The Effect of Patent Pools on Patenting and Innovation - Evidence from Contemporary Technology Standards

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Abstract

We analyze the effect of patent pools on the incentives to file patents related to a comprehensive sample of Information and Communication Technology (ICT) standards. We measure a positive effect of the announcement of a pool on the filing rates for standard-related patents. We identify an exogenous policy change between 1997 and 1999, when antitrust authorities adopted a more permissive stance towards pooling of patents. An important number of pools were created in the wake or in response to this policy change. Studying these pools, we find a significant increase in patenting rates after pool announcement. This increase in patenting is primarily attributable to future members of the pool, as confirmed by Instrumental Variable regressions using firm-level characteristics associated with a higher likelihood of joining a patent pool. Pool creations taking place in later years could be more easily anticipated. Indeed, we find that the announcements of later pools is preceded by unusually high levels of patenting. Furthermore, we show that pool announcements with a higher likelihood of successful pool creation are followed by a stronger increase in patenting. We find no significant effect of patent pool announcements on the number of citation-weighted patent files.

JEL-Classification: L24, O34
Kewords: Patent Pools, Technology Standards, Patent Licensing, Innovation incentives

1 Introduction

Complex Information and Communication Technologies (ICT), and in particular technology standards, are often protected by a large number of complementary patents. In this context, it has become frequent that companies license out their patents through patent pools, providing users with a single license for a bundle of patents held by different firms. This mechanism can help to increase transparency and reduce transaction costs. Pools including only patents which are complementary and necessary for implementing a technology furthermore eliminate wasteful multiple margins (Lerner and Tirole, 2004). Recent antitrust guidelines have therefore endorsed the permissive stance towards such patent pools practiced over the last two decades[1].

The effect of patent pools on the incentives to innovate is however subject to debate. The theoretical literature (Lerner and Tirole, 2004; Dequiedt and Versaevel, 2013; Schmidt, 2014) mostly predicts a positive effect of pools on innovation incentives. Recent empirical research (Lampe and Moser, 2012; Joshi and Nerkar, 2011; Flamm, 2013) in contrast shows that the creation of several pools was followed by a decline in related innovation activities. These findings however only describe a decline in follow-on innovation once existing patents were bundled into a pool. The economic effect of patent pools also includes the incentives to file patents to be included into an announced or expected future pool.

This paper analyzes the effect of both the announcement and the creation of a patent pool on innovation. We create a unique database of 50 patent pool launches, including both effective pool creations and failed attempts. We investigate the relationship between pool announcement and creation and standard-related innovation efforts using data on more than 20,000 patents that are presumed essential to the standards underlying the pool licensing programs. Using the technological classification of the standard-essential patents, we build a comprehensive database of patents that are technologically related to these technology standards. We include patents filed by 190 companies contributing patented technology to the technology standards in our sample. We describe the usual pattern how the number of patent files evolves over time during the development of a standard. We then analyze whether the announcement or creation of a pool induces a change in the rate at which standard-related patents are filed.

We examine not only the reaction to observed pool creation, but also anticipatory patenting when a patent pool creation is expected. Economic theory predicts that expected pool creation induces anticipatory patenting in view of inclusion into the future pool (Lerner and Tirole, 2004; Dequiedt and Versaevel, 2013). The empirical analysis of the timing of innovation in standard development furthermore suggests that effective pool creation takes place after most significant innovation efforts have already been made. We therefore expect that substantial effects of patent pools on related innovation efforts materialize in the periods preceding the expected creation of a pool. Furthermore, expectation of a pool can induce firms to anticipate innovation investments, which is another potential

[1]see for instance Chapter 3 in the *Antitrust Guidelines for the Licensing of Intellectual Property Rights* issued by the Department of Justice (DoJ) in 2007. The guidelines are available at http://www.justice.gov/atr/public/hearings/ip/222655.pdf

explanation for the decline in innovation rate following up to pool creation observed in previous studies.

Expectations regarding pool creation have been strongly affected by an exogenous policy change from 1997 to 1999. While there have been pools in different technological areas until World War II (Lampe and Moser, 2012), stricter enforcement of competition law outlawed most attempted pool creations from the end of World War II until the 1990s (Gilbert, 2004). A new wave of patent pools was launched in the area of ICT technology standards. The earliest of these pools were developed in an uncertain policy environment. In 1997 and 1999, the European and American antitrust authorities however authorized a new model of patent pooling for two important standards. After this precedent, many other important pools including the same safeguards against anticompetitive abuses have been created and authorized. This policy change significantly altered the expectations of firms regarding the likelihood of a future pool creation. We can thus compare two groups of patent pools which developed in very different processes, giving rise to sensibly different expectations.

We find robust evidence for a significant positive effect of patent pools on patenting. The early patent pools launched in the wake of the policy change in competition policy are followed by a significant increase in patenting rates. There is no increase in patenting after pool launches in the later years, when pool creation has become a routine practice. These pool creations however follow up on periods of intense patenting. Both the increase in patenting after early pool launches and the high patenting intensity before the creation of later pools are attributable to prospective pool members. Instrumental Variable regressions confirm that firms more likely *ex ante* to join a patent pool display a stronger reaction to pool launches than other firms declaring to own standard-essential patents for the same standards.

We refine the analysis by computing the ex ante probability that a pool launch will result in a successful pool creation. We confirm that the magnitude of the effect of a pool announcement depends upon its likelihood of success. Once again, we use Instrumental Variable regressions to confirm that the effect of pool announcements is more pronounced in the case of standards for which a pool is *ex ante* more likely to be successful. Reiterating our analyses to explain changes in the number of citation-weighted patent files, we find little evidence for significant effects of pool announcement or creation. These findings suggest that while patent pools increase the incentives to file additional patents, they do not seem to provide as significant impulses for significant technological innovation.

