Participant Diversity in Patent Pool Formation

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Abstract: ICT standards are supported by patents owned by firms that may be competitors who need to cooperate to establish a standard, suggesting the conflicting agendas that may affect the progression of a standard to a patent pool. We study the impact of participant diversity on the speed of progression of an ICT standard to a patent pool. Specifically, we explore three elements of diversity of Standard Essential Patent owners: business model, knowledge and business area. Our results show that the impact of participant diversity is very nuanced and unexpected. Participants concentrated in similar business areas will influence a standard to become a patent pool sooner while, surprisingly, standards that have participants with diverse knowledge stocks are unlikely to become patent pools.

Keywords: ICT standards, patent pools, heterogeneity.

1. Introduction

The products created by the Information and Communications Technology (ICT) suppliers are crucial resources for a modern economy. ICT products such as computer parts, cellphones, computer networking products and software are used by firms in all economic sectors and allow the creation of digital platforms and ecosystems. Technological standards ensure these ICT products are compatible with each other and that the markets for them can develop. Incorporating technological standards, specifically those created through *de jure* standardization[1], into ICT products is fraught with intellectual property conflicts for the ICT supplier, which can retard standards adoption and, thus, delay technological progress in the long run. This is because girding most technological standards is a bundle of intellectual property owned by a multitude of firms in the form of patents. Therefore, incorporating a technological standard can expose ICT suppliers to infringement litigation unless they have licensed all the (sometimes thousands of) underlying patents.

In this study we examine the formation of patent pools which as an efficient mechanism for ICT standards adopters to avoid costly litigation and, in particular, we study the speed of patent pool formation. Patent pools are formed when owners of standard essential patents (SEPs) agree to create and join a pool and thereby create an efficient way for ICT standards adoption - suppliers license all the patents underlying a standard *en masse*. Apart from the broader societal benefits of faster ICT standards adoption, patent owners also benefit from faster patent pool formation for two reasons. Faster ICT standards adoption can create first mover advantages for patent owners, over subsequent innovators, and thus protect the innovation from the rent-destroying effects of imitation (Shapiro, 2000). Indeed it has been found that licensing revenues are negatively related to the time required for

[1] In this study we focus exclusively on consensus-based ICT standards and standardization.

commercialization (Markman et al., 2005). Second, many of the SEP owners are also themselves potential adopters of the ICT standards (Contreras, 2019). As patent pool members, these owners are granted cross-licensing rights to the other patents in the pool. Quicker access to other technologies in the pool will reduce commercialization time and extract more profit from new products, develop next generation products and service extensions and avoid price competition (Eisenhardt & Martin, 2000).

Critical to patent pools is a formalized consensus between firms from diverse industry sectors, including non-ICT sectors, that have very different objectives and interests as participants. In particular, we aim to better understand the tension that arises in forming ICT patent pools when participants [2]have differing business models, knowledge resources and business areas, referred to henceforth as participant diversity. The literature is ambivalent about whether participant diversity has a positive or negative impact on consensus required for ICT standards to succeed. On the one hand, such diversity implies excessive breadth, and thus may dilute technical understanding and commercial investment, leading to weaker consensus (Ranganathan & Rosenkopf, 2014a). On the other hand, participant diversity may mitigate direct rivalry and thereby facilitate consensus (Markus et al., 2006). The goal of this study seeks to explore how participant diversity affects the speed with which a patent pool is created after a standard has been established.

The literature has shown that some SEP owners may choose to not join a patent pool (Layne-Farrar & Lerner, 2011; Mattioli, 2018), suggesting that patent pool formation can be delayed when there is internal conflict among the SEP owners. As speed to patent pool formation has not yet been studied, we borrow elements from the literature of innovation, acquisition and standards establishment to form theoretical predictions about how participants diversity can alleviate or elongate the length of time that lapses between the creation of a standard and the patent pool formation. We argue that a conflict may

[2] We use the terms 'participants' and 'SEP owners' interchangeably in this paper. When referring to participants in the standardization process, we want to make clear that we are not referring to the ISO committee members who approve the establishment of a standard. We are, in fact, referring to the owners of the SEPs that support and underly the standard.

arise from participants with business models concentrated in ICT manufacturing, diversified knowledge stocks and diversified business areas.

We test our hypotheses on almost 1000 global ICT standards and find that standards with a high proportion of SEP owners that are ICT users and are concentrated in the same business areas will form a patent pool faster. Our results unexpectedly showed that standards with SEP owners whose technological knowledge is concentrated will unlikely form a patent pool. Overall, the results indicate that standard participant diversity is nuanced and that the different elements of diversity require their own examination.

