (2003) and Hall and MacGarvie (2006). As a result, I identified 19,385 software patents applied for to the USPTO by 37 countries and regions during the period of 1995-2012.
2. I utilized the information of joint application of business method software patents to build a social network where the object of complicated network is linked vertexes and lines, and regard a firm as a vertex, the joint application between the firms as a line. I highlight some important characteristics, e.g., betweenness centrality, structural equivalence, and brokerage role, etc., in this network of joint patent applications. Results of the visualization analysis suggested that, the major players with the betweenness centrality and itinerant in business method software development field are mostly American big banks.
3. In regression analysis, I employed patent citations as a dependent variable to represent the knowledge flows or knowledge transfers, and investigated the relationship between the characteristics, i.e., relative centrality, structural equivalent cluster and brokerages, and knowledge flows. Estimated results suggested that, more knowledge flows are observed between the firms that are in the same structural equivalent clusters. In such cluster, the firm with higher values of “relative centrality” will cite more patents

from its counterpart firm.

4. Among the different types of the brokerage roles, I find positive promotion to knowledge transfer when the citing and cited firms both serve the role of the itinerant as well as the role of the gatekeeper/Representative, while the firms that act as the gatekeeper/Representative role cite less patent from the firms that do not enact this kind of role.

Overall, study of knowledge flows with regard to business method software provide visual and econometric insights into the behavior of firms. This has implications how knowledge evolves over time and for technology policy. For instance, the role of large firms in knowledge flows could be redeeming factors in antitrust cases. Obviously, the findings based on a particular technology would from verification from other cases.

Chapter 4. Review of Recent Development of Empirical Literature on Technological Standard

Technology standards are an essential component of economic activities, because they assumed to increase chances for sustainable market participation by promoting interoperability of parts and components that are necessary for design and production of complex products and facilitate exchange for commodities and financial assets traded on organized financial market. Technology standards are also considered as important tools to increase bargaining power and licensing revenues by combining with firms' strategies within Standard Setting Organizations (SSOs) standardization processes.

In this chapter, I focus on the recent development in technology standard and Standard Setting Organizations (SSOs): I discuss the definitions on technology standards, Standard Setting Organizations (SSOs) and Standard Essential Patents (SEPs), gather up information about Intellectual Property Rights (IPR) policies in SSOs. Then I survey empirical studies related to recent topics on technology standards. Finally, I introduce two databases which are widely used in the world and also referred in my paper.

4.1. Definitions of Technology Standards, Standard Setting Organization and Standard Essential Patents

4.1.1. Technology Standard

Standard is universally or widely accepted, agreed upon, or established means of determining what something should be, including concept, norm, or principle established by agreement, authority, or custom, and used generally as an example or model to compare or measure the quality or performance of a practice or procedure. The CENELEC[11] defines a standard formally, which is "document, established by consensus and approved by a recognized body that provides, for common and repeated

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[11] The European Committee for Electrotechnical Standardization. See http://www.cencenelec.eu/standards/DefEN/Pages/default.aspx

use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context".

Standards are becoming increasingly important, as they are needed to ensure interoperability between complex products and services at various points in the value chain. Standards can strongly influence technical direction, activities and search heuristics, and thus influence technological change. In many complex product industries fields, standardization is the primary method of achieving alignment between actors (Bekkers and Marinilli, 2012). Standards also have economic effects. Practically every industry operates on the base of technology standards, some are so mundane and pervasive that we tend not to notice them (Spulber, 2016).

For example, we can plug electric appliance into any socket in our country, or insert the USB into any computer interface, without adjustment. This is the significance of the underlying standard, and the economic effects of technology standards extend far beyond a few high-profile legal cases in high-tech.

4.1.2. Standard Setting Organizations (SSOs)

Generally, formal international technology standards are developed and undated within Standard-Setting Organizations (Barron et al., 2014). SSOs affect efficiency throughout the economy, with more than one thousand organizations developing hundreds of thousands of technology standards[12]. SSOs involve many standard and participating members all over the world, for example, the ISO/IEC JTC 1 (an acronym for "Joint Technical Committee 1"), which has 3160 published standards, 510 standards under development, and 32 participating country members, such as United States, Japan, Korea, Germany, France, etc.[13]. Different from JTC 1, in which membership is mainly open to national organizations, there are many other types of the SSOs, in which most of members are private firms, universities, public research institutions and other industry organizations. For example, The World Wide Web Consortium (W3C) that

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[12] For a list of standards, see https://www.consortiuminfo.org/links/#.WxXiUYjFKUk. The list includes categorized links and overviews of 1068 organizations, and more are added as they are announced

[13] See https://www.iso.org/committee/45020.html.

develops standards used in connection with the Web, among other technologies, has more than 450 members[14]. The most of member in the W3C are private firms that include Adobe, Apple, Cisco, Facebook, Huawei, etc. These SSOs often have tiered membership, where higher tiers are associated with more rights to sit on the board of the SSO, or chair working groups. The higher rights are usually associated with higher membership fee (Barron and Spulber, 2018). At the same time, it can be seen that SSOs provide vertical coordination among suppliers, producers and distributors, and SSOs are important for coordination of R&D, entrepreneurship, and product innovation in many industries (Spulber, 2018).

The core function of SSOs is to make decision by their members on the adoption of a standard. That is, who is eligible to vote, how voting power is allocated, and what approval thresholds are required are important issues to analyze for the adoption of a standard (Barron and Spulber, 2018). At the same time, these decision rules vary significantly across SSOs ranging from majority rule to full consensus (Spulber, 2018).

An SSO incorporates all variants of groups that develop standards, including Special Interest Groups (SIGs), standards-development organizations (SDOs), consortia, and other entities. The acronym SSO is often used interchangeably with SDO but, in principle, the former term covers the activities of both setting and managing standards, including associated intellectual property issues (Maskus, 2013).

SSO members participate in the institution voluntarily and their compliance with the technology standards is also voluntary (Barron and Spulber, 2018). Given that participation in SSO can be expensive and time consuming, why so many firms do choose to participate actively in voluntary, consensus-based standard setting activities.

According to Braveman (2013), SSOs have many potential benefits, whose collaborative work can advance technology, promote health and safety, and enhance quality and efficiency. From an antitrust perspective, by facilitating comparability and interoperability, SSOs can lessen barriers to entry, increase competition, reduce costs, and thus serve consumer welfare. The literature in the economics focused on the institution of SSOs has largely focused on one role: that of a forum where competitors

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[14] See http://www.w3.org/Consortium/Member/List.

can resolve conflicts. According to Farrell and Saloner (1988), the SSO is a place where the two parties can negotiate, but has no institutional features (e.g., rules governing decision-making or requiring concessions from sponsors).

4.1.3. Essential Patents

Most SSOs have adopted policies requiring that participants either disclose and/or license patents that are essential to the implementation of the standards (Contreras, 2017). These standard essential patents are indispensable in order to manufacture a product or offer a service based on the standards (Bekkers et al., 2011). Accordingly, a key element for standard development organizations' disclosure and licensing polices is how patents (or patent claims) are classified as "essential" to a standard, and what essentiality entails in practice.

Different standard development organization may define essentiality differently. Bekkers and Updegrove (2012) identify different features of standard development organization essentiality definitions that varied considerably over the ten standard setting organizations. Here we pay attention on several main features of them and summarize those in Table 7.

Table 7 Definition of Essentiality at the twelve Studied SSOs and Consortiums

	ITU/ISO/IEC	IEEE	ETSI	ANSI	IETF	OASIS	VITA	W3C	HDMI	NFC
Characterization	SSO	Consortium	SSO	SSO	Consortium	Consortium	Consortium	Consortium	Consortium	Consortium
Size	Large	Large	Large	Large	Large	Medium	Medium	Large	Small	Medium
Geographical focus	Worldwide	Worldwide	European /worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide
Excludes commercial essentiality	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes
Excludes non-essential claims	Yes	Yes	No/Yes(1)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Defines timing of essentiality test	No	Yes	Yes	No	No	Yes	No	Yes	No	No

Note: (1) ETSI does not explicitly distinguish between individual claims, but the commitments only apply to patents to the extent that they end up being essential. As such, actual licensing commitments are restricted to essential claims. Nevertheless, the essentiality definition is about patents as such, not claims

Source: Bekkers and Updegrove (2013)

The essential patents may strengthen the patentee's case for infringement by accused products that comply with the standard. For instance, in 2014, Unwired Planet, that acquired a portfolio of more than 2,800 patents from Ericsson in 2013, asserted six of these patents in the UK against a group of defendants including Huawei, Samsung and Google. Unwired Planet claimed that five of the six patents were essential to a portion of ETSI's 4G LTE standard. Then by April 2016, three of these technical trials had been completed with findings that two of Unwired Planet's asserted patents were valid and essential and two were not. In the cases Unwired Planet was successful, the court's decision regarding essentiality of the asserted patents hinged on the question of claim construction. a UK High Court, after a detailed claim construction exercise, agreed with Unwired Planet's construction and concluded that the patent was essential to the standard and thereby infringed (Contreras, 2017).

Patents often contain a number of different claims, some of which may cover technology included in a standard, and others of which may not. In essential claim infringement cases, the litigants will often argue whether a given claim is, or is not, essential. In the latter case, the non-essential claims should not be licensed on fair, reasonable and non-discriminatory (FRAND) conditions (talked about later). According to Bekkers and Updegrove (2012), nine of the ten standard development organizations' policies have IPR policies that refer to essential claims, as compared to "essential patents".

Many SSOs adopted an intellectual property policy that requires participants in the standard's development to: disclose any SEPs during the standard's development, this can entail revelation of trade secrets and patents that may be subject to circumvention, by inventing around, or investment in complementary patents that can limit the innovators ability to earn a return on its investment. The SSOs also require patent holders license any SEPs on fair, reasonable, and non-discriminatory (FRAND) terms, and also open the standard-setting process to all willing participants.

Next, we discuss IPR policies in SSOs.

4.2. Intellectual Property Rights (IPR) Policies in SSOs.

Intellectual property rights (IPR), and particularly patent claims, provide special challenges to standards developers. According to Bekkers and Updegrove (2013), the SSO IPR policies regarding SEPs may cover two important aspects: rules on the disclosure of SEPs, and member obligations to make licensing commitment. Besides these two important types of the SSOs roles, Farrell et al. (2007) also discussed negotiation rules that could help make negotiations better on royalty negotiation practices.

The most common rules related to IPR policies are traditionally referred to as “fair”, and “reasonable and non-discriminatory” (or FRAND) terms. The FRAND commitment is a voluntary agreement between the SSOs and their member, i.e., the holders of essential patents (Barron and Spulber, 2018).

As most formal standards bodies have adopted a FRAND policy, the members are obliged to notify any essential patent they hold and are requested to issue a public statement that they are willing to license for royalty-free or royalty-bearing under the FRAND conditions. However, this procedure may create some degree of uncertainty about using the lists of essential patents as indicator for knowledge position. First, firms are allowed to submit “blanket claims”, stating that they will license essential patents on FRAND conditions. Such blanket claims do not reveal individual patents, but help their owners possess large portfolios of essential patents even if the owners don’t own any essential patents at all. Inversely, there is some degree of “over-claiming”, where firms declaring patents to be essential while they are not in fact, for the purpose of licensing their patents (Bekkers and Martinelli, 2012). And this may arise from few legal or regulatory penalties associated with declaring too many patents as essential versus severe penalties for under-declaring (Contreras, 2017).

Some literature pay attention on the relationship between the SSO IPR policies and operations of different SSOs. Many works seek to explain it in terms of a policy tradeoff for an SSO: stronger rules mitigate the hold-up problem but could cause some patent holders not to join the SSO (Farrell et al., 2007).

Lerner and Tirole (2006) discussed theoretically forum shopping on the SSOs activities. Their model predicts that the sponsor of an attractive technology (such as

SEPs) can afford to make few concessions (such as royalty-free licensing or FRAND) to prospective users and to choose an SSO that is relatively friendly to the sponsor. Chiao et al. (2007) empirically explored SSOs' policy choices. They proposed some proxies to measure the orientation of the SSO to sponsors, which include the nature of the SSOs' organization, membership and the voting rules, and found a negative relationship between the extent to which an SSO is oriented to technology sponsors and the concession level related to royalty-free licensing or FRAND required of sponsors.

4.3. Some Recent Topics about Empirical Studies on Technology Standard

4.3.1. Roles and Effects of Consortium

As discussed above, standards have been traditionally defined cooperatively by governments or industry actors within formal SSOs. However, these formal SSOs are often perceived to be slow and bureaucratic, particularly when intellectual property rights have become part of the negotiation. e.g.: 3G wireless telecom standard studied here is associated with around 16,000 essential patent disclosures, and its development took most of a decade (Delcamp and Leiponen, 2012). Statistically, the speed of international standard setting of ISO and IEC is 7.5 years in 1990s. Farrell (1996) and Simcoe (2003) depict the standard-setting process as a "war of attrition" between multiple parties, the highest quality project ends up being selected. The time until this selection is seen as "delay", will be a function of the presence of vested interests.

To accelerate the process, sub-groups of firms may create less formal upstream alliances or consortia. These types of collaborative organizations offer opportunities to discuss, promote certain technologies, or they can be used to actually develop new technical specifications that will subsequently be submitted to formal SSOs for official approval (DeLacey et al. 2006). The European Committee for Standardization (Comité Européen de Normalisation or CEN) maintains a list of over 200 important international multi-vendor ICT consortia and admits that "Much of the key standardization activity in ICT is carried out by industry consortia rather than in formal standards organizations such as CEN and ISO" (CEN, 2012). In the estimated sample by Bekkers and

Updegrove (2012) shown in table 7, seven of the ten standard development organizations are consortia, while only ITU/ISO/IEC, ETSI and ANSI are formal SSOs.

According to Delcamp and Leiponen (2012), monopolization of key technologies underpinning a widely used standard is likely to lead to excessive royalties and potential holdup that can slow down technology adoption and reduce social welfare. Consortia primarily is a mean to share and reduce R&D expenses, enable scale economies and reduce effort duplication among participants. Firms' incentives to collaborate in these consortiums are mutual exchange of information, access to complementary R&D, learning, influencing, and advertising. Especially small firms often join the working groups in order to learn from their competitors (Baron and Pohlmann, 2013). What's more, participation in standardization consortia may offer a venue for firms to promote their technologies and become central and powerful players in an innovation network and increases a firm's power to influence standard setting. On the other hand, due to that R&D investments create knowledge spillovers, spillovers are positive externalities that enhance the social benefits of R&D investments. Consortia may enable the internalization of these spillovers (Delcamp and Leiponen, 2012).

However, participation in standardization consortia may also have demerits. Private consortia tend to be closed and undemocratic. Firms have to support expenses such as membership fees, and travel, meeting, and human resource costs, and multiple levels of membership differentiated by a steep fee structure, whereby it can be prohibitively expensive for smaller firms to participate in the "sponsor" levels, whereas members on lower levels are likely to be excluded from committee chairpersonships, formal votes, or rights to submit technical appeals. What's more, it can induce the risks of technology leakage and imitation: internal research groups just to absorb knowledge from consortium work, secrecy is thus no longer an effective protection method and member firms may need to follow alternative appropriation strategies (Delcamp and Leiponen, 2012).