2 Review of the Literature

The notion of patent pool can describe different licensing mechanisms. Spulber (2013) analyzes patent pools as cross-licensing agreements. Cross-licensing agreements induce incentives to free-ride on other firms' innovation efforts and thus provide lower innovation incentives than individual licensing. Furthermore, the term patent pool has been in the past applied to price-fixing cartels among holders of substitutable patents. Such agreements are found to induce higher prices and reduce innovation efforts (Lampe and Moser, 2012). We will restrict our analysis to contemporary ICT patent pools. These pools provide standardized licensing contracts for bundles of patents held by pool members to all interested parties [2]. Furthermore, strict antitrust enforcement leads contemporary patent pools to appoint third party experts to ascertain that all patents included are strictly complementary and necessary for the implementation of a particular technology standard. In addition, pools are not allowed to restrict the rights of their members to negotiate bilateral licensing agreements with potential licensees who do not wish to purchase a pool license.

For the case of patent pools operating under these rules, Lerner and Tirole (2004) and a stream of subsequent theoretical literature predict a positive effect on the incentives to invest in related R&D. By cutting down multiple margins, reducing transaction costs and facilitating patent enforcement (Delcamp, 2015), patent pools generate value for the holders of the included patents. Patent pools should thus induce an unambiguous positive effect on ex ante incentives to invest in R&D in view of obtaining patents qualifying for inclusion into a pool (Lerner and Tirole, 2004; Schmidt, 2014). Aoki and Schiff (2008) and Schmidt (2010) predict that prospective patent pools can even induce wasteful overinvestment. Dequiedt and Versaevel (2013) analyze the dynamic incentives for R&D in view of a patent pool. In their model, patent pools increase innovation incentives, and especially induce patent races preceding the launch of the pool. Patent pools are also expected to have positive ex post effects on innovation. By solving the royalty stacking problem, pools reduce the cost and increase the profit margin for follow-up innovators (Llanes and Trento, 2012).

The effects of pools on innovation are less clear when firms can strategically adapt the propensity to patent. Many pools redistribute royalties according to the number of patents, inducing incentives to inflate patent portfolios (Baron and Delcamp, 2015; Peters, 2011)[3].Choi and Gerlach (2013) find that patent pools can be detrimental for innovation because they induce an increase in the incentives to file weak patents, i.e. patents that have a lower likelihood of being found valid in court. While these arguments can explain a negative effect of patent pools on innovation, they nevertheless predict a positive effect of patent pools on the filing rate of patents qualifying for such a pool.

In contrast to these arguments, recent empirical advances point to a negative effect of patent pools not only on innovation, but also on patenting. Lampe and Moser (2010) find that the creation of a sewing machine patent pool in the 19th century was followed by a decline in innovation[4]. In a study of patent pools in the 1930s, Lampe and Moser (2012) find that most of these pools had a negative effect on subsequent patenting in the field. The patent pools created before 1945 frequently included substitutable patents and therefore chilled down technological rivalry. These concerns do not apply to contemporary pools. Joshi and Nerkar (2011) nevertheless find that the creation of the DVD patent pools was followed by a decline in related patenting by pool licensors and licensees. Flamm (2013) highlights contrasted effects of patent pools for optical disk technology depending

[2]Even though in some instances patent pools co-exist with cross-licensing agreements between pool members, cross-licensing is not a feature of the patent pool itself. Patent pools offer non-discriminatory licenses at the same conditions to pool members and outside licensees.

[3]Layne-Farrar and Lerner (2011) find that holders of the most valuable patents prefer staying out of pools practicing such a numerical royalty sharing rule.

[4]The authors discuss evidence for an increased patent propensity, but a decreased rate of progress in the technical performance of sewing machines.

upon the details of the organizational arrangement. While he identifies a positive effect of the CD patent pool, he discusses evidence for a negative effect of the DVD patent pools.

All existing empirical studies identify the effect of the pool by measuring a change in the rate of patenting or innovation once existing patents are bundled into pools. The theoretical analysis of patent pools in contrast focuses on the incentives to file patents to be included into a prospective pool. The existing empirical literature does not analyze whether the expectation of a pool induces incremental innovation incentives. Simcoe (2007) argues that the reduced difficulties in creating patent pools after 1999 have contributed to the surge in the number of declared standard essential patents. There is so far however no empirical evidence to confirm this hypothesis. This paper fills this gap and analyzes the effect of occurred and announced patent pool creations on the incentives to innovate.

This paper also departs from the existing literature by analyzing a large set of both institutionally and technologically similar patent pools. Furthermore, this is the first empirical paper explicitly relating the analysis of patent pool creation to the preceding standard development. Almost all contemporary patent pools are created for technological standards developed in standard setting organizations (SSO). Llanes and Poblete (2014) present a theoretical model combining the analysis of standard setting and pool formation. They show that taking the standard development process into account has sharp implications for the predicted effects of patent pools. A growing body of empirical literature studies innovation in technological standards[5]. This is the first empirical study on patent pools using data on the process of standard development in order to distinguish the effect of pool creation from the effects of the preceding standardization activities.

3 Empirical methodology

3.1 Data: Patent pools, technology standards and declared standard-essential patents

We built up a novel, comprehensive database of 50 contemporary patent pools, including both effectively created pools and failed pooling attempts. For each patent pool, we identify the licensing administrator and search the website of the administrator for the first mention of the pool project. In many cases, this is a call for patents issued by a licensing administrator willing to operate a pool for a specific technology. We also identify the date of effective pool creation, which is defined as the date from which on it is effectively possible to take a license from the pool, and the date of pool withdrawal if the pool no longer operates. Using the Internet Archives, we download the list of pool members for every year since pool creation, and check for each company the period of membership. We have made the full dataset on patent pools available online[6].

The aim of our analysis is to assess whether patent pools have contributed to fuel patent-driven innovation in technology standards. We therefore identify for each patent pool the standard or set of standards describing the technology licensed out through the

[5] e.g. Leiponen (2008); Rysman and Simcoe (2008); Delcamp and Leiponen (2014); Baron et al. (2014)

[6] http://www.law.northwestern.edu/faculty/programs/searlecenter/innovationeconomics/data/technologystandards/index.h