2. Background

2.1 Link between standards and patent pools

In general, ICT standards are established by standard setting organizations (SSOs) and the patents that underly a particular standard are declared by the patent owners themselves (Baron & Delcamp, 2015a; Delcamp, 2011). These patents are called standard essential patents (SEPs). The adoption of the new ICT standards by ICT users may be impeded significantly if adopters are faced with a patent thicket. Patent thickets are dense webs of incremental patents that must be individually licensed and negotiated from potentially many different patent owners. Patent thickets lead to lower downstream innovation and higher costs for firms which commercialize the standard's technology. They also lead to a decrease in venture capital, which lowers subsequent market entry and interoperability in the target technology markets (Cockburn & MacGarvie, 2009, 2011). The objective of a patent pool is to facilitate bundled licensing of the patents and encourage formal utilization of a technology while mitigating deterrents such as patent thickets (Wen et al., 2013).

The formation of the standard and the patent pool are not simultaneous, nor is a patent pool a necessary condition of a standard. Although there are exceptions, usually the standard is established first by an SSO and then a period of time passes during which some of the owners of SEPs may attempt to form a patent pool through a licensing facilitator (Mattioli, 2018). Typically, the licensing facilitator

issues a public call for patents and hires an independent expert to evaluate whether any declared patents are essential to the standard. This essentiality evaluation step is rigorous and expensive, and is performed separately from the SEP process for the standard. This onerous procedure may, in part, explain why so few patent pools exist compared to standards (Contreras, 2019). Biddle, White and Woods (2010) find that of 251 standards implemented in a typical laptop computer, only 3% were subject to patent pools, with the remainder subject to FRAND (fair, reasonable and non-discriminatory) or royalty-free licensing commitments.

2.2 Standards literature

Most of the technologies that underly the standards developed by SSOs are patented and these patents are owned by companies, universities, and sometimes individuals (Contreras, 2019). The patents owners individually submit technical contributions to the standard-setting process which is overseen by the SSO. The SSO forms a committee that is comprised of stakeholders of the standard such as patent owners, vendors, manufacturers and sometimes consumer groups. The committee members will jointly determine whether the patents are SEPs, meaning that they are necessary for the manufacture and/or use of a standard-compliant product.

There are several firm-level and environmental factors that can facilitate the establishment of a standard. Ranganathan and Rosenkopf (2014b) examine the ballots in standards committee decision meetings and find that the more central a firm is within the knowledge network of committee member firms, the lower its opposition to the standard. The reasoning is that if a firm's knowledge is central, then its more likely that the knowledge is already foundational among its peers in the committee and that the standard will build on this knowledge. Axelrod, Mitchell, Thomas, Bennett and Bruderer (1995) estimate an alliance of firms involved in the Unix standard and find that firms' incentives to join a standard-setting alliance increase with the number of firms in the standard as it will increase the chances that the standard will become established. Ranganathan, Ghosh and Rosenkopf (2018)

investigate the tone of emails of standards committee members regarding impending standards. They find that the more competitive a firm's product market space, the more the firm's technological overlap with other firms will increase its collaborative support during standards creation because of the urgency to increase current market size. Blind and Mang (2016) use German survey data to examine the incentive to participate in standard setting committees. They find firm R&D intensity and innovation has a positive influence because investments in R&D will be reinforced with standardization and that small firms want to be involved to gain access to complementary resources.

Conversely, the establishment of a standard can be inhibited by committee member characteristics as well. Ranganathan and Rosenkopf (2014b) find that the more central a focal firm is within the commercialization network of the member firms, the higher its opposition to the standard. The logic is that commercialization is the exploitation of current technology and firms that are central in the commercialization network have an advanced competitive position with complementarities with *current* technology and do not want to change that position. Ranganathan et al. (2018) find that the broader the firm's investments in product complements, the more the firm's technological overlaps with other firms will decrease its collaborative support during standards creation. This is because more complements make a company more invested in current technology.

2.3 Patent pools primer

Patent pools form to enable the adoption of technology standards in society by reducing intellectual property traps such as patent thickets, royalty stacking and, legal uncertainty, as well as basic transaction costs of users negotiating with multiple licensors. Patent pools are an efficient mechanism to reduce costs associated with bilateral negotiations and SEP disputes, by facilitating transactions through a 'one-stop shop' (Koundinya, 2020). Through the sheer simplicity of cutting down the number of licenses needed to comply with a standard down to (ideally) one, patent pools reduce transaction costs and the risk of royalty stacking by setting a unique royalty rate for a bundle of SEPs

(Baron & Delcamp, 2015a). Merges and Mattioli (2017) find that patent pools are an enormous cost saver for society. They estimate the costs of running two patent pools (MPEG Audio and HEVC) compared to the licensee costs associated with the alternative where those patent pools did not exist and find that there is over $1b of transaction costs saved for those two patent pools combined.