Some consortia substitute for more formal SSOs and issue their own standards, but most of them actually accompany formal standardization. Consortia is not a mean for members to contractualize R&D. However, they increase the propensity of their members to build upon each other's technology (Delcamp and Leiponen, 2012), thereby enhancing R&D coordination while improving their chances to influence the standard setting process (Leiponen, 2008) and to obtain essential patents (Pohlmann and Blind, 2012). The precise role of consortia in standard development differs substantially from standard to standard. For instance, upstream consortia are active in the development of technical specifications to be submitted as proposals to the working groups, while downstream consortia deal with the promotion, maintenance or enforcement of existing standards. Baron and Pohlmann (2013) find that among the firms contributing to a standard, technological specialists are less likely to be member of a consortium. Firms specializing on the same technological components of the standard are significantly more likely to jointly be members of the same consortium, and companies are more likely to be members of the same consortium with companies specializing in R&D that is substitutable rather than complementary to their own patent portfolio. In spite of this heterogeneity, all standards consortia have in common that they consist in subsets of companies participating in a more inclusive formal standard development process, and that their objective is to coordinate their members' contribution to this shared technological standard (Baron and Pohlmann, 2013).

4.3.2. Strategic Behavior in SEPs Claim

Some recent literature focused on the values or knowledge positions of the SEPs. Baron and Pohlmann (2015) argued that, many patented inventions are made in the process of standard development (e.g. address a specific need or problem in a standardized technology), but not included in the standard. This is because many different firms make contributions to standards under development, and contributions are subject to votes by SSO members. In their recent study, Bekkers and Martinelli (2012) indicated that claims of essentiality are the results of strategic behavior of the patent's owner instead of the actual technical relevance. A strategically operating patent owner might try to get deeply involved in the drafting of the standard and use opportunities to suggest technologies that it owns patents on, if other participants have a similar agenda and incentives for such practice, it will result in increase of their own portfolio of essential patents.

As most formal standards bodies have adopted a FRAND policy, members are obliged to notify any essential patent they hold and are requested to issue a public statement that they are willing to license for royalty-free or royalty-bearing under the

FRAND conditions. However, this procedure may create some degree of uncertainty about using the lists of essential patents as indicator for knowledge position. First, companies are allowed to submit “blanket claims”, stating that they will license essential patents on FRAND conditions. Such blanked claims do not reveal individual patents, but help their owners possess large portfolios of essential patents even if the owners don’t own any essential patents at all. Inversely, there is some degree of “over-claiming”, where firms declaring patents to be essential while they are not in fact, for the purpose of licensing their patents (Bekkers and Martinelli, 2012). And this may arise from few legal or regulatory penalties associated with declaring too many patents as essential versus severe penalties for under-declaring (Contreras, 2017).

4.3.3. Technology Standard and Knowledge Spillovers

It is well understood that the non-rival nature of knowledge as a productive asset creates the possibility of “knowledge spillovers”. Economists have been attempting to quantify the extent and impact of knowledge spillovers. One line of research of this type has utilized patent citations to identify a “paper trail” that may be associated with knowledge flows between firms (Jaffe and Trajtenberg, 2000). Patent citations presumably convey information or knowledge flows between innovations or patent holders. The number of citations a patent has can also been seen to be linked to the market value of the company owning the patent and the value of the technology (Hall, et al. 2005). Leiponen (2008) studied a number of consortia contributing to 3GPP. She shows empirically that connections with peers in related consortia enabled members to better influence the selection of standard components at 3GPP. Delcamp and Leiponen (2012) set up an empirical model to test whether consortium participation by a firm increases the likelihood that its patent is cited by other members of the same consortia in their patents that are declared as essential for the wireless telecommunication system UMTS. The results show that joining a consortium connected with 3GPP increases cross-citations between the members’ patents. If a firm attended a relevant technical consortium, other members of the same consortium were significantly more likely to cite its earlier patents in their own current patents that eventually led to essential IP declarations. They also argue that if knowledge spillovers rather than strategic citation are primarily driving citations, then technical consortia should be more conducive to them. Baron and Meniere (2014) also observe an increase in patent output after a firm joined a consortium. What' more, in Baron and Pohlmann (2014), they predict standard setting organizations may be oriented towards two different regime--Public Good or Rent Seeking, that induce opposite effects of consortium formation on firms' R&D investment. They established a model to demonstrate the innovation output, as measured by the number of citations-weighted patent priority filings. The empirical results show that companies increase their own output of citation-weighted patents after joining a consortium. Other consortium members also increase their innovation output as a reaction to a new firm joining the consortium. Both effects are significantly weaker or even revised in the case of a Rent Seeking regime.

4.4. Some Development in Database Construction for Technology Standard

As indicated by Baron and Spulber (2015), because the development and implementation of technology standards interacts with economic decisions and market transactions, it is necessary to take standards into account in empirical economic analysis. Thus, some databases are created for this purpose.

The Searle Center Database on Technology Standards and Standard Setting Organizations (SSO) is made by Baron and Spulber in 2015[15]. The Searle Center Database consists of quantifiable characteristics of 797,711 standard documents issued by 615 different SSOs, and the database describes the rules of 36 SSOs on standard-essential patents (SEPs), openness, participation, and standard adoption procedures. In addition, the database identifies institutional membership for a sample of 191 standards organizations including SSOs and other organizations directly involved in the development of technology standards. What's more, the database includes information on various document characteristics, such as the publication date, the issuing SSO, the technological classification, the number of pages, references between documents, equivalence between documents issued by different SSOs, and withdrawal dates (if the document is inactive).

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[15] See http://www.law.northwestern.edu/research-faculty/searlecenter/innovationeconomics/data/technologystandards/.

On the other hand, Bekkers et al. built Disclosed Standard Essential Patents Database (dSEP) which was previously called as the OEIDD database[16]. The dSEP database provides a full overview of all disclosed IPR at setting organizations world-wide. Based on the archives of thirteen major SSOs as of March 2011, the disclosure data is cleaned, harmonized, and all disclosed the United States Patent and Trademark Office (USPTO) or the European Patent Office (EPO) patents or patent applications are matched against patent identities in the PATSTAT database[17]. Overall, the database contains 45,349 'disclosures' (disclosed patents, patent applications or blankets), from 938 different firms or organizations, with 13,402 USPTO or EPO patents or patent applications identified in PATSTAT (with 6900 unique USPTO or EPO patents or patent applications), belonging to 4816 different INPADOC patent families and 5340 different DOCDB patent families[18].

In summary, the two databases introduced above cover the common aspect, they both pay attention the big famous SSO like CEN (European Standard Committee), IEC (International Eletrotechnical Commission), ISO (International Organization for Standardization) and JTC1 (introduced last chapter). And they both provide the information about which companies are involved in each SSO, together with year information and the patent office. As for the quantity of information, of course the former is bigger and we can easily use the statistical analysis software to analyze the competition or cooperation of firms in each SSO. In addition, more topics can be found, like consortium and patent citation (introduced in the following chapter). However, the later database provides us with more detailed information like unique application ID for each patent, which can be used to merge with larger database like PATSTAT for further information. And how to better combine the two databases will also be a research project for the users of the databases.

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[16] See http://ssopatents.org/.

[17] EPO Worldwide Patent Statistical Database. See the following website for more details, https://www.epo.org/searching-for-patents/business/patstat.html#tab-1.

[18] INPADOC are Legal status data that relates to information on the events during the lifetime of a patent application and DOCDB data is the backbone of many commercial products and services. It includes bibliographic data from over 90 countries worldwide. See the following website for more details. https://www.epo.org/searching-for-patents/data/bulk-data-sets.html.

4.5 Summary

In this chapter, I surveyed recent literature about technology standard, Standard Setting Organization (SSO) and standard essential patents (SEPs), including the definitions about the topics above, the information about Intellectual Property Rights (IPR) policies in SSOs. Also, empirical studies related to technology standards and databases. Anyway, as these topics are abstract and invisible enough, it's not easy for us to capture the meaning or imagine how they can affect our life/society/country, I would like to talk a little about the case in Japan, and try to give my humble opinion.

As a matter of fact, Japan has attached great importance to standardization. The current standardization system in Japan has been contributing greatly to the development of the manufacturing industry and the improvement of the living of the people since the establishment after the war. However, there are also problems during the process of standardization, for example, the number of international standards led by Japan is limited, and thus it is difficult to meet the need to participate in international standards competition. And there is not a tendency that individual companies are formulating rules to expand and acquire markets compared to the United States and European countries (METI, 2017).

Based on this situation, it is more important than ever to actively participate in international standardization and to ensure international consistency in JIS/JAS and domestic regulations[19]. Also, it is necessary for companies and the governments to be involved quickly in the rules' formation before technological marketization is realized, and propel the open innovation beyond the national border, R&D and standardization simultaneously proceed in global corporate consortium.

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[19] JIS and JAS refer to Japanese Industrial Standards and Japanese Agriculture Standard.

Chapter 5. Essential Patents and Knowledge Position, a Network Analysis on the Basis of Patent Citation

As indicated by Bekkers and Martinelli (2012), using network analysis on measuring knowledge positions in the “main path” of standards-based markets, the essential patents did not match very well with the actual knowledge positions of firms in the most cases. They argued that companies may not always declare important patents they hold as essential patents in SSOs standardization processes. Both the propensity to declare patents as standard-essential and timing of declaration may be subject to the firms’ strategic considerations.

In this chapter, I pay attention on essential patents declared by member firms in JTC1. My sample includes 1149 essential patents declared by 63 member firms during the period of 1995-2010. I also build a dataset for the citation relationships between the patents, which involves more than 15000 pairs of citations between the essential patents and between the essential patents and other patents held by the member firms.

In network analysis part, I focus on the knowledge position of the patents not only on “main path” discussed in the earlier literature, but also in brokerage processes. While the “main path” method is widely found to result in a valid representation of technological development, such an approach is likely to have serious limitations. A typical “main path” includes only a dozen or two dozen patents, even if the knowledge field includes as large as 10,000 patents or more. The advantage of the broker position in a network is that the participants who are positioned an information brokers between groups with different information backgrounds benefit from information flows, and have a positive influence on their quantitative and qualitative output, and even can induce competition or conflict between neighbours who are not linked directly. Thus, the approach to brokerage and affiliations may help us to understand more the roles of patents that dominate a transactional or exchange of knowledge network.

I also implement regression analyses for the determinants of strategies of the SSOs members related to the declaration of essential patents by employing the timing for cooperation and entry into an industry SSO, and patent portfolio of the SSOs members.

5.1. Essential Patents in the JTC1

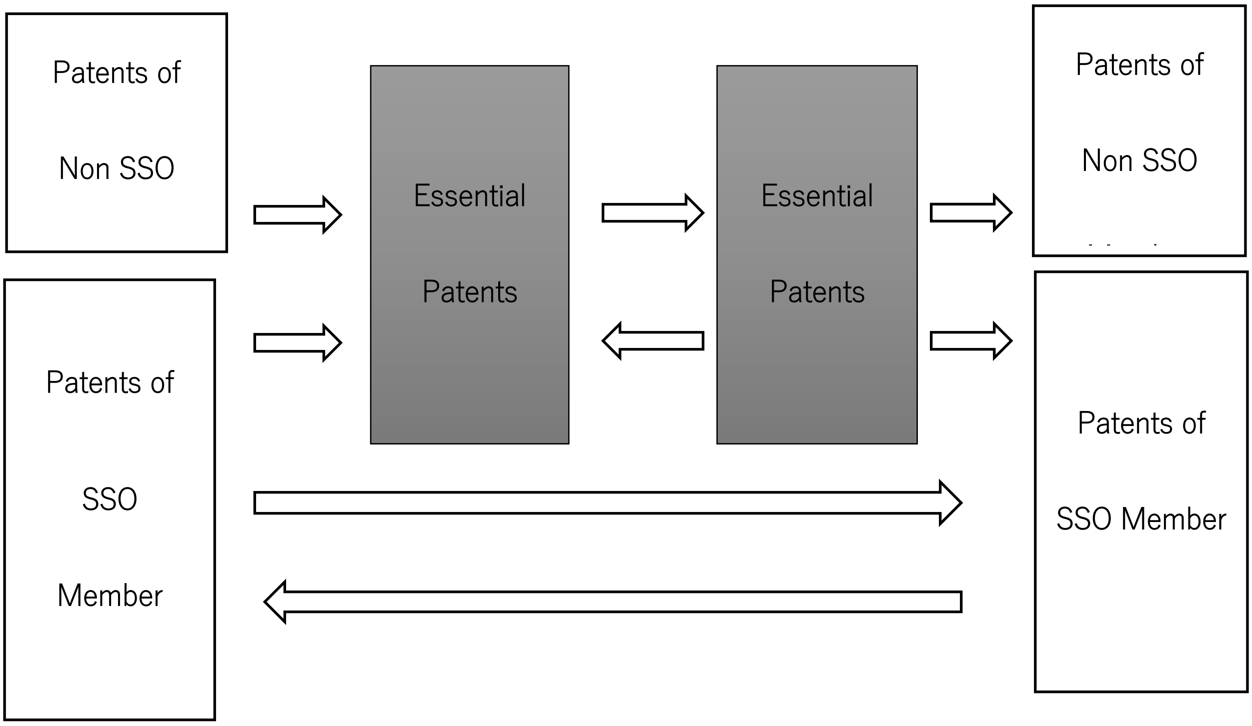
JTC1, a standard setting organization (SSO) has brought about a number of very successful and relevant ICT standards in the fields of multimedia (e.g.: MPEG), IC cards ("smart cards"), ICT security, database query and programming languages as well as character sets.

My sample includes 1149 standard essential patents (SEP) declared by 63 JTC1 member firms during the period of 1990-2010. Since the JTC1 includes more than 400 technology standards, the member firms may declare the same patent to different standards. Thus, I identify 387 patents, in which 276 patents are published in the USPTO and 111 published in the EPO. Then I use "docdb_family_id", a unique code defined by the PATSTAT for identifying patent family, to clean the sample, and obtain finally 241 standard essential patents published in the USPTO.

5.1.1. Patent Citations

All patents listed in the dSEP are matched with patent identities in the PATSTAT, which allow us to merge them with the information of patent citations for the USPTO patents in the same database.

Figure 25 Patent Citation Relationships for the Sample



Patent citations presumably convey information or knowledge flows between innovations or patent holders. As shown in Figure 25, I concentrate my sample for the patent citation relationships between the JTC1 member firms' patents. I also include patents held by firms that are not the JTC1 member if they cite the SEPs or are cited by the SEPs. Thus, after deleting the biased citations whose year of cited is bigger than year of citing, I obtain more than 15,000 pairs of patent citations.