Standard or Project	Pool	Administrator	Pool Launch	Release
AGORA-C	AGORA-C	Via Licensing	2008	
AMR	AMR	VoiceAge	2004	1999
AMR-WB+	AMR-WB+	VoiceAge	2004	2004
AMR-WB/G.722.2	AMR-WB/G.722.2	VoiceAge	2009	2002
ATSC	ATSC	MPEGLA	2004	1995
AVC/H.264	AVC(MPEGLA)	MPEGLA	2002	2003
AVC	AVC(ViaLicensing)	Via Licensing	2002	2003
BluRay	One Blue	One Blue/One Red	2005	2002
BluRay	Premier BD	Premier BD	2005	2002
CDMA-2000	CDMA-2000	Sisvel	2007	2000
DAB	DAB	Philips	1998	1997
DVB-MHP	DVB-MHP	Via Licensing	2004	1998
dvb-t	dvb-t(MPEGLA)	MPEGLA	2001	1997
dvb-t	dvb-t(Sisvel)	Sisvel	2001	1997
dvb-t2	dvb-t2	Sisvel	2009	2009
DVD	DVD3C	Philips	1997	1995
DVD	DVD6C	Toshiba	1997	1995
Digital Radio Mondiale	Digital Radio Mondiale	Via Licensing	2002	2001
G 711.1	G 711.1	SiproLab	2008	2008
G 723.1	G 723.1	SiproLab	2000	1996
G 729	G 729	SiproLab	1998	1996
G 729.1	G 729.1	SiproLab	2006	2006
H.264 SVC	H.264 SVC	Sisvel	2012	2007
IEEE 1394	IEEE 1394	MPEGLA	1999	1995
IEEE 802.11a-g	IEEE 802.11	Via Licensing	2003	1997
LTE	LTE(Sisvel)	Sisvel	2009	2008
LTE	LTE(ViaLicensing)	Via Licensing	2009	2008
mp3	MPEG Audio	Sisvel	1990	1992
mp3	mp3 Licensing	Thomson	1990	1992
MPEG Surround	MPEG Surround	MPEGLA	2008	2007
MPEG2	MPEG2	MPEGLA	1993	1994
MPEG2 AAC	MPEG2 AAC	Via Licensing	1998	1996
MPEG4 Audio	MPEG4 Audio	Via Licensing	2002	1999
MPEG4 SLS	MPEG4 SLS	Via Licensing	2009	2005
MPEG4 Systems	MPEG4 Systems	MPEGLA	2000	1999
MPEG4 Visual	MPEG4 Visual	MPEGLA	2000	1999
MVC	MVC	MPEGLA	2011	2009
NFC	NFC	Via Licensing	2004	2003
OCAP	OCAP	Via Licensing	2004	
GSM	Second Generation Wireless	SiproLab	1998	1990
TOP Teletext	TOP Teletext	Sisvel	1998	
TV Anytime	TV Anytime	Via Licensing	2003	2003
UHF-RFID	UHF-RFID (MPEGLA)	MPEGLA	2005	2004
UHF-RFID	UHF-RFID (Sisvel)	Sisvel	2005	2004
UHF-RFID	UHF-RFID (Via Licensing)	Via Licensing	2005	2004
VC-1 (former VC-9)	VC-1	MPEGLA	2004	2006
W-CDMA	W-CDMA	Platform WCDMA	2004	2001
WSS	WSS	Sisvel	2009	1994

Table 1: Overview over the pools in our sample

pool. Matching pools with standards is straightforward, because pool administrators clearly display the technological standards that are covered by the pool license. For our analysis, we organize the data by firms and standards. Our pools are related to 43 different standards or standardization projects. The technology standards covered by pools can be single technical specifications (like a speech codec, e.g. G729.1), or complex technological systems consisting in hundreds of technical specifications (like BluRay or LTE)[7] In 7 cases, we identify multiple pools for the same standard [8]. In these cases, we use the earliest pool to determine the date of pool launch or the date at which licenses become available. A firm is classified as pool member if it is a member of either of the different competing pools.

We then identify the set of firms with patenting activities related to the technology standard underlying the pool. For 34 standards, we can access lists of declared standard-essential patents on the websites of the issuing SSO. We identify 8,891 declared essential patents from declarations made by 190 companies[9]. We define the set of firms with patenting activities related to the standard as comprising all firms that at some time were member of a pool related to the standard, all firms declaring to the SSO that they own standard-essential patents for this standard, and the 30 largest patent holders in the technological field of the standard. The technological field of the standard is described by the technological classification of the patents included in the pool and the declared standard-essential patents(see Section 3.2).

28 patent pools in our sample are related to technology standards issued by formal SSOs[10]. For these standards, we collected bibliographic information from the PERINORM database[11], including data on version updates, standard amendments, number of pages, technical classification and the year of standard release. In the case of patent pools related to consortium standards that are not included in the PERINORM database (such as DVD and Blu-Ray), we researched standard characteristics and the dates of standard version releases on the websites of the respective standards consortium.

[7]Patent pools like OneBlue are also referred to as "pools of pools", because they combine different licensing programs for different aspects of a complex technological system. We refer to these pools as *aggregate* pools. These pools bundle patent portfolios for different technological specifications that are all necessary for a particular technological system. We call a pool *disaggregate* if it covers a single technical specification that can be used in different technological systems (such as the video compression technology AVC that is used in optical disc standards, digital video broadcasting, and internet applications).

[8]In some cases, one pool is the successor of the other pool. In most cases however, the different pools simultaneously license out patents that are essential to the same standard, but held by different sets of firms.

[9]The number of declarations is higher than the number of declared patents, because we also include so-called blanket declarations (a generic declaration that a company owns essential patents without specifying the patent number), and we count patents declared essential to various standards as multiple declarations. For institutional aspects of the patent declaration data, refer to Bekkers et al. (2012)

[10]This notion refers to large organizations with institutionalized standardization procedures which operate on an international level: the formal SSOs in our sample are the International Organization for Standardization (ISO), the Joint Technical Committee 1 (JTC1) of ISO and the International Electrotechnical Commission (IEC), the International Telecommunication Union (ITU-T/ITU-R), the European Telecommunications Standards Institute (ETSI), and the Institute of Electrical and Electronics Engineering (IEEE)

[11]PERINORM is the World's biggest database with bibliographic information on formal standards and is regularly updated by the SSOs Deutsches Institut fur Normung (DIN), the British Standards Institute (BSI) and the Association francaise pour la normalisation (AFNOR).