Not all owners of SEPs join the associated patent pool (see Contreras (2019) for 'hold-outs' and Mattioli (2018) for 'outsiders'). Layne-Farrar and Lerner (2011b) estimate that most 'complete' modern PPs contain 89% of the patents that a licensee might need. One reason why patent pools are incomplete is that they often form through a gradual process (Mattioli, 2018). Patent pools form continuously with the inclusion of new members and the addition of new patents by incumbent members (Baron & Delcamp, 2015a). Mattioli (2018) find that the incentive to be an outsider is higher if a firm thinks they can garner higher royalties than they would being inside the patent pool by demanding high rates from licensees, but also exerting pressure on insiders by demanding a larger share of the pie in exchange for its cooperation. Mattioli (2018) concludes that the objective of having a complete pool (i.e.: with all SEPs) is not ideal as it would require costs of enticing holdouts/outsiders to join. Holdouts and outsiders are inevitable, but their presence is not a dealbreaker for the formation of a patent pool.

3 Hypotheses

The hypotheses will focus on the elements of ICT standard participant heterogeneity that can affect patent pool formation. All other characteristics of standards not pertaining to participant heterogeneity which have been already identified in the literature will included as control variables.

Although we recognize that it is not necessary to have all SEP owners to unanimously join to form a patent pool, we assert that the more SEP owners that join a patent pool, the more likely the patent pool will be established. Kouninya (2020) agrees: 'attempts to create patent pools have seemingly not been successful, for example in 2G, 3G and 4G standards, owing to a lack of participation by SEP holders, who have mostly engaged in bilateral negotiations.' As such, all three

hypotheses will seek to identify participant characteristics that inhibit joining patent pool and, therefore, slow down the transition to a patent pool.

3.1 Business model diversity of participants

Layne-Farrar and Lerner (2011) find that vertically integrated firms have a higher likelihood of joining patent pools as joining will lower the royalties it will have to pay and lower transaction costs for subsequent product development that uses the standard. Mattioli (2018) makes a similar conclusion that non-manufacturing firms have less incentive to join a patent pool because they do not value reciprocal licensing. Manufacturing firms invested in the current technology would want to support a patent pool to take advantage of free licensing access to the other patents more than research-based firms whose main revenues are only in the technology market. Faster technology commercialization leads to more positive outcomes such as reducing costs, being first to market and higher returns to innovation (Markman et al., 2005). SEP owners are innovators and themselves benefit from the cross-licensing afforded to patent pool participants (Contreras, 2019). The sooner they can do this, the sooner they begin lowering their own costs and benefiting from complementary products that use the same standard. ICT product life cycles are very short and those firms that are invested in the technology will have a large incentive to compress time to commercialization to ensure profits before the next ICT product renders theirs obsolete. It can also be argued that because diversified firms are typically large, they could instead protect their intellectual property by litigating against patent pools owners who infringe upon its technology (Choi, 2010), influencing the firm to stand apart from the patent pool.

Although the majority of SEP owners are ICT manufacturing firms, there are a few business models other than ICT manufactures among the SEP owners with different motivations to join a patent pool: research institutions and universities, non-ICT manufacturing firms and service firms. All three of these types of SEP owners prefer that the standard established continues to be the accepted standard

as they will gain the most through royalties (Mattioli, 2018) and not having to upgrade their equipment and practices to accommodate new standards. Non-ICT manufacturing firms and service firms involved in the standardization process are typically users of standards rather than manufactures of compatible ICT products. They will not gain any more from joining a patent pool than they already reaped when the standard became established. Therefore, we assert that:

> **Hypothesis 1**: Standards with a higher diversity of business models among the participants slower than those with a concentration of business models in ICT manufacturing.

3.2 Knowledge diversity of participants

The transition of a standard to a patent pool is a unique situation but, at the same time, has similarities to the dynamics involved in research alliances and acquisitions in that the participants are working together to form a cohesion of technologies. Lane and Lubatkin (1998) argue that the ease of knowledge transfer is largely determined by the similarity in knowledge bases of the partners. Ahuja and Katila (2001) found that the relatedness of acquired and acquiring knowledge bases enhances innovation performance. One reason for this, they suggest, is that technological similarity between two parties reflects common skills and expertise, and shared languages and mindsets - all of which reduce asymmetric information and facilitate effective and speedy communication and learning.