5.1.2. Other Covariants

I acquire data related to the determinants of the strategies of the SSO member firms on the SEPs from the Searle Center Database (Baron and Spulber (2015)). The data comprises number of employees, number of patent application, and ratio of R&D expenditure to total sales for the JTC1 member firms in the sample period. With regard to the timing for cooperation and entry into the JTC1, I employ the year of the first pool launch for the JTC1 that is also released in the Searle Center Database. All statistical descriptions are shown in Table 10.

5.2. Social Network Analysis

This section highlights some characteristics of patens in the JTC1 by employing methodologies currently developed in practice. This type of network analysis allows identification of important players in the JTC1 and their connectedness can be used in analysis of competitor or for identifying main partners in this Standard Setting Organization.

5.2.1 Investigating the Presence of Essential Patents on the *main path*

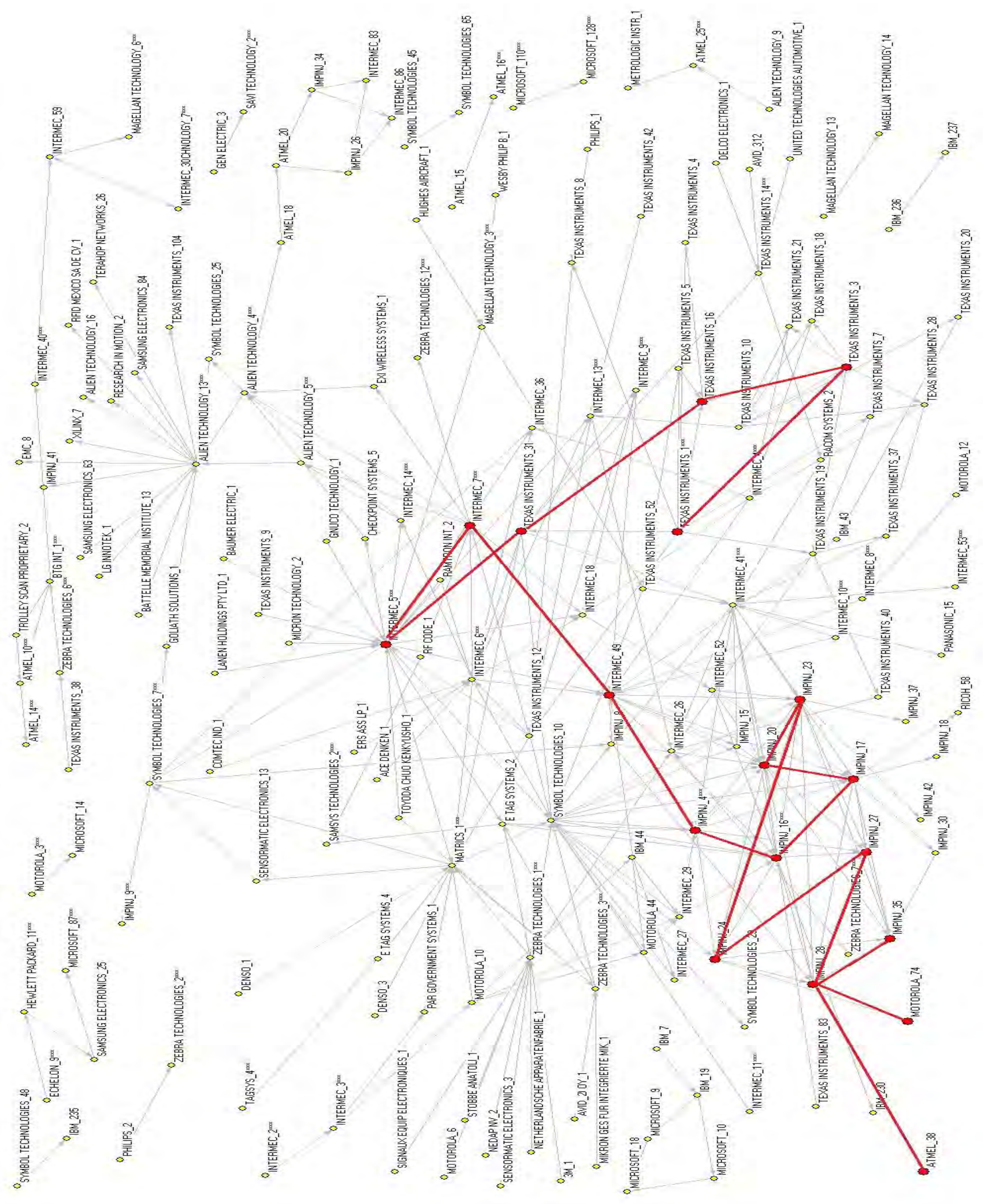
In general, an item receiving more citations is deemed more importance. In most citation networks, however, all patents are linked into one bicomponent. This cohesion concept does not take time into account. It does not reflect the incremental development of knowledge nor does it identify the patents that that were vital to this development. Therefore, a special technique for citation analysis was developed that explicitly focus on the flow of time. It is called *main path* analysis (de Nooy et al. (2005)).

Let us think of a citation network as a system of channels that transport scientific knowledge or information. A patent that integrates information from several previous items and adds substantial new knowledge receives many citations, and it will make citations to previous articles more or less redundant. As a consequence, it is an important junction of channels and a great deal of knowledge flows through it. If knowledge flows through citations, a citation that is needed in paths between many patents is more crucial than a patent that is hardly needed for linking patents. The most important citations constitute one or more *main paths*, which are likely to be the backbones of a technology tradition.

Main path analysis calculates the extent to which a particular citation or patent is needed for linking patents, which is called the traversal count or traversal weight of a citation or a patent. First, the procedure counts all paths from each source (a patent that is not citing with the data set) to each sink (an article that is not cited within the data set), and it counts the number of paths that use a citation by the total number of paths between source and sink vertices in the network. This proportion is the traversal weight of a citation. In this chapter, I employ an algorithm called as the Search Path Link Count (SPLC), that weights each edge proportionally to how often a given link is present all the paths that can link between any start point (i.e., patents that do not cite any other patent) to any end point or sink (i.e., patents that do not receive any citation). Thus, the paths with the highest SPLC values are more likely to be on the *main path*.

Bekkers and Martinelli (2012) assumed that the *main path* is an accurate description of the most important contributions to the field, and one might expect that most of the patents on this *main path* are indeed claimed to be essential to the standard (but not necessarily all, because the standard might not have employed all the top inventions in the field).

Figure 26 *Main Path* and Selected Citation Network



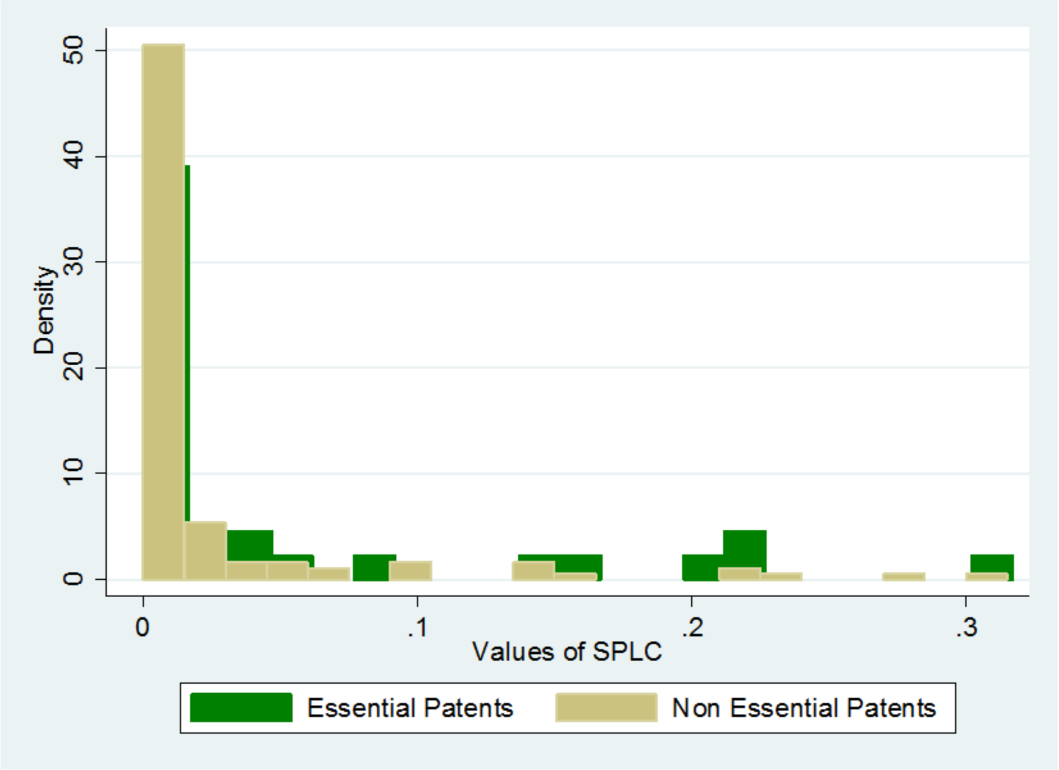
Note: ***are essential patents claimed by their owners

Figure 26 illustrates a selected citation network in which the values (or weight) of the SPLC are larger than 0.004. The network consists of 180 patents, and out of them 41 patents with “***” are the SEPs. Figure 2 also show, in a solid line, the *main path* with the highest SPLC values. The *main path* comprises 5 essential patents and 13 other patents that are not claimed by the SSO member firms.

Table 8 Quantile of the Values of SPLC in Selected Network

	Values of SPLC									
	Mean	1%	5%	10%	25%	50%	75%	90%	95%	99%
Non Essential Patents	0.00135	0.00000	0.00000	0.00000	0.00001	0.00002	0.00009	0.00059	0.00179	0.01812
Essential Patents	0.00695	0.00000	0.00000	0.00000	0.00002	0.00006	0.00046	0.00334	0.01258	0.21333

Figure 27 Histogram of the Values of SPLC in Selected Network



Furthermore, Table 8 and Figure 27 reveal the distributions of the SPLC values for the SEPs as well as the patents that are not claimed in the selected network. Although the average values of the SPLC for the SEPs are larger than those for no claimed patents, compared with the latter, the former does not overwhelmingly contribute to the *main path*. My finding in the JTC1 is consistent with those in Bekkers and Martinelli (2012).

5.2.2. Visualization Analysis on *Brokerage Roles*

While the *main path* approach is widely used and results in a valid representation of the *main path* of technological development, such approach is likely to face serious limitations. The question is whether such "over selective" path lack the necessary degree of granularity. Some companies might have contributed important knowledge, but their patents are not part of the *main path* themselves. Recognizing these restrictions, my paper proposes alternative approach that makes it more apt to evaluate knowledge position. That is approach of *brokerage roles*.

Research into *brokerage roles* is concerned with describing the types of *brokerage roles* that dominate a transactional or exchange network. In addition, individual positions within the network may be characterized by the dominant type of brokerage role, and hypotheses may be tested about the personal characteristics of individuals with certain types of *brokerage role*.