3.2 Measuring standard-related patenting

We create a measure of standard-related patent counts using information on patents that are presumed to be essential to these standards. This includes patents declared as standard-essential by their owners, and patents evaluated to be standard-essential by the patent pool evaluation expert. While standard essential patents claim an invention that is necessarily used by any implementation of a standard, they only constitute a small share of patents that actually relate to the standardized technology. In case of the declared standard-essential patents, the claim of standard essentiality is not assessed by a third party, and both the propensity to declare patents as standard-essential and the timing of declaration are subject to strategic considerations (Bekkers et al., 2012; Ganglmair and Tarantino, 2014). In case of the patents evaluated by the pool experts, these only include patents that were submitted to the pool, thus excluding the patenting activities of pool outsiders.

Similar to Baron et al. (2014), our approach is not to count SEPs but to make use of the CPC/IPC classifications of SEPs to identify other patents that also are relevant to the standards. To this end, we gather more than 20,000 different standard essential patent families to map specific standards documents to disaggregated CPC and IPC classes (8 digit classification). The technological field of each standard is characterized by a vector of weights on each CPC/IPC class identified as relevant for each standard. The weight is calculated as the relative prevalence of this CPC/IPC class in the sample of standard-essential patents. We compare different weights for primary and extended CPC/IPC classes, different subclass aggregations (4 and 8 digits) as well as different patent counts (discounted by families or forward citations) and different company-standard pair groupings to test our method of mapping patent activities to standard relevant CPCs/IPCs (comparison of the different weights and counts can be consulted in the appendix).

We build up a panel of company-standard pairs, tracking each firm's patent filing activities using the PATSTAT database. We make use of company name cleaning methods, identifying all patent numbers, INPADOC family IDs, primary and extended CPC/IPC as well as a count of forward citations per patent. We aggregate all information to the patent family level counting priority families for each company-year observation per CPC/IPC. We compute family counts for each standard-company-year combination in our sample (for details of the matching methods consult the appendix). For testing the fit of our measure, we compare the evolution of family counts with a standard's lifetime development. The main technology development of a standardized technology is completed when the first version of the standard document is released. One would thus expect innovation activities to decrease just after a standard release. Figure 2 plots our aggregated measure of standard related family counts over the standards lifetime 13 years prior and 13 after a standard release. The plots are normalized coefficients of regressed standard age dummies over the full sample of observation (please consult the appendix for the regression details).

Figure 1 reveals that standard-related patenting follows a hump shape, peaking prior to standard release. The shape of the curve very well shows that our measure of standard related patenting correlates with the timing of standardization (for a further validation of our measure consult the appendix). While most innovation takes place before standard release, there are still significant levels of patenting observed up to several years after standard release.Baron and Delcamp (2015) document that a significant share of the

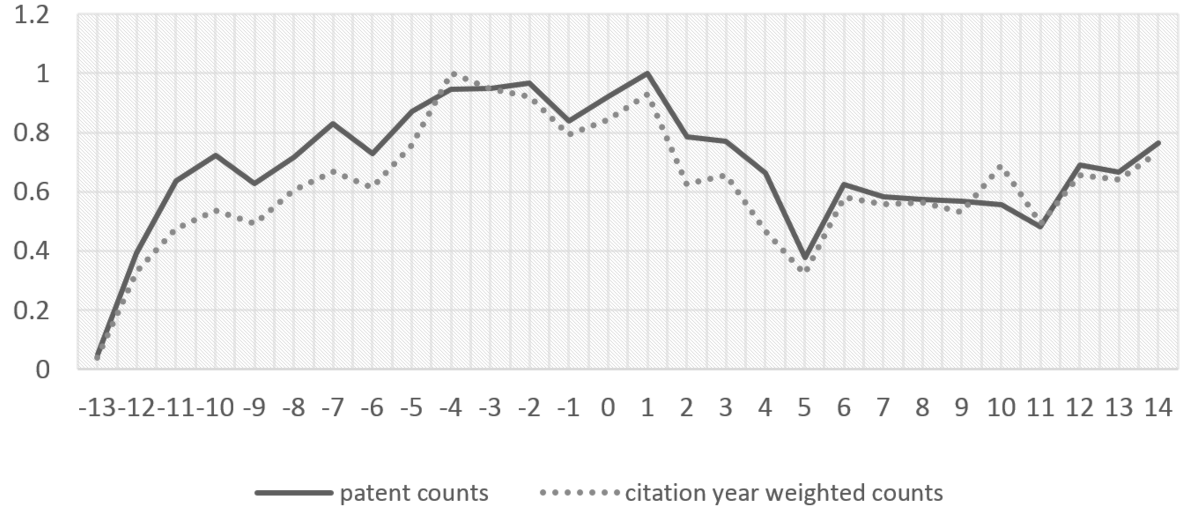

Figure 1: Normalized coefficients of standard age dummies before and after standard release

patents included in a pool have been filed after pool creation and standard release. Part of this patenting activity could be a response to observed pool creation. The figure however illustrates that it would be a mistake to identify the effect of patent pools from a change in the level of patenting before and after pool creation without taking the standard development into account. Pool creation occurs in a late stage in the technological life cycle of a standard, where innovation efforts generally decline significantly. Controlling for the standard life cycle is crucial in order to relate the observed rate of patenting and innovation to a plausible counterfactual.

3.3 The policy change

Patent pools were common in the late 19th Century and the first half of the 20th Century. Lampe and Moser (2012) reviewed as many as 20 patent pool that were active in the 1930s. These pools benefited from a lenient enforcement of US antitrust law, even though many of these pools involved explicit price-fixing among holders of technological substitutes (Lampe and Moser, 2012). After World War II, the enforcement of competition law towards patent licensing became more restrictive in general [12], and no other patent pool was successfully created until the 1990s.

The situation changed again in 1995, when the Department of Justice issued new guidelines for a more benevolent scrutiny of patent licensing[13] and placed the analysis of patent pools under the rule of reason. *"The 1995 guidelines were a cautious endorsement of patent pools that revived the practice"* (Miller and Almeling, 2007). The standard for

[12]This tougher stance was stated explicitly in 1970 in the U.S. Department of Justice's list of "nine no-no's", nine practices in patenting licenses that would be considered per-se illegal" (Gilbert and Shapiro, 1997)

[13]"The 1995 Guidelines extolled the procompetitive benefits of patent licensing and prescribed a cautious approach to antitrust scrutiny of patent license agreements" (Homiller, 2006)

applying the rule of reason to patent pools was set in the three subsequent years. In two favorable business reviews in 1997 and 1999, the European and US competition authorities cleared the MPEG2 and DVD patent pools, the first modern patent pools related to ICT technology standards[14]. In March 1998, the FTC challenged a patent pool bundling competing patents held by two different firms, Summit Technology Inc. and VISX Inc [15], thus clarifying the legal boundaries to the practice of pooling patents.