The innovation speed literature also has some applicability to the situation underlying the speed to patent pool formation in that it considers the time to merge together externally sourced technologies to form a new innovation. This literature has established that innovations between parties with technological familiarity will occur faster. Leone and Reichstein (2012) showed that a technology user's ('licensee') invention time increases if it licenses-in a technology that it is unfamiliar with as in-house familiarity about licensed technology enables the firm to adopt the embodied knowledge quickly. It is well-accepted in the alliance literature that similar firms, especially those with knowledge homogeneity, will quickly achieve innovation outcomes including speed because of the mutual technical

understanding (Kogut & Zander, 1992) and are more likely to cooperate with each other unimpeded because of ease of identification and valuation (Mowery et al., 1998).

The process of forming a patent pool requires understanding from all participants of the technologies that underly the standard. Although SEP owners are not innovating with the technology in the standard, in a similar fashion many participants will need to have understanding and absorptive capacities for the technology when they use it in their compatible ICT products.

> **Hypothesis 2**: Standards with participants that have a concentration of technical knowledge form a patent pool faster than those standards with participants that have diverse knowledge.

3.3 Business area diversity of participants

Ranganathan and Rosenkopf (2014b) find that firms more central in their commercialization network are less likely to support a standard because more centrally located firm's knowledge is foundational along its peers already in the committee and the standard represents future technology which differs from the existing knowledge in the network. However, for our study, we assume that the standard has already been established and we are concerned with how quickly a patent pool can form from that existing standard. Our study is concerned with the *current technology*. This is an important distinction because if a standard already exists, then it is possible that some commercial manufacturers have already gained access to the standard's technology by licensing-in individual patents. If any one competitor is already using the standard, then it is to the advantage of all its competitors to also gain access to the standard through the cheapest and simplest way possible: the patent pool.

> **Hypothesis 3**: Standards with participants that have more concentrated commercial interests will form a patent pool faster than standards with more diverse commercial interests.

4 Empirical Section

4.1 Data sample

To attain the list of ICT standards and their Standard Essential Patents (SEPs), we used two databases from the Searle Center on Law, Regulation, and Economic Growth. The first database, known as the Searle Center Database on Technology Standards and Standard Setting Organizations, contains bibliographic information on published technology standards (outlined in Baron & Spulber (2018)) and has recently used in Jones, Leiponen & Vasudeva (2021). The second database contains the most comprehensive database of declared SEPs (outlined in Baron & Pohlmann (2018)) and has been recently used in Miller and Toh (2022).

The Searle Centre (SC) compiled their standards database and SEPs database separately and it was a complicated and onerous process to link the two due to the base observation in the standards dataset being SEP patent publication numbers and SEP application numbers in the SEP database. We verified our merging process and final list of standards with their associated SEPs with the lead researchers of the Searle Centre. The main source of the SC database is the declaration letters sent to the SSOs which assert patent essentiality for a standard. SC used the patent numbers in the declaration letters to identify the SEP's original applicant(s) as well as their most recent assignees (current owners) using IPlytics. As patent ownership can change, we use the recent assignee instead of original applicant or even declaring company[3] as the owner of the SEP.

After cleaning and dropping omitted observations and eliminating standards with very few SEP owners (less than 3) or very few SEPs (less than 6), the usable data is comprised of 947 distinct standards, 462 distinct SEP owners (an average of 10.5 per standard, range of 3-133) and an average of 1929 SEPs per standard (range of 6-88176).

The list of ICT patent pools was made using three sources; Layne-Farrar & Lerner (2011b) examined 9 patent pools, Baron & Pohlmann (2011) listed 28 patent pools and Baron & Pohlmann

[3] Most often, the declaring companies are the current owners of the declared SEPs but not necessarily. Sometimes they are sitting members of the SSO committee or even a third party who are very sure that the patents in question are SEPs.

(2015) listed 50. These studies are the main academic empirical sources of patent pools (Mattioli, 2019). There was considerable overlap between the three sources, and we were able compile a final list of 48 patent pools with matching standards in our dataset.

4.2 Model

The survival analysis we employ is a Cox regression which assumes no particular distribution of the hazard rate but the results are similar if the distribution is exponential or lognormal. The model we utilize is

$$ln(t_j) = \beta_0 + x_j\beta_x + \mu_j, \quad (1)$$

where t_j is the length of time to the event (formation of the patent pool) for standard *j*, x_j is a vector of standard-specific variables, and μ_j is an error term that is normally distributed.

4.3 Variables

Dependant variables: We use two different but similar measures for the time to patent pool formation. They both have the same end time but a different start time. The start time is intended to be the establishment of the standard which underlies the patent pool that eventually forms. *dv_publish* uses the official publish date for the first version of the standard as the start date. Whereas *dv_declare* uses the date of the first declaration letter received by the SSO as a proxy for the unofficial establishment date for the standard. The declaration date for a standard is valid for many SOS participants as the standard becomes salient before the official publishing of the standard by the SOS. Both variables use the launch date of the patent pool as the end date. If a standard does not form into a patent pool, the end date is the last day of the dataset (July 1st, 2017).