Figure 28 Values of *itinerant* in Selected Network

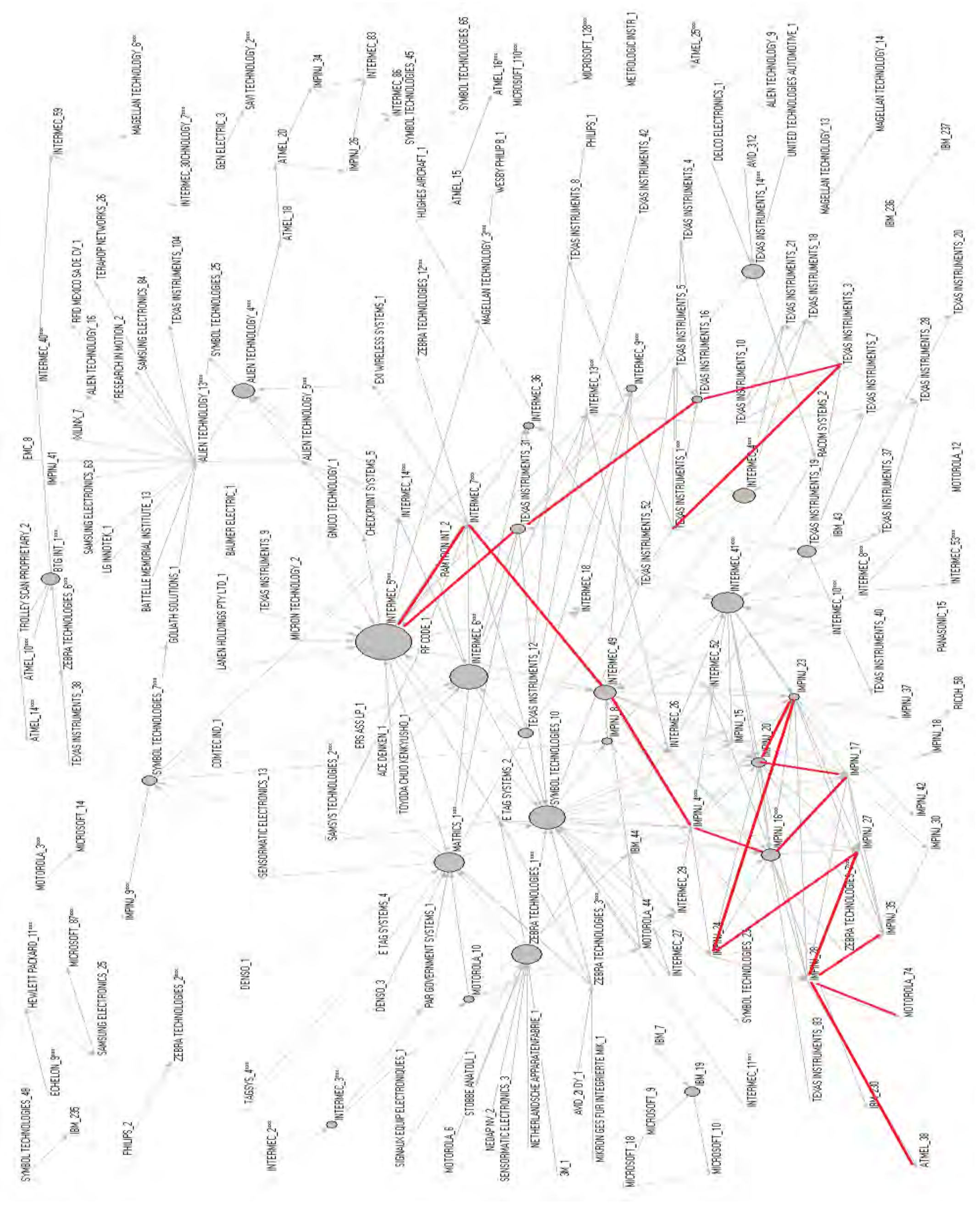


Figure 29 Values of *Representative* in Selected Network

Figure 30 Values of *Gatekeeper* in Selected Network

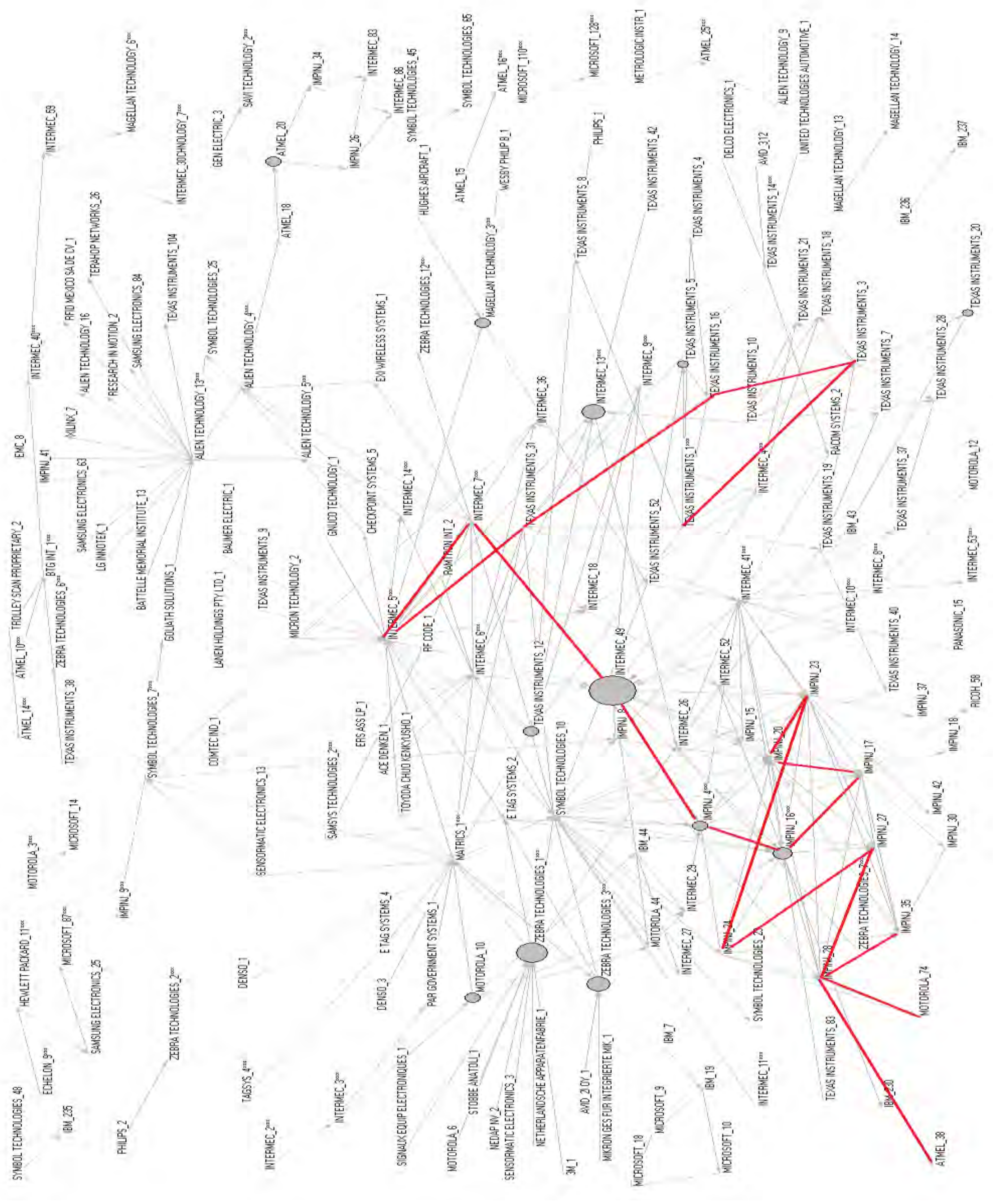


Figure 31 Values of *Liaison* in Selected Network

Table 9 Number of *Brokerage Role* in Full Network

	Number of *Brokerage*		
Roles of *Brokerage*	Non Essential Patents	Essential Patents	Total
Itinerant	49(1.90%)	183(75.93%)	232(100.00%)
Liaison	338(1.12%)	194(80.50%)	532(100.00%)
Representative	29(1.12%)	7(2.90%)	36(100.00%)
Gatekeeper	51(1.98%)	4(1.66%)	55(100.00%)
Total	2581	241	

Figures 28, 29, 30, and 31 demonstrate values of "*itinerant*", "*representative*", "*gatekeeper*" and "*liaison*" for the selected network. The size of nodes shows the extent to which the patents play different broker roles in the network. At the same time, as can be seen from the table 9, among the total 241 SEPs, approximately 76 and 81% of the SEPs play the roles of "*itinerant*" and "*liaison*" respectively, while those for the patents not claimed are less than 2%. My findings suggest that there is a strong relationship between the broker roles such as "*itinerant*" and "*liaison*" and the SEPs, which means the patents that serve as *itinerant* and *liaison* may be more likely to be claimed as the SEPs. On the other hand, however, only 2.9% of essential patents are representative and 1.66% of essential patents are *gatekeeper*, compared with 1.98 and 1.12% for the patents not claimed.

My social network analysis provides evidence that I am confronted with a selection effect: the values of essential patents are not only more strongly cumulative, but also more valuable than non- essential patents from their technological field. This can result from the fact that standard setting organizations often choose between different technological options and select the best technologies for inclusion into the standard. But the SPLC values of essential patents are not absolutely larger than non- essential patents, which implies that the patents claimed to be essential are not necessary on the *main path*.

5.3. Empirical Analysis on the Relation between *Main Path*, *Brokerage roles* and SEPs

The aim of this section is to explore empirically the relations between *main path*, brokerage role and the SEPs, and investigate the determinants of the SEPs.

I build dependent variable related to the SEPs, where it equals unit if the patent is claimed to be essential, and zero otherwise. I also consider in the regressions with index for *betweenness centrality*.

5.3.1. Baseline Regressions

Table 10 Statistical Descriptions

Variable	Obs	Mean	Std. Dev.	Min	Max
Dummy for Essential Patents	2,822	0.085	0.280	0	1.000
Values of SPLC	2,822	0.002	0.016	0	0.311
Betweenness Centrality	2,822	0.002	0.011	0	0.218
Itinerant	2,822	4.914	44.638	0	1220.000
Liaison	2,822	22.427	176.095	0	4529.000
Representative	2,822	0.053	0.720	0	22.000
Gatekeeper	2,822	0.047	0.471	0	14.000
No. of Employees	2,419	80416	70646	1	264880
Sales	2,270	25300	17987	1	71186
No. of Patent Applications	2,229	2692	3459	2	11424
R&D Expenditure	2,254	1952	1369	1	3872
Year of First Pool Launch	2,392	1995	5	1990	2005

Table 11 Baseline Estimations with Logit Regression Model

Covariables	I	II
Dependent Var:		
Dummy for Essential Patents		
Values of PNLC	5.286	5.413
	(1.11)	(1.12)
Itinerant	**0.656*****	**0.705*****
	(4.65)	**(4.56)**
Liaison	0.005	
	(0.80)	
Representative	**0.152***	**0.159****
	(1.74)	**(2.09)**
Gatekeeper	0.152	0.147
	(1.09)	(1.03)
Betweenness Centrality		16.035
		(1.48)
Log Likelihood	-232.77	-233.30
No. of Obs.	1819	1819

Note: (1) All regressions include fixed effects for the SSO member firms.

(2) The values in the parenthesis are t statistics.

(3) "***", "**" and "*" denote significant level at 1, 5, 10% respectively.

Table 12 Logit Estimates for Determinants of Strategies related to the SEPs

	I	II	III	IV	V	VI	VII	VIII
Dependent Var:								
Dummy for Essential Patents								
Values of PNLC	7.455	5.582	7.237	7.237	7.183	5.534	7.119	7.119
	(1.35)	(1.12)	(1.31)	(1.31)	(1.29)	(1.12)	(1.29)	(1.29)
Itinerant	**0.653*****	**0.671*****	**0.658*****	**0.658*****	**0.559*****	**0.640*****	**0.562*****	**0.562*****
	(4.47)	**(5.68)**	**(4.54)**	**(4.54)**	**(5.34)**	**(4.89)**	**(5.33)**	**(5.33)**
Liaison	-0.006	-0.002	-0.006	-0.006				
	(-0.75)	(-0.29)	(-0.78)	(-0.78)				
Representative	**0.149****	**0.159****	**0.149****	**0.149****	**0.146****	**0.158****	**0.146****	**0.146****
	(2.28)	**(2.28)**	**(2.27)**	**(2.27)**	**(2.20)**	**(2.25)**	**(2.20)**	**(2.20)**
Gatekeeper	-0.473	-0.274**	-0.478	-0.478	-0.482	-0.273**	-0.485	-0.485
	(-0.74)	(-2.32)	(-0.75)	(-0.75)	(-0.77)	(-2.35)	(-0.77)	(-0.77)
Betweenness Centrality					5.508	10.438	4.018	4.024
					(0.31)	(0.90)	(0.21)	(0.21)
Log of Employees	**1.215*****	**-2.161*****		**1.460*****	**1.180*****	**-2.158*****		**1.252*****
	(4.79)	**(-3.95)**		**(3.29)**	**(3.91)**	**(-4.14)**		**(3.26)**
Log of Patent Applications	0.175		**1.514*****	0.304	0.183		**1.279*****	0.241
	(0.70)		**(3.01)**	(1.08)	(0.73)		**(2.98)**	(0.90)
Ratio of R&D to Sales	**31.603****				**29.487***			
	(2.08)				**(1.78)**			
Year of First Pool Launch	-0.006	**0.372*****	**0.461*****	**0.197***	-0.006	**0.350*****	**0.373*****	**0.147**
	(-0.06)	**(4.33)**	**(2.93)**	**(1.87)**	(-0.06)	**(3.77)**	**(2.74)**	**(1.48)**
Log Likelihood	-168.46	-186.76	-168.38	-168.38	-168.96	-186.70	-168.91	-168.91
No. of Obs.	1287	1409	1287	1287	1287	1409	1287	1287

Note: (1) All regressions include fixed effects for the SSO member firms.

(2) The values in the parenthesis are t statistics.

(3) "***", "**" and "*" denote significant level at 1, 5, 10% respectively.

Table 10 presents the results of the regression analyses for the impacts of SPLC value and *brokerage roles* on the patents claimed essential. First of all, the coefficients for the *itinerant* are strongly positive and significant for both models, indicating the patents with the *itinerant* position will be more likely to be claimed essential. On the other hand, coefficients for the representative are also positive and significant. However, the significant level seems to be weak. Contrast to those for *itinerant*, we can find coefficients for the SPLC value are not significant in either of my models, which verified the conclusion again that patents on the *main path* are not necessarily essential patents. The coefficients for the *liaison* are insignificant, that may be due to problem of multicollinearity because there is a strong correlate relation between values of the itinerant and liaison.

Furthermore, the coefficient for the *betweenness centrality* is not significant, indicating high *betweenness centrality* value are not contributing to a firm' patents be claimed essential.

5.3.2. Estimates for Determinants of Strategies related to the SEPs

Table 12 allows underlining a couple of results. First of all, I can get the same conclusion with Table 11 that strong link between the declaration to be essential and patents served as the *itinerant* and *representative*. And the coefficients for the SPLC and *betweenness centrality* allow refining the previous results from last table. And the firms in *gatekeeper* position seem not help their patents be claimed essential.

With regard to the determinants of the strategies of the SSO member firms, the estimates of number of patent applications and the R&D intensity reveal to be positive and significant in some cases, suggesting the SSO member firms with larger patent portfolio and engaging in more R&D activities are more likely to claim their patents to be essential. However, the impacts of the number of employees are mixed.

What is noticeable is that the coefficients for the "year of first pool launch" are strongly positive and significant for the five models. It can be inferred from this result that the new patents launched in pool are more likely to be claimed essential. This may be due to the fact that SSO member firms make contributions to standards is under development. The later the firm firstly launches the SEPs to the pool, the more it claims the patents to be the SEPs.

5.4 Summary

In this chapter, I implemented the empirical analysis of the knowledge position of firms in high-tech, standards-based markets. Being able to assess knowledge positions is important because they are assumed to increase chances for sustainable market participation, bargaining power, and licensing revenues. My study focused on the JTC1, I attempted to utilize social network technique to find out the characteristic, i.e., *main path*, *betweenness centrality* and *brokerage roles* in patent citation network of the JTC1, and carried out regression analysis of effects of these characteristics on the declaration of the SEPs. Main conclusions are:

1. The *main path* analysis does identify the most important technological advances and breakthroughs in the development of this technology, yet is too selective to fully assess knowledge positions of firms;
2. Alternative to the *main path* analysis, the *brokerage roles*, as proposed in this paper, does result in a better measurement of knowledge position, and matches more suitably the outcomes of the historical/technical narrative and an analysis of knowledge flows.
3. Claims of essentiality are the result of strategic behavior of the patent's owner. As important patents often occupy brokerage positions, firms usually attend to claim their really important patents to be essential.

Chapter 6. IPR Policies and Membership in Standard Setting Organizations: A Social Network Analysis IPR Policies and Membership in Standard Setting Organizations:

A Social Network Analysis

Whereas technical standards and Standard Setting Organizations (SSOs) are omnipresent and essential to mass production and mass communications, relatively little is formally known about the propensity of firms to belong to certain SSOs. This paper uses a social network analysis technique to empirically analyze the behavior of market participants and their propensities to belong to SSOs. I concentrate my study on standard setting organizations features and their intellectual property rights (IPR) policies such as licensing rules, disclosure requirements, as well as the features of the decision process of standards. Using data on more than 1060 member firms as participants in 28 SSOs, I am able to uniquely graph the membership of firms in SSOs by highlighting some important characteristics. Finally, I use a multinomial logit regression analysis to study the propensities of firms to belong to four SSO and member firms' network communities.

6.1. Data Description

Despite the SSOs' economic importance and dynamism, they have received surprisingly little empirical scrutiny (Chiao et al., 2007). One reason for that is that, as indicated by Baron and Spulber (2018), data on SSO membership has so far only been available and used for single SSOs or small groups of related SSOs and consortia.

In this chapter, in order to analyze the relationship between the SSOs' IPR policies and the membership of the SSOs, especially for multinational private firms, I employ the Searle Center Database. I merge the database's SCDB *sso policies file* with the SCDB *members file*, to obtain the information of IPR policies and membership for SSOs which are most engaged in the ICT field[20].

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[20] I also reference Bekkers and Updegrove (2013) to obtain additional information for the IPR

I clean/sanitize the private firms' name and identify 1066 observations that are active in the 28 SSOs during the period of 1995 and 2015. I also use PATSTAT ver. Oct. 2016, a patent data set, to collect the information for the firms' patent applications and patent classifications in the United States Patent and Trademark Office (USPTO). Then I utilize the sample to show the two-mode social network relations that will be discussed in the next section, between the SSOs and their memberships, and investigate empirically the relationship between the SSOs' IPR policies and their membership in section 5.