The favorable business review by European and American competition authorities of two large pool licensing schemes between 1997 and 1999 triggered a new wave of patent pools following the examples of MPEG2 and DVD. Including very similar safeguards as the pools previously authorized, none of these pool creations has met any resistance from antitrust authorities. *"The DOJ business review letters provide* ***a template*** *for patent pooling arrangements that should not run afoul of the antitrust laws. The letters embody a new thinking in economics and law and* ***contrast sharply*** *with early judicial opinions about the legality of patent pooling arrangements."* (Gilbert, 2004).

The number of pools announced and created increases after 1999. Pool licensing has become more routine and more predictable. At least four licensing firms started specializing on the administration of patent pools[16]. Beginning in 2000, these licensing administrators launched several new pool licensing programs every year. In at least one instance, an important SSO has initiated a formal collaboration with a licensing administrator[17]. Several SSOs adopted explicit policies to encourage the formation of patent pools for their standards[18] Over time, an increasing number of new pools are related to new technology standards succeeding on a standard that was already licensed through a pool. In many cases, there is a very substantial overlap between the membership of the pools for the previous and the new standard generation[19]. Baron and Delcamp (2015) find that past involvement in previous patent pools is a very significant predictor of how quickly firms join a new pool.

Overall, our observation period from 1992 to 2013 has thus been a period of a pronounced policy change with respect to pools. The early patent pools were announced and created in an uncertain policy environment. The timing and success of pool formation were therefore subject to changes in competition law enforcement practice in addition to the technological life cycle of the specific standard. Furthermore, companies could not fully anticipate the future possibility of monetizing their patents through a patent pool while the standard was under development. The pools launched more recently result from a stable institutional environment, and respond only to technological and commercial considerations. Companies can easily anticipate future pool creations, and often decide

[14] see the business review letters: http://www.justice.gov/atr/public/busreview/2485.pdf, http://www.justice.gov/atr/public/busreview/215742.pdf.

[15] http://www.ftc.gov/news-events/press-releases/1998/08/summit-and-visx-settle-ftc-charges-violating-antitrust-laws

[16] These four firms are: MPEGLA, Via Licensing, Sisvel and SiproLab

[17] Collaboration agreement between IEEE and Via Licensing of December 2008

[18] The DVB consortium e.g. states in its IPR policy: *"The DVB fosters by applying a number of tools to encourage patent holders to form patent pools promptly after standardisation"*.

[19] E.g. the three founding members of DVD3C in 1999 all joined the OneBlue patent pool for BluRay 13 years later, whereas X of the 9 DVD6C members are today members of the PremierBD patent pool for BluRay.

on whether to become a pool member even while the standard specification is still under development[20]. We will take this change in the policy environment into account, and will make use of this exogenous source of variation in order to identify the causal effect of pool announcements and creation.

4 Results

4.1 Reaction to pool announcement and creation

We begin our analysis by regressing standard-related patent files on variables describing the standard development process. Our method of mapping the standards underlying the pools to related technology classes has resulted in a count of standard-related patent applications. The evolution of this count is characterized by an inverted-U relationship around standard release: the intensity of standard-related patenting increases up to standard release and eventually decreases. We will control for this ”typical” pattern of patenting in the standard development process by including a square of the age of the standard age in the regression. Standard age measures the number of years since standard release (and is negative before standard release). The square of standard age thus measures the distance in time to a future or past standard release.

All firms are observed over the whole period of time, and we apply standard-firm pair fixed effects. We furthermore control for technological shocks in the wider technological field, policy changes or macroeconomic effects by including a full set of year dummies. We furthermore include two control variables. First, we include the 1 year lag of the cumulative number of patent declarations made by all firms to the specific standard. This is an important control variable that captures strategic interactions between firms, for instance patent races or portfolio patenting strategies in the context of patent wars. Second, we wish to control for changes in the market success or implementation rate of the standard. We therefore use the yearly number of mentions of the standard name in business communications by the entire sample of firms, which we obtain from ProQuest (Baron et al., 2014). The mentions of standards in business communications should correlate for instance with the market introduction of new products implementing the standard.

We estimate this baseline model (Model 1), which will be our empirical workhorse throughout the analysis, for the entire sample of standard-company pairs. The sample consists in firms that appear to develop technologies related to this particular standard, either because they declare standard-essential patents, join a standard-related pool, or figure among the Top 30 patent holders in the standard-related technological field. Results are displayed in the following Table 2.

We analyze the effect of pools by including a set of different variables. *Call open* indicates that a pool has been announced, but not yet created. In the case of failed launches, the variable is set back to zero after three years. *Licenses available* indicates

[20]The DVB e.g. provides for *a mechanism for early confirmation by a technology contributor of its willingness to participate in a pooling effort*; and *information meetings of patent holders and other interested parties while the specification is under development.*

	(1) Related patents Fixed Effect OLS	(2) Related patents Fixed Effect OLS
Call open		-304.0538
		(-3.20)
Licenses available		-530.2445
		(-6.00)
Standard age squared	-5.3973	-6.4256
	(-17.90)	(-17.92)
Declarations_cumul	1.0881	1.1315
	(28.21)	(27.66)
Newsfeed_cumul	0.0014	0.0006
	(0.59)	(0.24)
Constant	888.1672	934.7575
Observations	23,478	21,819
Groups	1,118	1,039

t statistics in parentheses
Year fixed effects included but not reported

Table 2: Regression results Models 1 and 2

that at least one patent pool has been created and is active for this standard. The results of this specification are in line with the existing empirical literature (Joshi and Nerkar, 2011; Lampe and Moser, 2010, 2012). The announcement of a future pool creation, and even more so the creation of a pool, are followed by a significant decrease in the rates of standard-related patenting. We however argue that this decrease must not be interpreted as a causal effect. This estimated "effect" of pool announcement and creation can have multiple non-causal explanations. Patent pools can for instance be endogenously created as reaction to peaks in patenting. Furthermore, companies could increase their level of patenting in expectation of a pool announcement in the near future. The prospect of a pool creation could also induce firms to expedite their R&D and anticipate standard-related patenting (Dequiedt and Versaevel, 2013). Finally, our general baseline model of patenting over standard development does obviously not capture the standard specific details of the life cycle from R&D and standard development to implementation and licensing. The creation of a patent pool is likely to simply correlate with the moment in time at which the technology is ready for implementation, and manufacturing companies can begin subscribing to a licensing program. All these different considerations are consistent with a decline in patenting rates after pool creation. We will address this issue in the following sections.