Independent variables: The regressions and variables in this dataset are all at the standard-level despite the large amount of SEP-level data that was gathered in order to compile the standard-level variables. The independent variables are designed to measure the heterogeneity among the SEP owners within each standard.

SEP owner business model diversity. We create two separate but related measures for this variable. First, the Herfindahl index of the SEP owners' business model is crafted for each standard. We searched the company profile for each unique SEP owner on the Nexis Uni database and coded each SEP owner as 1. University/research institute, 2. manufacturing ICT firm, 3. manufacturing non-ICT firm or 4. ICT service firm. The ICT industry is comprised of many different types of entities with different relationships with ICT: suppliers, users and service providers and the coding is intended to reflect the intricacies that each type of participant may bring to the forming a patent pool. Layne-Farrar and Lerner (2011) measured their vertical integration variable as those that contribute patent to the standard and also manufacture a product based on that standard. Ideally, we would have preferred to replicate their measure but the large number of unique SEP owners and standards in our dataset prevented this. A Herfindahl index, in this case, is simply the sum of the squared shares of business models in each standard. A standard with this Herfindahl measure close to one has a high concentration of SEP owners in one of the four categories while conversely, a measure closer to zero reflects a more even diversity of business models. The second measure for this variable is the proportion of SEP owners that are manufacturing non-ICT firms (i.e.: banks or pharmaceutical firms) or service firms (i.e.: telecommunication firms). These two categories reflect the users of the ICT industry meaning that their commercial interest rely on the current standard and although they may manufacture a small number of ICT products, they are usually for their own purposes, not for retail sale. We expect that if the diversity of the SEP owners is high or if the proportion of SEP owners that are users of the ICT industry, then the progression to a patent pool is slower.

SEP owner knowledge diversity. This variable is the Herfindahl index for the combined patent stocks of patent owners in a standard. The entire knowledge stock of all the SEP owners in a given standard plays a role in standard setting in that it technologically informs each SEP owner as well as the entire group of SEP owners together. We expect that the more concentrated is the knowledge base of

the entire standard, the faster the progress to a patent pool. We searched for the patent stocks of the SEP owners in Patstat, a worldwide patent statistical database. To measure knowledge heterogeneity of the assignees within each standard, we gathered the World International Property Organization (WIPO) technology classification for each patent. We calculated a Herfindahl index for each standard using the 35 WIPO technical patent categories for all the pooled SEP owners' patents. The measure shows how diverse are the historical knowledge areas are for all the participants in a standard. It will range from 0 to 1 where 0 indicates the SEP owners have very diverse knowledge stocks and 1 indicates they are concentrated in one particular technology area.

SEP owner business area diversity. Each SEP owner is associated with a primary SIC (standard industrial classification) which represents the main commercialization interests of the firm. Non-commercial SEP owners such as universities and research institutes were coded with a fictional (but consistent) SIC. We take the 4-digit SIC classification for each owner and calculate the Herfindahl index for each standard. This measure ranges from 0 to 1 where 1 would indicate that the SEPs owners in the standard are all from one particular SIC. We expect standards with a higher concentration of SEP owners in the same business area will become a patent pool faster.

Control variables: *Standard technical area diversity* reflects the diversity of technology in the standard itself and is measured using a Herfindahl index of all the International Patent Classifications (IPC) among the SEPs in the standard. The IPCs are a classification of the paramount technological area of a patent. We would expect that the more diverse the technology, the slower the standard would become a patent pool. There is an onerous, labour-intensive process to prove the essentiality of each patent in a patent pool on the part of the licensing agency (Contreras, 2019) and the more disparate are the technological areas from which they come, the more technical staff and time will be needed for the essentiality task.

Standard ownership diversity is a control variable that measures SEP ownership concentration within a standard. It is calculated using a Herfindahl index of the SEP owners in standard where the shares are the number of SEPs owned by a unique firm in the standard. The innovation speed literature has found that the more parties involved, the longer it will take to innovate (Markman et al., 2005). This is mostly due to the complexities that arise when processes span organizational boundaries. Aspects of the innovation process can be found in the patent pool formation process in that different technologies, sometimes owned by different entities, are patiently learned, adapted and merged together to form a new and separate technology/process/project. Layne-Farrar and Lerner (2011) empirically found that larger founding member groups will reduce incentive to join patent pool although they did not theorize about it. Baron and Delcamp (2015b) examine the incentives to join a patent pool and find that incumbent members introduce more narrow patents than new members. Incumbent members have the majority of patents in pool and make more revenues, so this implies that a high concentration of patents in less patent owners' hands would facilitate the formation of a patent pool. Keeping in mind that a completely concentrated ownership would not have an incentive to join a patent pool. Ignoring this specific case, we would expect that standards with fewer SEP owners would become patent pools faster.