6.2. Networks Analysis of Membership in SSOs

6.2.1. Two-mode Network

Once transformed into a bilateral data set, i.e., the SSOs and the member of the SSOs, the network structure of the SSOs' memberships can be studied. In such two-mode network, there are two kinds of vertices, one representing firms that engage in different SSOs, and the other representing the SSOs which these firms belong. The affiliations connect between the SSOs and firms, and a firm does not connect with any other firm directly.

The one-mode networks can be created from the two-mode network: a network of interlocking SSOs and a network of firms that are members of the same SSO. Especially for the latter, the firms can be connected by multiple lines (routes), indicating that two firms affiliate in more than one SSO. I can measure centrality by using *betweenness centrality* proposed by Freeman (1979).

The *betweenness centrality* calculates the extent to which a company is located on the shortest path between any two nodes in the one-mode network and captures both the centrality and the spanning of structural holes in the network, and reflects the extent to which the company plays an important role in SSOs activities.

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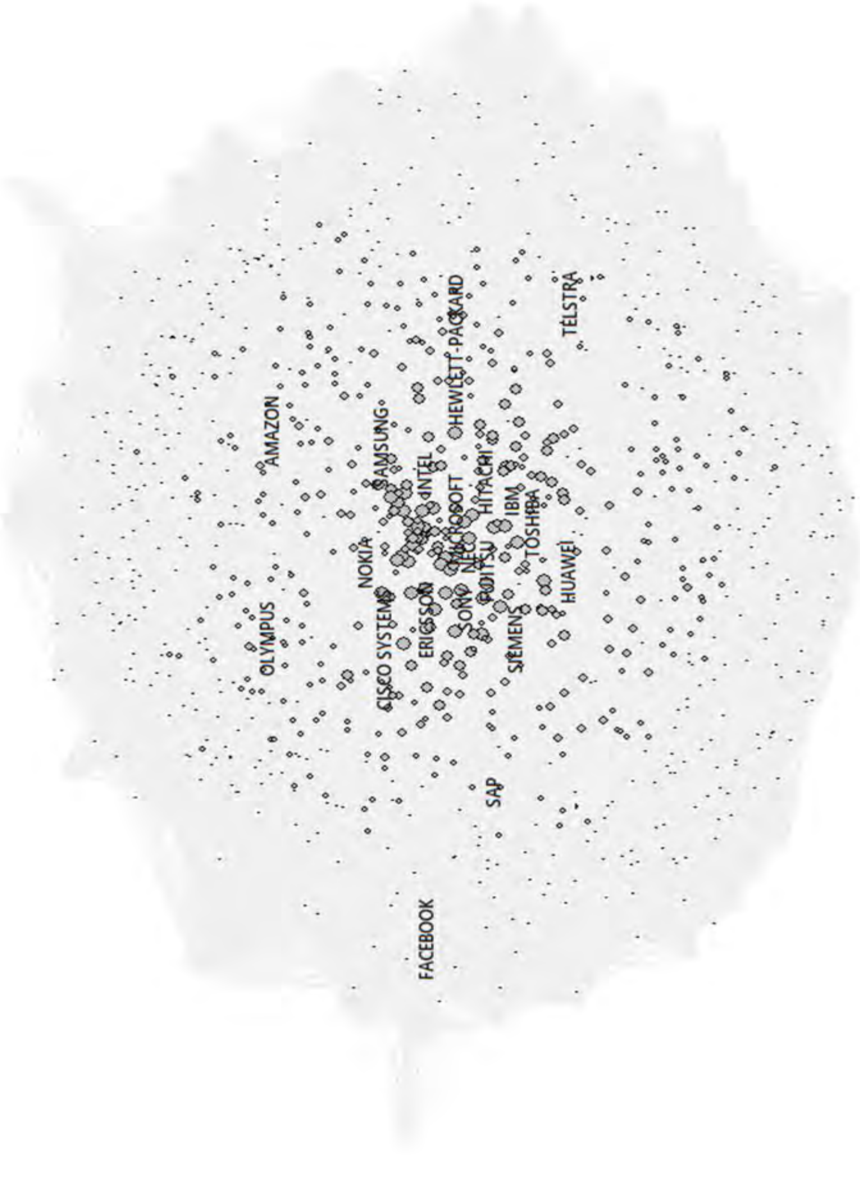
policies that are necessary in empirical analysis.

Figure 32. Image of *Betweenness Centrality*



Note: *Betweenness centrality* calculates the extent to which a company is located on the shorted path between any two nodes in the one-mode network (see Section 4). The vertex (of the firms) sizes show values of *betweenness centrality*, and the positions of the vertexes (of the firms) in the networks are determined with the Kamada–Kawai energy command of *Pajek*.

Figure 32 depicts *betweenness centrality* for the sample firms. As shown in this figure, INTEL, IBM, MICROSOFT, HITACHI, TOSHIBA and HEWLETT-PACKARD locate in the center of the network with biggest size of the vertex, and there are some firms with relatively high value of *betweenness centrality* around the central firms, such as HUAWEI TECHNOLOGIES and SAMSUNG ELECTRONICS, the firms from emerging economies. In contrast to those firms, the figure also shows that FACEBOOK and AMAZON, two firms of the Big Four tech firms (GAFA) are located peripherally because they only associated with less SSOs activities[21]. It may be that the market power, partly associated with scale economies and network externalities, that FACEBOOK and AMAZON possess induce them to locate in periphery. This can have implications for antitrust enforcement.

6.2.2. Communities in the Two-mode Network

The two-mode network comprises more than a thousand of nodes that related to 28 SSOs and 1066 firms. One of the ways to analyze the properties of these nodes is by understanding their group behavior, i.e., community properties. In this chapter, I employ Louvain method for community detection in two-mode network.[22]

The Louvain method searches for the partition of vertices into clusters with the highest value of modularity[23]. Modularity was introduced by Newman and Girvan (2004) for undirected graphs as a formalization of the common requirement that the connections within graph clusters should be dense, and the connections between different graph clusters that should be sparse (Randlof and Noack, 2011).

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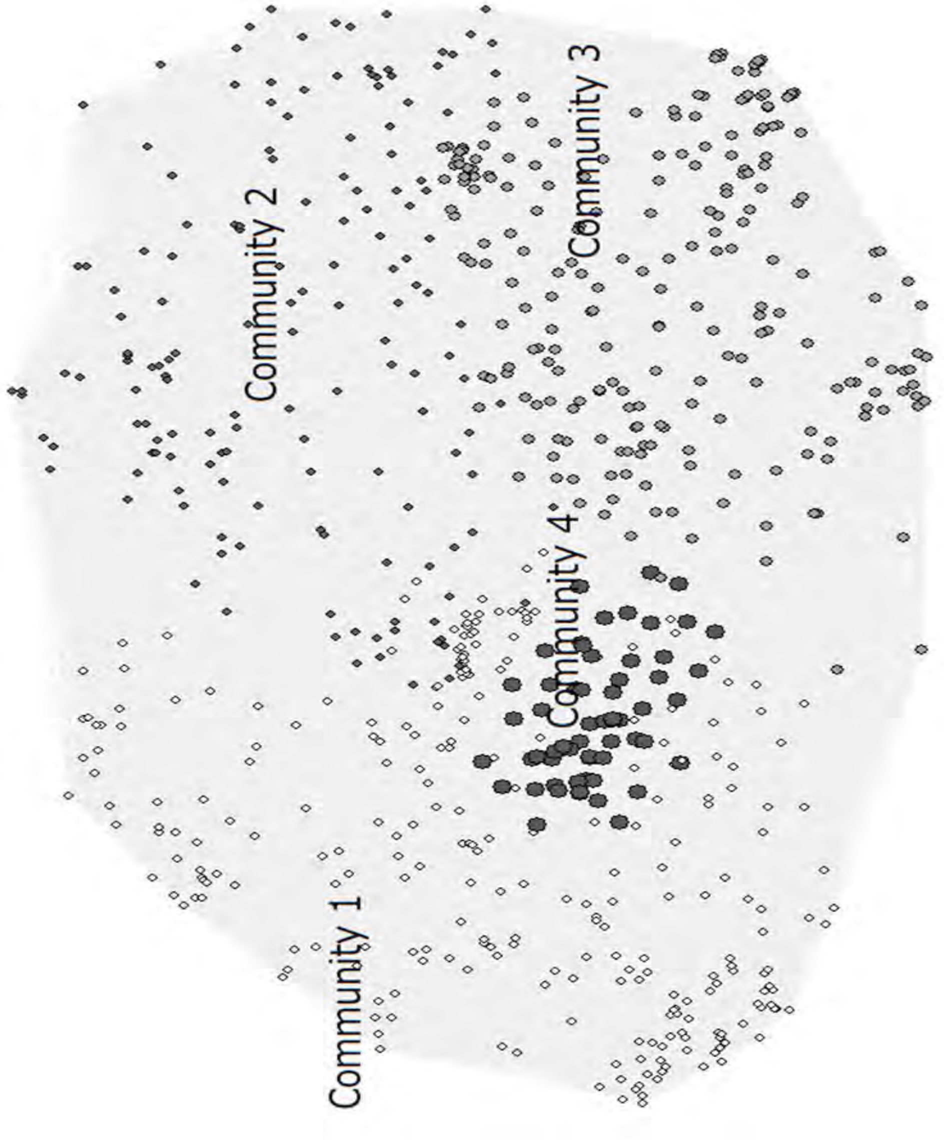
[21] Due to space limitations, I only note the names for selected members in the figure. The full names for the sample companies for the figure are available on request.

[22] Placement of firms in communities may be seen as an empirical complement to the vertically differentiated groups noted by Spulber (2018).

[23] The method is a greedy optimization method that attempts to optimize the "modularity" of the network (modularity is defined here). The optimization is performed in two steps. First, the method looks for "small" communities by optimizing modularity locally. Second, it aggregates nodes belonging to the same community and builds a new network whose nodes are the communities. These steps are repeated iteratively until a maximum of modularity is attained and a hierarchy of communities is produced (Blondel, 2011).

Figure 33. Image of Communities



Note: The Louvain method is used to place firms in communities. This method searches for the partition of vertices into clusters with the highest value of modularity. Lines connected with firms within the community are supposed to have larger values than those between the communities. The larger values suggest that the member firms in the community involve in more same SSOs than those between the communities.

The Figure 33 represents an image of four communities/clusters measured by the software *Pajek*, in which the resolution parameter is set to 1.0 and the communities are obtained with the modularity 0.47. The four communities are marked with four different forms, in which small diamond refers to community 1, small black diamond is community 2, circle is community 3, and large black circle is community 4. These vertices separated in terms of communities, but the borders of communities are ambiguous, even joined with each other to some extent. However, lines connected with firms within a community are supposed to have larger values, i.e., involvement in more same SSOs than those between the communities. Then I list the names of firms in each cluster.

Table 13. Member Firms in the Communities

Community	1	2	3	4
Member	INTEL	NEC	TOSHIBA	BOEING
	IBM	TEXAS INSTRUMENTS	STMICROELECTRONICS	RAYTHEON COMPANY
	HITACHI	SUN MICROSYSTEMS	GOOGLE	MITRE
	HEWLETT-PACKARD	PHILIPS	CANON	LOCKHEED MARTIN
	SIEMENS	THOMSON	DELL COMPUTER	AVAYA
	NOKIA	THALES	ADVANCED MICRO DEVICES	BAE SYSTEMS
	ERICSSON AB	OKI ELECTRIC INDUSTRY	RICOH	WIND RIVER
	MOTOROLA SOLUTIONS	RENESAS ELECTRONICS	NVIDIA	RED HAT
	MITSUBISHI	SANYO	ROBERT BOSCH	VIASAT
	MICROSOFT	GENERAL DYNAMICS	HONEYWELL	SOFTWARE AG
	HUAWEI TECHNOLOGIES	TYCO ELECTRONICS	SANDISK	SAP AG
	FUJITSU	NATIONAL SEMICONDUCTOR	TOYOTA MOTOR	TATA CONSULTANCY
	SAMSUNG ELECTRONICS	COMPAQ	HYUNDAI	QINETIQ
	CISCO SYSTEMS	GENERAL ELECTRIC	LENOVO	INVENSYS
	NTT	XILINX	DOLBY LABORATORIES	CRITICAL PATH
	ALCATEL-LUCENT	LSI LOGIC	VICTOR COMPANY OF JAPAN	DELOITTE
	NORTEL NETWORKS	LSI	LEXMARK INTERNATIONAL	DIGITAL EQUIPMENT
	ORACLE	ALTERA	PIONEER ELECTRONIC	INFOSYS
	SONY	NORTHROP GRUMMAN	DENSO	TRW
	ZTE	YOKOGAWA ELECTRIC	ADOBE SYSTEMS	OBJECTIVE INTERFACE SYSTEMS
	……	……	……	……
Total	376	368	228	94
SSOs mostly involved	TIA	PCI-SIG	CEA	TOG
	ETSI	JEDEC	Wi-Fi Alliance	OASIS
	3GPP	VESA	PCI-SIG	DMTF

The number of firms in communities 1-4 are 376, 368, 228, and 94, respectively. What come into notice is that, in the community 1, there are some leading telecommunications companies that are active in the SSOs such as Telecommunications Industry Association (TIA) and European Telecommunications Standards Institute (ETSI) on developing standards of the internet technologies, especially on the 5G network, internet of things and so on.

On the other hand, community 2 includes leading global companies that share more SSOs such as PCI-SIG and JEDEC Solid State Technology Association on developing standards for the semiconductor and microelectronics industry.

The SSOs that firms are involved in community 3 quite overlap with those in the community 2. However, the firms in community 3 pay more attention on consumer technologies. These firms' standardization activities are associated with the design and manufacture of consumer electronics products and related services, and so on.

Although the number of firms in community 4 are least among the four communities, this community include some important companies that are technology and innovation leaders in defense, civil government, business applications and cybersecurity solutions.

In the next section, I will check the IPR policies of the SSOs, to find out if there is relationship between the SSOs' IPR policies and the SSOs membership, say, the communities of the SSOs member companies in my case.

6.3. Empirical Analysis of Effects of IPR Policies on SSOs Membership

Although many studies have focused on the SSO IPR policies, few studies have examined the relation between SSOs' IPR policies and their membership in a formal empirical analysis. I attempt to fill this gap based on the fact that a firm can choose between different SSOs to develop a standard, and different IPR policies in these SSOs may play different roles on the behavior of the SSOs membership. In the empirical analysis, I focus on the rules on the disclosure of SEPs, and member obligations to make licensing commitment. Furthermore, I also discuss the roles of the SSOs' policy-making processes on the SSOs membership.

To implement the empirical analysis, we uniquely quantify IPR rules and policy making rules in SSOs.