4.2 Patenting around pool announcement

We highlighted a decline in the intensity of standard-related patenting after the announcement and especially after the creation of a patent pool. There are good reasons to think that this does not reflect the causal effect of patent pools on patenting incentives. In particular, the economic theory on patent pools (Lerner and Tirole, 2004; Aoki and Schiff, 2008; Dequiedt and Versaevel, 2013) to a very large extent focuses upon the effect of expected patent pools on the incentives to file patents that could be included in the pool.

The actual creation of pools typically occurs late in the standard life cycle. It is implausible to expect high rates of significant inventions leading to standard-essential patents that occur after companies already started licensing from the pool. In order to identify the causal effect of patent pools, we therefore focus on the announcements of future pools (what we call *pool launch*.

Model 3 (Table 3) shows that these pools announcements take place in periods characterized by high intensity of standard-related patenting. We include dummy variables for periods respectively 2 years or 1 year before, or 1 year or 2 years after pool announcement, as well as a dummy for the year of pool announcement itself. Both in the periods before and after pool announcement, the levels of patenting are higher than explained by standard fixed effects and standard age. We need to disentangle the reaction of firms to pool announcements from the endogenous timing of these events. Furthermore, we expect that companies can observe signals of future pool announcements, and that a large part of the effect of pool announcements can take the form of anticipatory behavior.

We rely in this section on a pronounced policy change that occurred over a relatively short period of time as a source of exogenous variation. As discussed, the positive business review of two important patent pools by American and European competition authorities from 1997 to 1999 reflect a drastic change in the competition law enforcement practice with respect to patent pools. A set of early patent pools thus were created as in the wake or as immediate consequence of changes in the regulatory environment. All these pools were the first of their kind, and the first pool operated by their respective licensing administrator. The creation of these pools was difficult to anticipate, and the timing of the creation of these pools at least in part responds to the timing of the regulatory change. After this policy change, a large number of pools have been created by specialized pool licensing administrators running multiple, very similar, pool licensing programs. These pools are easier to anticipate, and the timing of pool announcement is fully dictated by strategic and technological considerations.

In Models 4 and 5, we find empirical support for this analysis[21]. While patenting picks up after the launch of the early patent pools (announced up to 1999), the announcement of these pools is not preceded by periods of unusually high levels of patenting. This is consistent with our idea that these pools were more difficult to anticipate, and that the regulatory constraints prevented these pools from being endogenously created as a direct response to peaks in patenting. We find the reverse result for the case of patent pools announced after 1999. The announcement of these pools occurs in years characterized by significantly higher than usual levels of patenting (and especially following up to periods of intense patenting). There is however no indication that patenting picks up after pool announcement in the case of these later pools.

The preceding analysis suggests to focus on the group of early pools for the identification of the causal effects of pool announcement on patenting. Indeed, for this group of pools, we find no evidence for significant anticipatory behavior or that the timing of pool creation in responds to peaks in patenting. In the following, we use heterogeneity in firm and

[21] In order to account for smaller sample size in the subsamples, we conflate periods before pool announcements (one year or two years before announcements) and periods after announcement (the year of announcement as well as the two following years) into two different variables.

	(3)	(4)	(5)
	Related patents	Related patents	Related patents
	All pools	Early pools	Later pools
	Fixed Effect OLS	Fixed Effect OLS	Fixed Effect OLS
Launch minus 2	463.7	11.22	519.5
	(4.48)	(0.13)	(4.05)
Launch minus 1	468.0	48.17	518.4
	(4.65)	(0.64)	(4.04)
Year of launch	447.0	61.93	237.1
	(4.43)	(0.83)	(1.83)
Launch plus 1	327.4	-24.02	52.48
	(3.25)	(-0.32)	(0.41)
Launch plus 2	290.8	311.6	-134.4
	(2.89)	(4.72)	(-1.02)
Standard age squared	-4.741	0.726	-2.808
	(-15.10)	(0.81)	(-6.69)
Declarations_cumulative	1.084	0.128	3.243
	(28.10)	(4.51)	(39.75)
Newsfeed cumulative	0.000861	-0.000186	-0.0825
	(0.35)	(-0.16)	(-11.90)
Constant	709.9	176.7	602.0
	(7.75)	(3.07)	(5.18)
Observations	23478	5565	17913
Groups	1,118	265	853

t statistics in parentheses

Year fixed effects included but not reported

Table 3: Regression results Models 3, 4 and 5

standard characteristics for difference-in-differences analysis. In particular, we will show that firms that are more likely to join a patent pool display a stronger increase in patenting in response to the pool announcement, and that the effect of pool announcement is stronger in the case of standards for which a pool is more likely to draw an important share of the relevant patents.

4.3 Effect of pool announcements: Pool members vs. outsiders

To further refine our results, we analyze the effect of patent pools on pool members and outsiders. In most cases, only a minority of the qualifying firms decide to join a pool (Layne-Farrar and Lerner, 2011). Furthermore, the decision to join a patent pool or not can to an important extent be explained by observable characteristics of the firm or its standard-related patent portfolio. Layne-Farrar and Lerner (2011) for instance show that pool membership is less attractive for firms holding high-quality patents, and more attractive for firms that themselves practice the technology standard related to the pool.