Standard size reflects the size of the standard and is measured simply as the number of SEPs in a standard. We would expect that the more patents that need to be determined to be essential on the part of the licensing agency, the slower the process to become a patent pool.

Standard patent pool experience is measured as the proportion of SEP owners in the standard that have been part of a patent pool before the establishment of the standard. Both the acquisition literature (Haleblian et al., 2006) and the alliance literature (Shi et al., 2012) agree that past experience in acquisition or alliances will lead to a higher probability of the same activity due to routines, processes and possibly dedicated staff for the activity. Al-Laham, Amburgey and Bates (2008) found that acquisition experience translates to increasing faster subsequent acquisitions after the first one as the

firm is better able to identify potential partners more quickly and learn from the alliance more efficiently. Stemming from this similar literature, we expect that more patent pool experience should mean faster (and more likely) patent pool formation.

Table 1 shows the variables and their descriptions. As the focus of this study is diversity, many of the variables are measured as Herfindahl indexes. Herfindahl indexes range between 0 and 1 where 1 indicates concentration and 0 indicates greater heterogeneity and breadth. Table 2 displays the variables' correlations.

Table 1: Description of Variables

Name	Description	obs	mean	sd	min	max
Dependent variables						
dv_declare	Number of days between standard's first declared SEP and patent pool announcement (or end of dataset)	947	4083.7	1571.6	101	12252
dv_publish	Number of days between standard's publish date and patent pool announcement (or end of dataset)	941	4921.8	1819.6	56	10714
Independent variables						
SEP owner business model diversity (H1)	Herfindahl index of SEP owners' business models of which there are 4: university/research institute, manufacturing ICT firm, manufacturing non-ICT firm or ICT service firm	948	0.97	0.08	0.36	1
SEP owner user proportion (H1)	Proportion of SEP owners that are service firms and non-ICT firms	948	0.07	0.12	0	1
SEP owner knowledge diversity (H2)	Herfindahl index of technical categories of SEP owners' total combined patent stocks	948	0.17	0.11	0.06	0.72
SEP owner business area diversity (H3)	Herfindahl index of SEP owners' Standard Industrial Classifications (SICs)	948	0.69	0.26	0.17	1
Control variables						
Standard technical area diversity	Herfindahl index of International Patent Classification (IPCs) of SEPs in standard	948	0.25	0.21	0.02	1
Standard ownership diversity	Herfindahl index of SEPs owned by unique owners in standard	948	0.45	0.20	0.09	0.97
Standard size	Number of SEPs in standard, in thousands	948	1.92	6.99	0.006	88.176
Standard patent pool experience	Proportion of standard's SEP owners with previous patent pool experience	948	0.30	0.23	0	1

Table 2: Correlation of Variables

	1	2	3	4	5	6	7	8	9	10
Dependent variables										
1 dv_declare	1									
2 dv_publish	0.73	1								
Independent variables										
3 SEP owner business model diversity (H1)	-0.01	0.02	1							
4 SEP owner user proportion (H1)	0.04	0.001	-0.53	1						
5 SEP owner knowledge diversity (H2)	-0.18	-0.11	0.15	-0.22	1					
6 SEP owner business area diversity (H3)	-0.15	0.03	0.08	-0.02	0.39	1				
Control variables										
7 Standard technical area diversity	0.10	0.36	0.09	-0.14	0.26	0.48	1			
8 Standard ownership diversity	-0.17	0.07	0.02	0.03	0.24	0.66	0.49	1		
9 Standard size	0.03	-0.07	-0.09	0.23	-0.22	-0.22	-0.22	-0.24	1	
10 Standard patent pool experience	-0.38	-0.52	0.01	-0.05	-0.02	-0.22	-0.33	-0.09	-0.04	1

4.4 Results

The estimations for the survival model are displayed in Table 3. We find very consistent results across the two dependent variables which implies that the starting point for the time to failure (first declaration letter or publish date of the standard's first version) does not seem to matter. Survival in this context means that a standard has not become a patent pool. We present the hazard ratios and they are interpreted as follows. If a hazard ratio is less than 1 (and significant), then higher values of the variable contribute to longer survival rates (ie: will not become a patent pool or if it does become a patent pool, it will take longer to do so). If the hazard ratio is more than 1 (and significant), then higher values of the variable contribute to the likelihood of failure (ie: more likely to become a patent pool or will become one sooner).