6.3.1. Indices for IPR policies

I highlight major IPR policies summarized in Bekkers and Andrew (2013), Barron and Spulber (2018) and the Searle Center Database (SCDB). Some of them are related to the SEPs and their licenses, and some of them may influence a company's behavior as a participant in SSOs. The indexation of the IPR policies is as the follows.

(1) **Licensing Terms**: Almost all SSOs in sample require licensing on fair, reasonable and non-discriminatory (FRAND) terms, which is the least restrictive option. Additionally, there is another option in which firms are willing to offer licenses of SEPs royalty-free. I convert all the policies into an index. In this case, if an SSO requires royalty-free on FRAND terms, I set it to 3. If an SSO requires FRAND while royalty-free is optional, I set it to 2. The index is 1 if only FRAND, and zero for the case of "no obligation".

(2) **Disclosure Requirement**: Almost all SSOs expect their members to disclose their patents that may be (or potentially become) essential to a standard. I set it to 2 if one SSO requires disclosure and set it to 1 if the requirement is not a strict yes or only being "encouraged" and zero for the case of "Not specified".

(3) **Disclosure Timing**: Many SSOs generally ask for "timely" disclosure, or disclosing SEPs "as early as possible", and some of them have adopted more specific policies. The required timing can be a specified number of days either after the publication of a specification, standard or draft standard, or before the (final) vote on a standard. In addition, SSOs may require that a disclosure statement must be made simultaneously with a technical contribution to the standard. The most generous disclosure policy allows patents to be disclosed within 90 days from issuance of a final specification. Furthermore, some SSOs that do specify a disclosure timing require disclosure prior to approval/vote on a standard. I set the related index to 2 for these two cases. On the other hand, I set it to 1 for the case of "as soon as possible", and zero for the case of "not specified".

(4) **Discourage Blanket Statement**: These are generic statements by a firm declaring that it holds one or more SEPs for a specific standard or standard project, as opposed to the disclosure of a specific and clearly identified patent or patent claim. Some of the SSOs accept but discourage blanket declarations.

Blanket declarations generally are not allowed if the patent holder chooses not to make its patents available for licensing. If an SSO explicitly requires the disclosure of special patents we give the index a score of 2. If an SSO discourages blanket declarations, I give a 1. Otherwise, if the blanket statement is allowed, I give -1; and zero denotes for the case of “not specified”.

In addition to specifying the general nature of the required licensing offer for SEPs, many SSOs adopt additional rules on SEP licensing. Here I consider another two licensing rules.

(5) **Defensive**: If an SSO explicitly allow the defensive suspension of a FRAND or royalty-free licensing contract on SEPs in case the patent holder is sued by the license, I set the related index to 2, and if the SSO allow this condition but does not claim explicitly, I set it to 1. Otherwise for the case of “not allowed” I set it to -1, and zero for the case of “not specified”.

(6) **Irrevocability**: There is no example of an SSO policy stipulating that licensing commitments may be revocable. So, if it is irrevocability, I set it to unit, and zero for “not specified”.

Overall, there are many dimensions to IPR policies related to SSOs and how to quantify them.

6.3.2. Indices for SSO Policy Making Process

Further, I also consider some variables which represent the features of the SSOs’ policy-making processes. Again, these would figure in firms’ decision to join or remain in a particular SSO.

(1) **Open Meetings**: Many SSOs provide information and opportunities to participate to non-members. The level of openness to the general public varies substantially between different SSOs. I set the index to 2 for “Yes”, 1 for “Invitation-based”, zero for “Not specified”, and -1 for the case of “No”.

(2) **Quorum**: In the SSOs, a vote on a standard document typically is conditioned on the existence of a sufficient quorum for meetings. The quorum range varies between different SSOs from 30 to 100% (consensus decision-making process) of eligible voting members. I add value of 0% for the case of “no quorum”. Voting power may substitute for market power in some cases (Spulber, 2018).

(3) **Approval**: The requirement for the approval of a standard ranges from a simple

majority (50.1 %) to unanimity (100%) of expressed votes (abstentions not counted). I use directly the percentages of the approval thresholds in empirical analysis.

(4) **Appeals Allowed**: Many SSOs allow members to appeal votes and decisions on standards. Here, I set 1 for the case of "Yes", zero for "Not specified", and -1 for "No".

Again, different dimensions of SSO policy making process are quantified.

I also utilize *betweenness centrality* measured in the one-mode network, number of patent applications in the United State Patent and Trade Mark Office (USPTO), and Herfindahl-Hirschman Index (HHI) measured by 4-digit International Patent Classifications (IPC) that have been issued by the USPTO to their US patents for each member company as control variables in regressions.[24] Patents capture the technological process of a firm, while the HHI index captures market power, and *betweenness centrality* captures the importance of the firm in spatial terms. Alternatively, patents and HHI can be viewed as control variables on the size and scope of the firms' IPR portfolio.

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[24] Whereas, HHI captures market power, firms looking to join SSOs face a tradeoff between market power and voting power (Spulber, 2018).

Table 14. Descriptive Statistics

Variables	Community 1			Community 2			Community 3			Community 4		
	Obs.	Mean	SD	Obs.	Mean	SD	Obs.	Mean	SD	Obs.	Mean	SD
Licensing terms	1970	1.79	0.82	1416	1.76	0.78	849	1.55	0.72	269	2.48	0.77
Disclosure requirement	1970	1.25	0.61	1416	1.06	0.73	849	1.37	0.69	269	1.43	0.67
Disclosure timing	1937	1.18	0.61	1411	1.23	0.56	839	1.16	0.52	258	0.84	0.66
Discourage blanket	1970	0.70	1.26	1416	0.52	1.18	849	0.85	1.29	269	0.67	1.28
Defensive	1923	0.30	0.57	1392	0.46	0.73	837	0.09	0.87	204	0.54	0.57
Irrevocability	1970	0.48	0.50	1416	0.37	0.48	849	0.30	0.46	269	0.52	0.50
Open meetings	1978	0.19	0.90	1432	0.27	1.02	862	0.60	1.22	280	0.83	0.94
Quorum	1896	0.36	0.22	1385	0.47	0.20	823	0.43	0.20	225	0.54	0.35
Approval	1953	0.66	0.19	1417	0.61	0.15	851	0.64	0.16	280	0.62	0.30
Appeals allowed	1978	0.49	0.52	1432	0.33	0.49	862	0.51	0.53	280	0.48	0.50
No. of Patents	1978	8212.9	19034.2	1432	2505.4	6132.1	862	4487.1	11946.0	280	1001.6	1641.7
Betweenness centrality	1978	1.35	1.11	1432	0.75	0.75	862	0.78	0.74	280	0.58	0.70
HHI	1933	0.81	0.13	1419	0.76	0.18	858	0.80	0.15	276	0.72	0.24

Note: Date source for no. of patents and HHI is Patstat ver. Oct. 2016, and that for *Betweenness centrality* is meausre by *Pajek* 4.05.

Data source for other variables are all obtained from Bekker and Updegrove (2013) and the SCDB

Table 14 presents the statistics of indices for the IPR policies and other covariables for the four communities. Compared with other three clusters, the indices in community 4 show a stronger tendency or commitment in Licensing terms, Disclosure requirement, and Defensive suspension of FRAND. The SSOs in community 4 are also more open to the general public and non-members. Contrast to those in the community 4, the SSOs in community 1 seem more reluctant for providing information and opportunities to outsiders. Furthermore, community 1 shows higher values of *betweenness centrality* for member firms, suggesting that the companies are involved in more SSOs activities and located at more central positions in the one mode network. Compared with the other three communities, the SSOs in community 3 reveal their IPR policies more in moderation.

In my sample, the number of patents was the highest in Community 1, and the lowest in Community 4. At the same time, market concentration, denoted by HHI, shows the same trend across communities (Table 14).

The formal econometric analysis will reveal, which of these factors strongly dictate firms' placement in different communities.

6.3.3. Econometric Framework

To explain the drivers of SSO membership in different communities, I employ a formal econometric methodology. Because explanatory variables are typically observed only for the chosen alternative (or community in this chapter) and not for the other alternatives. That is, these variables are case-specific (or community-specific). So, I use multinomial logit model to test hypothesis that deals with the probability of belonging to a community[25].

If j community is base community, the multinomial logit model specifies that

$$\mathrm{P}(y = i|X_i) = \frac{exp(X_i\beta_i)}{1+\sum_{m\neq j} exp(X_m\beta_m)}; \quad i = 1, 2, \cdots; j-1, j+1, \cdots, J \qquad (2)$$

For the base community j,

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[25] See the details of the multinomial logit model in Wooldridge (2010, p.644).

$$P\left(y = j|X_j\right) = \frac{1}{1+\sum_{m\neq j} exp(X_m\beta_m)} \qquad (3)$$

Where X_i are the regressors for *i*th community-specific, which include the indexes discussed above for the IPR policies and policy making process in the SSOs in which the community *i*'s member firms are involved. X_i also include some control covariables such as logarithm of the number of USPTO patents, *betweenness centrality* and HHI for the member firms in the community *i*.

Due to the fact that the SSOs' IPR policies seem to be more moderate, I set community 3 as the base community, and compare the other three communities with the community 3. Thus, a positive coefficient from the regressions would mean that member firms in this community favor that IPR policy as compared with those in the base community.

6.3.4. Regression Results

Table 15. Drivers of Community Membership: Multinomial Logit Estimates

Dependent Varibles	Probability in Community 1				Probability in Community 2				Probability in Community 4			
Licensing terms	0.201***		0.357***	0.363***	0.389***		0.371***	0.309***	1.096***		1.173***	1.215***
	(3.11)		(5.46)	(4.74)	(5.82)		(5.51)	(4.15)	(6.47)		(5.67)	(4.05)
Disclosure requirement	-0.272***		-0.131	-0.143	-0.960***		-0.815***	-0.727***	-0.702***		-1.713***	-1.743***
	(-3.38)		(-1.16)	(-1.18)	(-10.96)		(-7.29)	(-6.11)	(-3.17)		(-4.75)	(-4.09)
Disclosure timing	0.166*		-0.030	-0.021	0.703***		0.630***	0.494***	-0.493***		0.008	-0.002
	(1.89)		(-0.25)	(-0.16)	(7.36)		(4.81)	(3.62)	(-2.91)		(0.04)	(-0.01)
Discourage blanket	-0.056		-0.029	-0.029	0.118**		0.215***	0.134**	0.252*		0.323**	0.300**
	(-1.15)		(-0.53)	(-0.51)	(2.41)		(3.85)	(2.26)	(1.83)		(2.17)	(2.02)
Defensive	0.240***		0.239***	0.230**	0.646***		0.799***	0.771***	0.592***		0.458*	0.400
	(3.17)		(2.60)	(2.53)	(7.91)		(8.63)	(8.44)	(4.18)		(1.93)	(1.39)
Irrevocability	0.602***			-0.053	-0.050			0.478***	0.231			-0.030
	(5.41)			(-0.33)	(-0.46)			(2.87)	(0.78)			(-0.08)
Open meetings		-0.509***	-0.418***	-0.431***		-0.262***	0.187**	0.277***		0.107	0.262	0.270
		(-9.37)	(-5.76)	(-5.39)		(-4.20)	(2.27)	(3.23)		(1.27)	(1.36)	(1.45)
Quorum		-0.878***	-1.816***	-1.833***		1.048***	0.038	0.232		1.095***	-3.406***	-3.375***
		(-4.32)	(-6.45)	(-6.39)		(4.46)	(0.12)	(0.74)		(3.33)	(-6.16)	(-5.72)
Approval		0.470	-0.625	-0.641		-1.625***	-1.509***	-1.593***		2.354***	-0.638	-0.485
		(1.49)	(-1.52)	(-1.56)		(-4.68)	(-2.85)	(-3.04)		(5.74)	(-0.41)	(-0.29)
Appeals allowed		0.452***	0.662***	0.707***		-0.141	-0.476**	-0.693***		-0.838***	0.182	0.189
		(3.95)	(4.64)	(4.22)		(-1.06)	(-2.49)	(-3.42)		(-4.08)	(0.46)	(0.47)
Log(No. of Patents)	-0.188***	-0.169***	-0.188***	-0.188***	0.031	0.050	0.030	0.029	-0.141**	-0.063	-0.208***	-0.210***
	(-5.59)	(-5.14)	(-5.32)	(-5.32)	(0.93)	(1.60)	(0.89)	(0.85)	(-2.12)	(-1.07)	(-2.61)	(-2.64)
Between Centrality	1.001***	1.002***	0.995***	0.994***	-0.019	-0.060	-0.048	-0.051	0.151	-0.008	0.460**	0.461**
	(11.95)	(12.25)	(11.21)	(11.23)	(-0.23)	(-0.76)	(-0.55)	(-0.58)	(0.85)	(-0.05)	(2.36)	(2.36)
HHI	-0.489	-0.432	-0.424	-0.409	-1.544***	-1.395***	-1.361***	-1.381***	-1.340**	-1.411**	-0.615	-0.584
	(-1.54)	(-1.40)	(-1.30)	(-1.26)	(-4.73)	(-4.52)	(-4.10)	(-4.16)	(-2.23)	(-2.54)	(-0.75)	(-0.71)
Chi2[p-value]	880.3[0.00]	753.8[0.00]	967.8[0.00]	958.7[0.00]	880.3[0.00]	753.8[0.00]	967.8[0.00]	958.7[0.00]	880.3[0.00]	753.8[0.00]	967.8[0.00]	958.7[0.00]
Log likelihood	-4455.59	-4578.15	-3987.80	-3997.21	-4455.59	-4578.15	-3987.80	-3997.21	-4455.59	-4578.15	-3987.80	-3997.21
No. of observation	4234	4267	4015	4015	4234	4267	4015	4015	4234	4267	4015	4015

Note: (1) The values in the parentheses are robust t statistics. (2) ***, ** and * denote significant level at 1, 5, 10% respectively.

(3) Community 3 is set as base category.

I utilize the multinomial logit regression technique to investigate the relations between SSOs membership and their IPR policies. The multinomial logit estimates are summarized in Table 15.

The estimation results show that coefficients of *betweenness centrality* are consistently and significantly positive for community 1, relatively to that in community 3 (base community), suggesting that member firms in community 1 are involved in more SSOs, and positioned more central in the one-mode network. On the other hand, the size of patent portfolio held by member firms, (i.e., log of number of patents) is negative and significant in 1 and 4, implying that compared with these two communities, member firms in the communities 2 and 3 are more likely to be those whose patent portfolio size is comparatively larger. At the same time, the estimates of HHI for the member firms show strongly significant and negative in community 2 and somewhat negative and significant in community 4. This suggests that member firms in the two communities might hold a more concentrated (market powerful) patent portfolio in more specific technology fields.

Then I turn to the estimation results for *Licensing terms* and *Disclosure requirement*, which supposed to represent the core IPR policy of SSOs. As indicated by Bekker and Updegrove (2013), most SSOs' IPR policies have two core elements: (1) rules for providing licensing commitments and (2) rules for disclosure of patents that may have essential claims. For all SSOs, the minimum goal is to ensure that all known essential IPRs are available under FRAND license terms.