We will thus investigate whether the effect of pool announcement documented in the previous sections is attributable to those companies that eventually joined the pool. We therefore create a time-invariant dummy variable indicating whether a company has ever been listed as pool member in our period of observation. We interact this variable with our dummy variables indicating 2 year periods before or after pool announcement. The results in Table 4 confirm that in the case of the early pools, the increase in patenting after pool announcement is fully attributable to those companies that opted to join the pool. Those companies that will never join the pool do not display a significant change in patenting rates after pool announcement. In the case of later pools, we also find that the high patenting intensity prior to pool announcement is to a large extent attributable to future pool members. Those companies that will never join the pool however also display a significantly higher than usual patenting intensity in the two years before pool announcement. This suggests that the peak in patenting prior to pool announcement not only reflects anticipatory behavior. For instance, it is plausible that patent pools are created in response to peaks in patenting. We thus focus on the set of early pools for identification of the causal effect of pool membership.

	(6) Related patents All pools Fixed Effect OLS	(7) Related patents Early pools Fixed Effect OLS	(8) Related patents Later pools Fixed Effect OLS
Launch minus 1,2	382.9	-14.25	371.5
	(4.48)	(-0.20)	(3.45)
Launch plus 0,1,2	377.7	47.02	54.32
	(5.27)	(0.89)	(0.58)
Launch_minus_1,2_member	340.6	194.4	599.5
	(2.03)	(1.70)	(2.91)
Launch_plus_0,1,2_member	-92.93	331.7	3.313
	(-0.67)	(3.86)	(0.02)
Standard age squared	-4.742	0.921	-2.817
	(-15.11)	(1.03)	(-6.71)
Declarations_cumulative	1.083	0.116	3.241
	(28.04)	(4.04)	(39.75)
Newsfeed_cumulative	0.000961	-0.000676	-0.0827
	(0.39)	(-0.57)	(-11.92)
Constant	725.2	218.4	742.7
	(8.01)	(3.36)	(6.17)
Observations	23478	5565	17913
Groups	1,118	265	853

t statistics in parentheses
Year fixed effects included but not reported

Table 4: Regression results Models 6, 7 and 8

The finding that the patenting rates of future pool members pick up after pool announcement may still be plagued by an endogeneity concern. The concern is that the causality may also go in the reverse direction: companies join an emerging pool because they have recently been very actively patenting in the related technological area. In order to address this concern, we identify general characteristics of firms measured at the time of the pool announcement (i.e. *ex ante* to the subsequent increase in patenting) that are strongly and significantly associated with being a pool member. In particular, we confirm a finding from the existing literature (Layne-Farrar and Lerner, 2011), which suggests that firms holding better quality patents (as measured by the average number of forward citations for their patents in the standard-related field) and firms that do not practice the technology themselves have a significantly lower probability of joining a pool. We do not observe which companies practice the standards in our sample. We can however categorize firms into manufacturing companies, network operators and R&D specialists. The latter groups comprises public research institutions, universities, pure R&D companies, fabless manufacturers and intermediaries in the market for technologies. R&D specialists have a significantly lower likelihood of joining patent pools - indeed, the propensity to join patent pools more generally decreases with the ratio of R&D expenditures over the value of sales.

As a first step, we thus estimate how the likelihood of joining a patent pool depends upon a list of *ex ante* firm characteristics. We therefore build a cross section of firm-standard pairs observed in the year of pool announcement. For each firm, we count the number of patents in the standard-related technological classes, the number of declared standard-essential patents, the number of patents in related technological classes weighted by forward citations, the total number of patents (in all technological fields), the total average number of forward citations by patent, the total number of declared standard-essential patents, we compute the ratio of R&D expenses over the value of sales, and we assign a dummy variable to R&D specialists. We run a logistic regression to explain whether a company will eventually join the announced pool, including dummies for the different standards. The results, presented in Table 5, are in line with findings in Layne-Farrar and Lerner (2011) and our discussions with practitioners. We find that the number of patents in the related field and the number of declared standard-essential patents are positively associated with the likelihood of being a pool member. The average "quality" (in terms of citations) of the standard-related portfolio, the overall number of patents owned by the firm, the general average quality of its portfolio, and the R&D intensity on the firm level, are all negatively associated with the propensity of joining a pool.

	(9) Member (time-invariant) Logit, cross-section at launch year
Num. related patents	0.00000885
	(2.22)
Declared SEPs	0.00571
	(1.76)
Num. related patents, cit.-wtd.	-0.00000837
	(-1.76)
Total number patents	-0.00000579
	(-3.00)
Cits. per patent	-0.00188
	(-3.44)
All SEP declarations	0.0000139
	(0.23)
R&D-specialists	-1.084
	(-1.56)
rdtosales	-8.812
	(-3.50)
Observations	748

t statistics in parentheses
Standard fixed effects included but not reported

Table 5: Regression results Model 9

We pick the two variables already suggested by Layne-Farrar and Lerner (2011) to instrument for future pool participation. First, we use the average quality of patents. We take the citation to patents ratio on the firm level in order to address more convincingly the exclusion criterion. A firm holding good quality patents for a particular standard is likely to intensify its investments in this particular area. The average quality of the patent portfolio at the firm level is less likely to be affected by this concern. Second, we use the dummy variable assigned to R&D specialists[22]. Because our explanatory variable is an interaction term between prospective membership and the period following up to pool announcement, we also interact our candidate instruments with the dummy for periods after pool announcement.

The results in Table 6 confirm the results from our previous Fixed Effect estimation. Prospective pool members react to pool announcement by increasing their patenting intensity. This also holds true if we instrument subsequent pool membership with *ex ante* firm level characteristics. This finding provides robust evidence for a causal effect of announced pool creation on the patenting activities of companies desirous to join a pool. In a next step, we confirm this finding by comparing the effects of pool announcements based on the *ex ante* characteristics of the standards.

4.4 Effect of pool announcements: Success of the pool creation

Not all patent pools are successful in attracting an important share of the patent holders that are relevant to the standard they are related to. Several pools that were announced by a pool licensing administrator even completely failed: the announcement was never followed by an actual pool creation. To a large extent, the difficulties of patent pools to draw a large share of the significant patent holders can be explained by publicly observable information, including information already available at the time of pool announcement. This is significant for our analysis, because we would expect that the reaction to the pool announcement also depends on the expected likelihood that the announced pool will succeed.