Table 3: Cox survival regressions with hazard ratios

	Dependant variable = dv_declare													
	Column 1		Column 2		Column 3		Column 4		Column 5		Column 6		Column 7	
	hazard (s.e.)		hazard (s.e.)		hazard (s.e.)		hazard (s.e.)		hazard (s.e.)		hazard (s.e.)		hazard (s.e.)	
Independent variables														
H1 SEP owner business model diversity			0.06 (0.09)	*							0.14 (0.22)			
H1 SEP owner user proportion					19.00 (23.65)	**							8.14 (10.48)	*
H2 SEP owner knowledge diversity							0 (0.01)	**			0.002 (0.005)	**	0 (0.01)	**
H3 SEP owner business area diversity									5.99 (5.81)	*	9.99 (10.08)	**	8.73 (8.9)	**
Controls														
Standard technical area diversity	0.02 (0.04)	**	0.03 (0.05)	**	0.03 (0.05)	*	0.06 (0.11)	*	0.01 (0.02)	**	0.05 (0.09)	*	0.05 (0.09)	*
Standard ownership diversity	0.67 (0.7)		0.67 (0.69)		0.49 (0.53)		0.74 (0.75)		0.13 (0.19)		0.09 (0.13)	*	0.08 (0.12)	*
Standard size	1.03 (0.01)	***	1.03 (0.01)	***	1.03 (0.01)	***	1.03 (0.01)	***	1.04 (0.01)	***	1.03 (0.01)	***	1.03 (0.01)	***
Standard patent pool experience	30.49 (24.33)	***	32.80 (26.45)	***	42.12 (34.06)	***	45.40 (37.30)	***	31.3 (24.35)	***	51.36 (41.95)	***	62.5 (51.35)	***
number of obs	947		947		947		947		947		947		947	
LR Chi^2 (df)	43.50 (4)	***	46.27 (5)	***	48.10 (5)	***	48.96 (5)	***	46.86 (5)	***	55.75 (7)	***	56.62 (7)	***
	Dependant variable = dv_publish													
	hazard (s.e.)		hazard (s.e.)		hazard (s.e.)		hazard (s.e.)		hazard (s.e.)		hazard (s.e.)		hazard (s.e.)	
Independent variables														
H1 SEP owner business model diversity			0.05 (0.07)	**							0.10 (0.14)	*		
H1 SEP owner user proportion					20.69 (23.17)	***							8.00 (9.05)	*
H2 SEP owner knowledge diversity							0.001 (0.004)	**			0.001 (0.002)	***	0.001 (0.002)	***
H3 SEP owner business area diversity									5.54 (5.28)	*	10.59 (10.53)	**	8.56 (8.66)	**
Controls														
Standard technical area diversity	0.02 (0.03)	**	0.02 (0.04)	**	0.02 (0.03)	**	0.04 (0.08)	*	0.01 (0.02)	**	0.03 (0.06)	*	0.03 (0.05)	**
Standard ownership diversity	0.61 (0.63)		0.59 (0.6)		0.45 (0.47)		0.76 (0.77)		0.13 (0.18)		0.09 (0.12)	*	0.10 (0.14)	*
Standard size	1.03 (0.01)	***	1.03 (0.01)	***	1.03 (0.01)	***	1.03 (0.01)	***	1.04 (0.01)	***	1.03 (0.01)	***	1.03 (0.01)	**
Standard patent pool experience	23.62 (18.92)	***	25.85 (20.93)	***	33.24 (26.92)	***	39.1 (32.91)	***	24.15 (18.71)	***	48.07 (40.29)	***	56.67 (47.69)	***
number of obs	941		941		941		941		941		941		941	
LR Chi^2 (df)	44.10 (4)	***	47.60 (5)	***	49.62 (5)	***	50.81 (5)	***	47.24 (5)	***	58.574 (7)	***	59.24 (7)	***

Note: p-values * <10%, **<5%, ***<1%

The control variables are consistently estimated across the models and show that SEP owners with patent pool experience are an important component to the standard becoming a patent pool sooner. Undoubtedly, the companies with previous patent pool experience are well-versed in asserting

patent essentiality to a licensing agency but also may play a role in initiating the process to begin with. Unexpectedly, the results show that standards with a large number of SEPs (*Standard size*) are more likely to become a patent pool. We find evidence that standards that are concentrated technologically (*Standard technical area diversity*) and in SEP ownership (*Standard ownership diversity*) take longer to become a patent pool, neither of which was expected. The results from the control variable highlight that patent pool formation is very unique and other technologically-based literatures perhaps do not apply on all levels, aside from the experience factor.