The estimates of *Licensing terms* are strongly positive and significant in communities or clusters 1, 2 and 4. These results imply that member firms in the three communities favor the fair, reasonable and non-discriminatory (FRAND) terms relatively more compared with those in community 3. Particularly for community 4, the larger size of estimated coefficients implies that firms favoring the FRAND policy most likely choose as membership in community 4, relative to other communities.

With regard to *Disclosure requirement*, however, the estimated coefficients show significantly negative for firms in communities 2 and 4, suggesting that compared with firms in community 3, the firms in the two communities are with a decreased reliance on rules of disclosure requirement. For instance, in the community 2, more than 80 firms are involved in the activities of PCI-SIG. According to the Searle Center Database (SCDB), this SSO did not specify their members to disclose their patents that may be or become essential to a standard.

The disclosure element of IPR policies also include *Disclosure timing*, *Blanket statement*, *Defensive* and *Irrevocability*. On the whole, the coefficients of these policies in the community 2 reveal strongly significant and positive relation. Compared with member firms in other three communities, member firms in community 2 have a tendency to pursue early disclosure and discourage blanket disclosure. At the same time, the member firms in communities 1 and 2 are more likely involved in SSOs that allow defensive suspension of a FRAND or royalty-free licensing contract on SEPs if the patent holder is sued by the license.

Furthermore, the regressions also include variables which represent the features of the SSOs' policy-making processes, i.e., *Open meetings*, *Quorum*, *Approval* and *Appeals allowed*. The estimated coefficients of *Open meetings* are significantly negative, implying that the member firms in community 1 seem to be reluctant in openness to the general public. On the other hand, for community 1, the estimates of *Quorum* and *Appeals allowed* show significantly negative and positive, respectively. Relative to other three communities, the member firms in community 1 have a tendency to pursue a policy that is associated with lower quorum range of eligible voting members that must be present when voting on standard document and allows members to appeal votes and decisions on standards.

Finally, as for the features of approval thresholds for standards, the estimates of *Approval* are significantly negative in community 2, which means that the SSOs with lower approval thresholds for standards may attract more member firms to be active in this community.

In closing, I provide some perspective of findings in relation to the literature. Unlike Chiao et al. (2007), where the relationship between user friendliness and concessions is examined in the nature of the SSOs, I paid more attention to the individual member firms and their consideration of the IPR policies of SSOs. The empirical results suggest that member firms' consideration of IPR policy orientation or features of the SSOs' policy making processes are very mixed and vary across different communities/clusters.

Thus, the results provide more information the behavior of market participants on the SSOs, especially on the SSOs' IPR policies. One implication is that regulations that mandate standrads, should consider potential implication on firms' propensities to join SSOs that might vary widely across industries. The concluding section follows.

6.4 Summary

Membership in SSOs is voluntary on the part of firms, and most SSOs favor open source standard setting procedures. With voluntary membership and the ability to join multiple SSOs, yet very little is formally known about firms' propensities to join SSOs and which factors matter in significantly driving such decisions. To address this gap, in 6th chapter I attempt to examine the relationship between SSOs' IPR policies and their membership. I employed the Searle Center Database on the SSOs and merge the SCDB's SSO policies file with the SCDB's *member* file, to obtain a sample for approximately 1060 member firms and indices of IPR policies for 28 SSOs. By using social network software *pajek*, I built a two-mode network for the relation between the SSOs and their member firms, I highlighted some indexes like *betweenness centrality,* and *community* to explore the features of the two-mode network.

Then I implemented an empirical analysis to investigate the relationship between the SSOs' IPR policies and the membership. I paid attention to the fact that a company can choose between different SSOs to develop a standard, and different IPR policies in these SSOs may play different roles on the behavior of the SSOs membership. Consequently, I focused on some crucial IPR policies and features of the SSOs' policy-making processes.

Main findings revealed:

1. The member firms IPR policy orientation or features of the SSOs' policy making processes vary across different communities. As pointed out by Bekker and Updegrove (2013) and Farrell et al. (2007), many SSOs have rules or policies relevant to the patent hold-up problem. These policies cover several very important areas, such as disclosure rules, requiring certain disclosures of essential patents, the timing and locus of license negotiations; and licensing rules, governing the level and structure of royalties. And most SSOs often require participants to license essential patents on "Fair, Reasonable and Non-discriminatory (FRAND)" term.
2. Most of the member firms favor the FRAND terms, whereas the member

companies in community 2 have a strong tendency to pursue early disclosure and discourage blanket disclosure. Note that the community 2 include leading global firms that share more SSOs such as PCI-SIG and JEDEC Solid State Technology Association on developing standards for the semiconductor and microelectronics industry.

3. The empirical analysis results also showed that, most member firms, especially those in community 1, seem to be with low openness level and reluctant to provide information and opportunities to the general public, even those companies in community 1 are involved in most SSOs activities. This finding has implications for knowledge flows and diffusion of information.

Although there exist heavily overlaps among the SSOs in which the member firms are involved, the firms' SSOs IPR policy orientation can be still identified in empirical analysis. Certain SSO IPR policies can substitute for government regulations.

These policy choices are more likely related to the member firms' technology features or IPR strategies. Consequently, the relationship between the SSOs IPR policies, and the member firms' technology features and IPR strategies are expected to be explored in future studies. Nevertheless, the present research has provided unique graphical and empirical insights into the formation and memberships of networks across SSOs.

Chapter 7. Conclusions and Discussions

In this paper, I focused on some important topics which refer to the business method patents and the technology standards and attempted to employ social network analysis on these empirical studies.

My studies can be summarized as the follows.

With regard to the comparison study in the development of software, I refined sample of software patents by searching keyword in the title of the patent document based on the Cooperative Patent Classification (CPC). As result, I identify more than 1.3 million software patents applied for to the USPTO by 66 countries and regions during the period of 1990–2012. Then I utilized the information of joint application for software patent to build a social network by using two kinds of indexes to measure the positions of firms, i.e., “betweenness centrality” and “brokerage roles”. The visualization analysis suggested that, on the one hand, Japanese software companies grow up quickly, and cooperate with others frequently. They became important players in the network and formed many own subnetworks. On the other hand, most Japanese companies are located peripherally compared with the US companies that situated almost in the center of the network on the R&D cooperation.

I further investigated the competitiveness of firms engaged in business method software development, by using the patent data at the firm level and social network technique to find out the networking characteristic, i.e., relative centrality, structural equivalence and brokerage roles in patent joint application network. My results of the visualization analysis suggested that, the major players with the betweenness centrality and itinerant in business method software development field are mostly American big banks. In my regression analysis, the estimated results suggested that, more knowledge flows are observed between the firms that are in the same structural equivalent clusters. In such cluster, the firm with higher values of “relative centrality” will cite more patents from its counterpart firm. Furtherly, among the different types of the brokerage roles, I found positive promotion to knowledge transfer when the citing and cited firms both serve the role of the itinerant as well as the role of the gatekeeper/Representative.

Overall, my study of knowledge flows with regard to business method software provide some implications how knowledge evolves over time and for technology policy.

In the later part of the paper, after having reviewed recent literature on recent development of empirical literature on technological standard, I paid attention on the twofold issues on the intellectual property right (IPR) strategies for high-tech companies in standards-based markets. One is knowledge positions in the “main path” of standards-based markets, and the other is the SSOs’ IPR policies and their relations with the SSOs membership.

Due to that being able to assess knowledge positions in the “main path” of standards-based markets is important because they are assumed to increase chances for sustainable market participation, bargaining power, and licensing revenues, my study focused on the JTC1, an SSO that provides a standards development environment related to develop worldwide Information and Communication Technology (ICT) standards for business and consumer applications. I attempted to utilize social network technique to find out the characteristic, i.e., main path, betweenness centrality and brokerage roles in patent citation network of the JTC1, and carried out regression analysis of effects of these characteristics on the declaration of the SEPs. My main findings suggested that, compared with the main path analysis, the brokerage roles, as proposed by my study, does result in a better measurement of knowledge position, and matches more suitably the outcomes of the historical/technical narrative and an analysis of knowledge flows. Furthermore, claims of essentiality are the result of strategic behavior of the patent's owner, where important patents often occupy brokerage positions, and firms usually attend to claim their really important patents to be essential.

With regard to the issue about the SSOs’ IPR policies and their relations with the SSOs membership, I employed the Searle Center Database on the SSOs and merge the SCDB’s SSO policies file with the SCDB’s member file, to obtain a sample for approximately 1060 member firms and indices of IPR policies for twenty eight SSOs. By using a two-mode network for the relation between the SSOs and their member firms, I highlighted some indexes like betweenness centrality, and community to explore the features of the two-mode network. My main findings suggested that, although there exist heavily overlaps among the SSOs in which the member firms are involved, the firms' SSOs IPR policy orientation can be still identified in empirical analysis. These policy choices are more likely related to the member firms' technology features or IPR strategies.

In this paper, my contributions to the literature are threefold. Firstly, I investigated the IPR strategies of high-tech companies by using detailed empirical analysis on latest topics such as knowledge flows and R&D cooperation in the business method patenting and the SSOs' policies and their relationship with membership. Secondly, I attempted to employ recent development in social network analysis technique and provided some relevant findings suggesting their usefulness for these techniques on the analysis of firms' IPR strategies. Lastly, my empirical analysis is based on vast databases, such as Patstat, a database developed by European Patent Office, and Searle Center Database (SCDB), a database recently developed for the analysis on the SSOs activities. Employing vast database allow us to implement more detailed and desired analysis on IPR strategies of high-tech companies' global expansions and competitions.

The studies included in the paper could be expended in a number of ways. Firstly, as indicated by Hall (2009), patenting for business method software is related to a slightly different technology area, one possible evolution of practice in the banking and financial services industry. This industry depends heavily on secure communication and transactions exchange among banks and brokerage houses with millions of such transactions daily and requires a very high level of accuracy, which implies a need for highly stable common standards. Thus, new transactions' standards or particular ways for these transactions exchange may be patented by many different situations as that in other industries such as in the semiconductor/computer industry. Consequently these different situations could be resulted in the different behavior in the IPR policies and membership in the SSO across these industries.

Secondly, in the further study there would be needed to develop a theoretical framework or a set of hypotheses for analyzing the relationship between standards organization membership and the rules of the organization. This theory framework could be used to explain firms' endogenous participation decision for the SSOs, or forming the communities of the membership in which firms create standards organizations with particular rules, or heterogeneity in standards organizations' characteristics that simply reflect technological differences.

Thirdly, there is wide range of industry-specific manufacturing standards organizations. In addition to hundreds of specialised industry SSOs, there are many general organizations that develop and distribute standards across broader industry groups (Spulber, 2018). Andrew Updegrove gave the most complete list in existence of organizations that develop, promote and/or support information and communications technology standards[26]. The list includes categorized links and overviews of 1120 organizations. Still, it is my initial step of the research about standards and standard setting organizations, and most obvious limitation of my paper is, both the number of data and the data source in my paper is limited, I should find more helpful released data in the future research.

Lastly, in the chapter 6, my regressions do not account for interdependence of the two-mode network data; because the model assumes that each firm makes their choice of SSOs independently of one another. In the future study, a statistical network model of ties between firms and SSOs should be introduced to explicitly account for network interdependence, accounting for the effect that one firm's membership can have on another firm's membership.

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[26] see http://www.brs-inc.com/Manufacturing/directory.asp.

[26] see http://www.consortiuminfo.org/links/#.VViiHflViko.

[26] See https://analyticsindiamag.com/top-7-network-analysis-tools-for-data-visualisation/

Reference

Ahuja, G. (2000) “Collaboration networks, structural holes, and innovation: A longitudinal study," *Administrative Science Quarterly*, Vol (45), pp.425-455.

Apostolato, I. (2013). “An overview of software applications for social network analysis,” *International Review of Social Research*, Vol (3), pp.71-77.

Martinelli, A. (2011) “An emerging paradigm or just another trajectory,” Laboratory of Economics and Management LEM Working Paper Series.

Barbera-Tomas, D., F. Jimenez-Saez and I. Castello-Molina, I. (2011), “Mapping the importance of the real world: The validity of connectivity analysis of patent citations networks,” *Research Policy*. Vol. 40 (3), 473-486.

Baron, J. and D. F. Spulber (2018), “Technology standards and standards setting organizations: Introduction to the Searle Center Database,” Northwestern Law & Econ Research Paper No. 17-16.

Baron, J. and K. Gupta (2018), “Unpacking 3GPP standards,” *Journal of Economics & Management Strategy*, forthcoming.

Baron, J. and T. Pohlmann (2013), “Who cooperates in standards consortia- rivals or complementors,” *Journal of Competition Law and Economics*, Vol. (9), pp. 905-929.

Baron, J. and T. Pohlmann (2018), “Mapping standards to patents using declarations of standard-essential patents,” *Journal of Economics and Management Strategy*, forthcoming.

Baron, J. and D. F. Spulber (2015), “Technology standards and standards organizations: introduction to the Searle Center Database,” manuscript, Northwestern University.

Baron, J. and T. Pohlmann (2013), “Who cooperates in standards consortia-rivals or complementors,” *Journal of Competition Law and Economics*, Vol. 9(4), pp.905-929.

Baron, J. and T. Pohlmann (2015), “Mapping standerds to patents using database of declared standard-essential patents and systems of technologial classification,” manuscript, Northwestern University.

Baron, J. and T. Pohlmann (2015), “The effect of patent pools on patentting and innovation-evidence from contemporary technology standards,” manuscript, Northwestern University.

Baron, J., Y. Meniere and T. Pohlmann (2014), “Standards consortia, and innovation,” Scopus, Vol (36) pp.22-35.

Bartkowski, A. and R. Schramm (2008). “Visualizing patent statistics by means of social network analysis tools,” *World Patent Information*, Vol (30), pp. 115-131.

Bekkers, R. and A. Martinelli (2012), “Knowledge positions in high-tech markets: Trajectories, standards, strategies and true innovators,” *Technological Forecasting and Social Change*, Vol. 79(7), pp. 1192-1216.

Bekkers, R. and A. Updegrove (2013), “A study of IPR policies and practices of a representative group of standard setting organizations worldwide,” conference; Presentation at the Symposium on Management of Intellectual Property in Standard-Setting Processes, 3-4 October 2012, Washington D.C.

Bekkers, R. and A. Updegrove (2013), “IPR policies and practices of a representative group of standards-setting organizations worldwide,” Presented to the Committee on Intellectual Property Management in Standard-Setting Processes, National Research Council, Washington, D.C., 2013.

Bekkers, R. and A. Martinelli (2012), “Knowledge positions in high-tech markets: Trajectories, standards, strategies and true innovators,” *Technological Forecasting and Social Change*, Vol. 79(5), pp. 1192-1216.

Bercovitz, J. and M. Feldman (2011), “The mechanisms of collaboration in inventive teams: composition, social networks, and geography,” *Research Policy*, Vol (40), pp. 81–93.

Bessen, J., and R. M. Hunt (2007). “An empirical look at software patents,” *Journal of Economics Management Strategy*, Vol (16), pp.157-189.

Blondel, V. D., J.-L. Guillaume, R. Lambiotte and E. Lefebvre (2008), “Fast unfolding of communities in large networks,” *Journal of Statistical Mechanics: Theory and Experiment*, Issue 10, pp.1-12.

Borgatti, S. P. (2012), “Social Network Analysis, Two-Mode Concepts”, In Robert A. Meyers (Ed.), Computational Complexity, Springer, New York, pp. 2912–2924.

Borgatti, S. P. and M. G. Everett (1997), “Network analysis of 2-mode data,” *Social Networks*, Vol. (19), pp.243-269.

Burt, B. (2013), “Standard-Setting Organizations can be risky business for their members,” manuscript, Toulouse School of Economics.

Braveman, B. (2013), “Standard-setting organizations can be risky business for their members,” manuscript, Toulouse School of Economics.

Burt, R. S. (1987). “Social contagion and innovation: Cohesion versus structural equivalence,” American Journal of Sociology, Vol. 92, pp. 287-335.

Burt, R. S. (1992). Structural Holes: The Social Structure of Competition, Harvard University Press, Cambridge.

Cameron, C. A. and P. K. Trivedi (2010), Microeconometrics Using Stata, Stata Press.

Chiao, B., J. Lerner and J. Tirole (2007), “The rules of standard-setting organizations: an empirical analysis,” *Rand Journal of Economics*, Vol. 38(4), pp. 905-930.

Chiao, B., J. Lerner, and J. Tirole (2006), “The rules of standard-setting organizations: an empirical analysis”, *Rand Journal of Economics*, Vol (38), pp.905-930.

CHSRF (2003). “Knowledge brokering in Canada’s health system,” Canadian Health Services Research Foundation Report.

Clarkson, G. (2004). “Objective identification of patent thickets: A network analytic approach,” Harvard Business School Doctoral Thesis.

Clarkson, G. (2005). “Objective identification of patent thickets,” University of Michigan Law School Working Paper 1-32.

Colazo, J. (2010). “Collaboration structure and performance in new software development: findings from the study of open source projects,” *International Journal of Innovation Management*, Vol (14), pp. 735–758.

Cole, R. E. and Y. Nakata (2014). “The Japanese software industry: what went wrong and what can we learn from it?” *California Management Review*, Vol (57), pp. 16-43.

Contreras, J. L. (2017), “Essentiality and standards-essential patents,” in J. L. Contreras (ed.), Research Handbook on Technical Standardization Law-Antitrust, Competition and Patent Law, Cambridge: Cambridge University Press.

Contreras, J. L. (2019), “Technical standards, standards-setting organizations and intellectual property: a survey of the literature (with an emphasis on empirical approaches),” in P. S. Menell and D. Schwartz (eds.), Research Handbook on the Economics of Intellectual Property Law, Vol. II – Analytical Method, Edward Elgar.

Cummings J. and R. Cross (2003). “Structural properties of work groups and their consequences for performance,” *Social Networks*, Vol. 25, pp. 197–210.

de Nooy, W., A. M. and V. Batagelj (2005). Exploratory Social Network Analysis with Pajek, Cambridge University Press, New York.

Delcamp, H. R. and A.Leiponen (2012), “Innovationg standards through informal consortia: the case of wireless telecommunications,” *International Journal of Industrial Organization*. Vol. (36), pp.36-47.

Dosi, G. (1982), “Technological paradigms and technological trajectories”, *Research Policy*, Vol (11), pp.147–162.

Epstein, R. A. and D. J. Kappos (2013), Legal remedies for patent infringement: from general principles to FRAND obligations for standard essential patents’, *Competition Policy International*, Vol. (9), pp.69-164.

European Commission Report (2014), “Patents and standards: A modern framework for IPR-based standardization,” Ref. Ares (2014)917720 -25/03/2014.

Farrell, J. and G. Saloner (1988), “Coordination through committees and markets,” *RAND Journal of Economics*, Vol. 19(2), pp. 235-252.

Farrell, J., J. Hayes, C. Shapiro and T. Sullivan (2007), “Standard setting, patents, and hold-up,” *Antitrust Law Journal*, Vol. 74(3), pp. 603-670.

Farrell, J. and G. Saloner (1988), “Coordination through committees and markets,” *RAND Journal of Economics*, Vol. 19(2), pp. 235-252.

Fontana, R., A. Nuvolari, B. Verspagen, (2009), “Mapping technological trajectories as patent citation networks: an application to data communication standards,” *Economics of Innovation and New Technology*, Vol. (18), pp. 311-336.

Freeman, L. C. (1979), “Centrality on social networks conceptual clarification,” *Social Networks*, Vol. 1(3), pp. 215-239.

Friedkin, N. (1998). A Structural Theory of Social Influence, Cambridge University Press.

Goel, R.K., (2019), IPR infringement in the United States: Impacts on the input and output of R&D. Journal of Technology Transfer, forthcoming.

Goel, R.K., J.W. Saunoris, and X. Zhang (2016). “Intranational and international knowledge flows: Effects on the formal and informal sectors,” *Contemporary Economic Policy*, Vol (34), pp. 297-311.

Goel, R.K., M.A. Nelson, (2019), Do external quality certifications improve firms’ conduct? International evidence from manufacturing and service industries. Quarterly Review of Economics and Finance, forthcoming.

Gould, R.V. and R.M. Fernandez (1989). “Structure of mediation: A formal approach to brokerage in transaction networks,” Sociological Methodology, Vol (19), pp.89-126.

Graf, H. and J. J. Kruger (2011). “The performance of gatekeepers in innovator networks,” Industry and Innovation, Vol (18), pp.69-88.

Graham, S. J. J. and D. C. Mowery (2003). “Intellectual property protection in the U.S. software industry” in : Cohen, W. M. and S. A. Merrill (eds), *Patent in the Knowledge Based Economy*, National Academy Press, Washington D.C.

Granovetter, M. (1985). “Economic action and social structure: The problem of embeddedness,” *American Journal of Sociology*, Vol (91), pp. 481–510.

Hall, B. H., A. Jaffe, M. Trajtenberg (2005), “Market Value and Patent Citations,” *The RAND Journal of Economics*, Vol. 36(1): pp. 16-38.

Hall, B. H. (2009). “Business and financial method patents, innovation, and policy,” *Scottish Journal of Political Economy*, Vol (56), pp. 443-473.

Hall, B. H. and M. MacGarvie (2010). “The private value of software patent,” *Research Policy*, Vol (39), pp. 994-1009

Hall, B. H., G. Thoma and S. Torrisi (2009). “Financial patenting in Europe,” *European Management Review*, Vol (6), pp. 45-63.

Hummon, N.P. and P. Doreian, (1989): “Connectivity in a Citation Network: The Development of DNA Theory”. *Social Networks*, Vol.11 (1), pp.39-63.

Hunt, R. M. (2010). “Business method patents and U.S. Financial Service,” Contemporary Economic Policy, Vol (28), pp.1-7.

Jaffe, A. B. and M. Trajtenberg (1999). “International knowledge flows: evidence from patent citations,” Economics of Innovation and New Technology, Vol (8), pp. 105–136.

Jaffe, A. B. and M. Trajtenberg (2002). Patents, Citation and Innovation, Cambridge, MIT Press.

Jaffe, Adam B. Manuel Trajtenberg, and Michael S. Fogarty (2000), “The meaning of patent citations: report on the NBER/CASE-WESTERN reserve survey of patentees,” NBER Working paper 7631.

Jiang, J., R. K. Goel and X. Zhang (2017), “Knowledge flows from business method software patents: influence of firms’ global social networks,” *Journal of Technology Transfer*, *Springer,* Vol.44(4), pp.1070-1096.

Jiang, J., R. K. Goel and X. Zhang (2016), “Essential patents and knowledge position, a network analysis on the basis of patent citation,” presented to the 15th international conference of the Japan Economic Policy Association in Hokkaido.

Jorge L. C. (2016), “Patents, Standards, and Borders: Addressing National Disparities Among Holders of Standard-Essential Patents: Trade and Innovation within Global Networks,” unpublished manuscript.

Josh, L., H.Tabakovic, J.Tirole (2016), “Patent Disclosers and Standard-Setting”, unpublished manuscript.

Kindleberger, C. P. (1983), “Standards as public, collective and private goods,” Kyklos, Vol. 36(3), pp. 377-396.

LaBelle, M. M. and H. M. Schooner (2014). “Big banks and business method patents,” *U. of Pennsylvania journal of business law*, Vol (16), pp.431-448.

Leiponen, A. E. (2008), “Competing through cooperation: the organization of standard setting in wireless telecommunications,” *Management Science*. Vol. 54(11), pp. 1904-1919.

Lerner, J. (2008) “The litigation of financial innovations,” NBER Working Paper No. 14324.

Lerner, J. and J. Tirole (2006), “A model of Forum Shopping,” *The American Economic Review*, Vol. 96(4), pp.1091-1113.

Lerner, J., H. Tabakovic, J. Tirole (2016), “Patent Disclosers and Standard-Setting”, unpublished manuscript.

Leydesdorff, L. and L. Vaughan (2006), “Co-occurrence matrices and their applications in information science: Extending ACA to the web environment,” *Journal of the American Society for Information Science and Technology*, Vol 57(12), pp. 1616-1628.

Long, J. C., F. C. Cunningham and J. Braithwaite (2013). “Bridges, brokers and boundary spanners in collaborative networks: A systematic review,” *BMC health Services Research*, Vol (13), pp.158-171.

MacGarvie, M. (2006). “Do firms learn from international trade?” *Review of Economics and Statistics*, Vol (88), pp. 46–60.

Martin, N. L. and P. P. Mykytyn, Jr (2013), “Evaluating the Financial Performance of Business Method Patent Owners”, *Information Systems Management*, Vol (26), pp.285–301

Maskus, K. and S. A. Merrill (2014), Patent Challenges for Standard-Setting in the Global Economy: Lessons from Information and Communication Technology, The National Academies Press, Washington, D.C.

Maurseth, P. B. and B. Verspagen (2002). “Knowledge spillovers in Europe: a patent citations analysis,” *Scandinavian Journal of Economics*, Vol (104), pp.531--545.

METI (2017), “The policy for technology standard certification in the future: Toward acquiring global market through rule and institution formation,” Industrial Structure Council Report (In Japanese), 2017.

Mina, A., R. Ramlogan, G.Tampubolon, and J. S. Metcalfe, (2007). “Mapping evolutionary trajectories: Applications to the growth and transformation of medical knowledge.” *Research Policy*, Vol.36 (5), pp.789-806.

Minns, S. E. (2014). “Innovation, firm strategy and patent litigation,” PhD thesis, University of British Columbia.

Newman, M. E. J. (2010), Networks: An Introduction, Oxford University Press.

Rotta, R. and A. Noack (2011), “Multilevel local search algorithms for modularity clustering,” *Journal of Experimental Algorithmics* Vol 16(2), Article 2.3.

Scotchmer, S. (2004), Innovation and Incentives. Cambridge: MIT Press.

Seaman, C., R. McQuaid and M. Pearson (2017). “Social networking in family businesses in a local economy,” *Local Economy*, Vol (32), pp. 451-466.

Slob, A.F.L., M. Rijnveld, A. S. Chapman and P. Strosser (2007). “Challenges of linking scientific knowledge to river basin management policy: Aqua Terra as a case study,” *Environmental Pollution*, Vol (148), pp. 867-874.

Spulber, D. F. (2011), “Should Business Method Inventions be Patentable?” *Journal of Legal Analysis*, Vol (3), pp. 265–340

Spulber, D. F. (2018), “Standard setting organizations and standard essential patents: Voting and markets,” *The Economic Journal*, forthcoming.

Spulber, D. F. (2016), “Standard Setting Organization and standard essential patents,” Northwestern Law & Econ Research Paper No. 16-21.

Sternitzke, C., A. Bartkowski and R. Schramm (2008), “Visualizing patent statistics by means of social network analysis tools,” *World Patent Information*, Vol. 30(2), pp.115-131.

Swann, G. M. P. (2010), “International standard and trade: A review of the empirical literature,” OECD Trade Policy Working Paper No.97, 2010.

van Kammern, J., D. de Savigny and N. Sewankambo (2006). “Using knowledge brokering to promote evidence based policy-making: The need for support structures,” *Bulletin of the World Health Organization*, Vol (84), pp. 608–612.

Varma, B. K. (2014), “Learn more about Patent Classification”, Treatise on Process Metallurgy, Vol (3): Industrial Processes, Elsevier Press.

Wagner, S. (2008). “Business method patents in Europe and their strategic use - evidence from franking device manufacturers,” *Economics of Innovation and New Technology* Vol (17), pp.173-94.

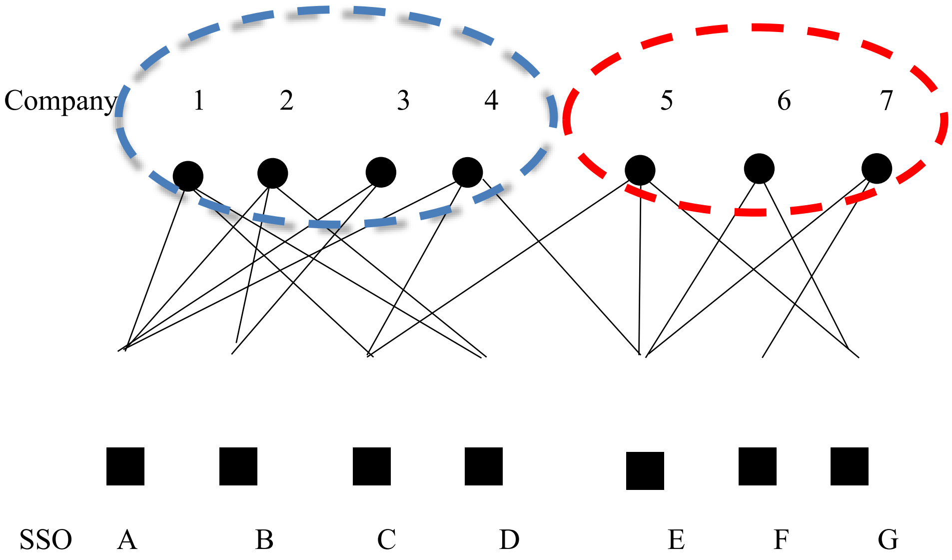
Wooldridge, J. M. (2010), Econometric Analysis of Cross Section and Panel Data (2nd Edition), Cambridge: MIT Press.

Yang, H., L. J. Zhiang and M. W. Peng (2011). “Behind acquisitions of alliance partners: Exploratory learning and network embeddedness,” *Academy of Management Journal*, Vol (54), pp.1069-1079.

APPENDIX

Assigning firms to communities

Clusters (or communities) divided according to modularity



Converting 2- mode network (companies and SSOs) to 1-mode network (companies)