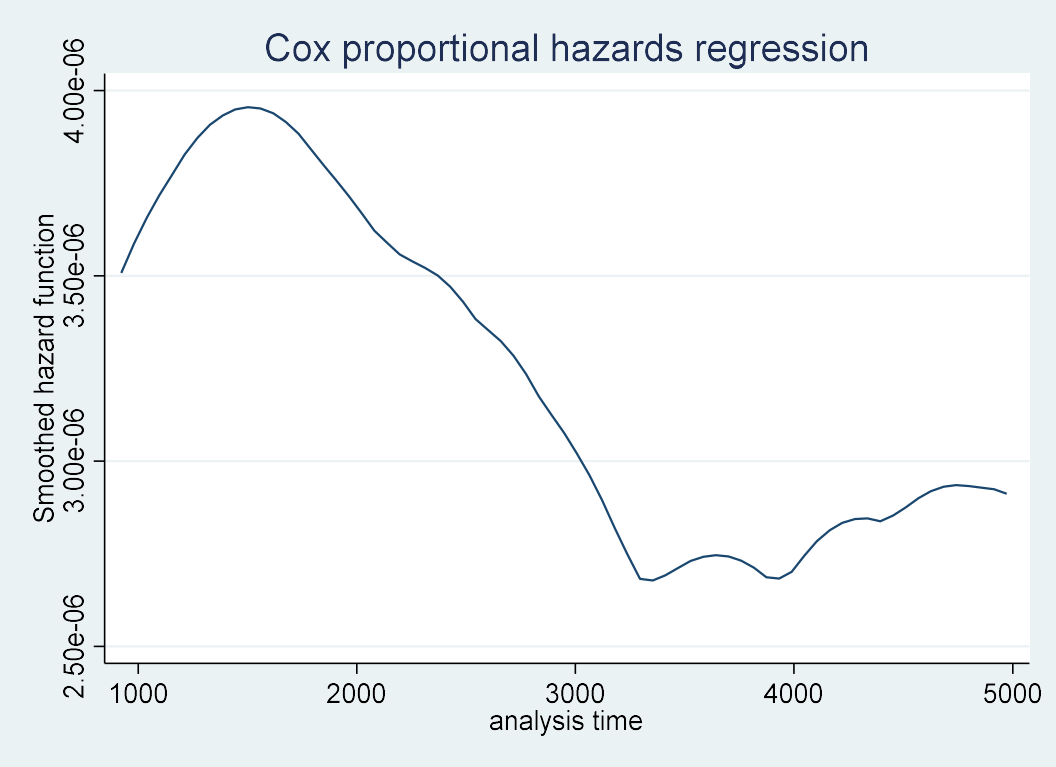
The results confirm that breadth of knowledge amongst the SEP owners is an important element in the patent pool formation process but not in the manner that we expected. The results show that standards with SEP owners that have a high concentration of knowledge have a longer survivor time which means that they will more slowly, if ever, become a patent pool. We expected that, in line with the technology acquisition and innovation speed literatures, more concentrated knowledge would contribute to quicker formation of patent pools, but we find the opposite. It is possible that standards with concentrated knowledge among the SEP owners may suffer from competition in the technology market which could be contributing to slow patent pool progression.

Standards with SEP owners concentrated in similar business areas will become patent pools sooner. This is due to the presence of the existing technology in the established standard already being present in the downstream industries which make complementary products based on the standard. Once the technology is available to one competitor, all the other competitors will also want access to the technology as soon as possible: through a patent pool.

We find weak evidence that standards with a high concentration of business models will take longer to become a patent pool which is very surprising given the previous literature which has found that vertically integrated firms would gain more from joining a patent pool through reciprocal licensing. We wondered whether this variable was messy because the vast majority of the business models

amongst the SEP owners is manufacturing ICT firms and the Herfindahl index is measure as close to 1 for many standards. We created a variable which teased out the proportion of the SEP owners that are firms that use the ICT standards for their own purposes rather than to manufacture complementary ICT products based on the standards. The results using this secondary measurement (weakly) confirm the first; that standards with a high proportion of user SEP owners will become patent pools sooner than those with a smaller proportion. It appears that even though ICT user firms have little to gain in terms of reciprocal licensing, they also have little resistance to joining a patent pool and little reason to hold out as they are not planning on reaping royalties from their ICT patents which are a low proportion of their overall patent stocks.

Figure 1 shows the survivor function using the data from the regression in Column 7 of Table 3 with *dv_pubish* as the dependent variable. The figure shows that standards that become a patent pool tend to do so in the early days post-standard establishment and then decrease afterwards. In fact, the point at the highest likelihood for a standard to form into a patent pool is 1438 days or just under 4 years.



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