In order to assess the success of a patent pool, we measure the share of the patents in the technological area of the standard that are owned by pool members[23]. We measure this share one year after the start of the licensing program (after *creation* of the pool). The share will obviously be zero for failed pool announcements. The highest share in our sample is 0.55. We then interact this measure of pool success with our dummy variables characterizing periods around pool creation. Following our general empirical strategy, we concentrate on patent pools announced up to 1999. The results of model 11 (Table 7) show that the increase in patenting intensity after pool announcement indeed depends upon the eventual success of the announced pool. In Model 12, we estimate whether the effect evidenced in Model 8 of pool announcements on the patenting of prospective pool

[22] We use the dummy variable instead of the R&D-to-sales ratio for practical reasons. We only observe the ratio of R&D over sales for a more limited sample of firms (excluding for instance public research institutions and other R&D specialists).

[23] In the case of competing pools, we measure the share of patents in the field that are owned by members of either of the two pools. This is clearly imperfect, but any discount on this rate to account for split pools would also be arbitrary

	(10)
	Fixed Effect 2SLS IV
	Early pools
	First stage: Launchplus012_member
Launchplus012	0.3581
	(39.80)
Launchminus012	0.0163
	(1.63)
Standard age squared	-0.00098
	(-6.88)
Declarations_cumulative	0.000042
	(9.37)
Newsfeed_cumulative	0.00002
	(5.29)
Launchplus_citperpats	-0.0001603
	(-12.07)
Launchplus_R&D_spec	-0.0562081
	(-2.69)
	Second stage: Number related patents
Launchplus012_member	837.1
	(1.69)
Launchplus012	-101.3
	(-0.66)
Launchminus012	31.50
	(0.49)
Standard age squared	1.422
	(1.38)
Declarations_cumulative	0.0955
	(2.64)
Newsfeed_cumulative	-0.00124
	(-0.94)
Observations	5,481
Groups	261

t statistics in parentheses
Year fixed effects included but not reported

Table 6: 2SLS IV Regression results Model 10

members also depends upon the future success of the announced pool. Model 12 reveals that the increase in patenting by prospective members as compared to outsiders indeed also depends upon the future success of the pool.

A word of caveat is warranted to qualify this finding. Indeed, it is possible that pool success *inter alia* depends upon factors that are correlated with patenting intensity after pool announcement. It is plausible for instance that the success of the patent pool depends upon the stage of the technological life cycle at which the pool is announced. The stage of the life cycle however is also correlated with trends in patenting intensity. The results in Table 7 give some credit to these concerns, because future pool success is also significantly positively correlated with patenting intensity just before pool announcement.

We therefore turn to a similar approach as in the previous section and look for variables describing the standard at the time of pool announcement that predict the success of the

	(11) Related patents Early pools Fixed Effect OLS	(12) Related patents Early pools Fixed Effect OLS
Launch minus 1,2	-48.26	-1.663
	(-0.52)	(-0.02)
Launch plus 0,1,2	-8.968	63.67
	(-0.14)	(1.06)
Launch_minus_1,2_membershare	579.9	
	(2.15)	
Launch_plus_0,1,2_membershare	1080.4	
	(5.04)	
Launch_minus_1,2_member		-90.73
		(-0.48)
Launch_plus_0,1,2_member		-355.3
		(-2.56)
Launch_minus_1,2_member_ms		1175.1
		(2.43)
Launch_plus_0,1,2_member_ms		2985.0
		(7.73)
Standard age squared	0.855	0.722
	(0.89)	(0.75)
Declarations_cumulative	0.111	0.117
	(3.52)	(3.73)
Newsfeed_cumulative	-0.000508	-0.000435
	(-0.38)	(-0.33)
Constant	204.0	198.2
	(2.59)	(2.53)
Observations	4851	4851
Groups	231	231

t statistics in parentheses
Year fixed effects included but not reported

Table 7: Regression results Models 11 and 12

pool after its creation. We use insights from discussions with practitioners to look for candidate variables. In particular, it is a well-known regularity that patent pools in the area of telecommunications include much smaller shares of the relevant patents than pools related for instance to audio-visual coding technologies (including consumer electronics standards such as DVD, or broadcasting standards such as DVB). This regularity can be explained by the smaller number of standard implementers, the higher profit margins of manufacturers, and the larger prevalence of cross-licensing agreements that are typical of telecommunication industries. Consumer electronics implementing audiovisual standards tend to be characterized by a large number of smaller manufacturers with lower profit margins. Patent pools are a more attractive solution for collecting royalty revenues from these different firms. We also include the HHI index describing the concentration of patent portfolios in the technological field related to the patent pool. A high HHI indicates that large shares of the patents are held by few firms, a situation that simplifies bilateral agreements and reduces the attractiveness of pool licensing. Furthermore, we include a dummy variable assigned to aggregate pools (pool programs for complex technological systems including multiple technical specifications). An aggregate pool licenses out a relatively larger bundle of patents for a relatively lower number of different uses. While the larger number of patent holders may increase the social welfare benefits from patent pools (by cutting down multiple margins), these benefits are not internalized by the pool members and thus do not constitute an incentive to join the pool. The incentives to join a patent pool however increase with the number of different uses that can be made of the technology, because the private gains from reduced transaction costs depend on the number of transactions that a patent holder needs to make in order to license out its technology. We therefore expect that disaggregate pools yield higher incentives to join than aggregate pools (a list of pools classified as aggregate or disaggregate, and telecom, audiovisual or other, as well as their HHI and their success rate can be consulted in the appendix).

	(13) Member share in related patents OLS cross-section one year after creation
HHI_patents	-0.354
	(-9.42)
Audiovisual	0.139
	(9.07)
Telecom	-0.0849
	(-4.65)
Aggregate	-0.131
	(-10.51)
Declarations_cumul	-0.00000898
	(-1.01)
Year of launch	-0.00231
	(-1.54)
Constant	4.934
	(1.65)
Observations	1,266

t statistics in parentheses

Table 8: Regression results Model 13

In Table 8, we display results of a linear regression of pool success (measured as the share of related patents owned by pool members one year after creation) on a list of *ex ante* firm characteristics. The results confirm our intuitions regarding the effects of different standard characteristics. In particular, we find that a higher concentration of patents, association with a telecommunication standard and the fact of licensing out complex bundles of multiple technical specifications are all associated with a significantly lower share of relevant patents that are owned by pool members. We will use the HHI concentration index as well as the dummy for audiovisual technologies to instrument for the future success of an announced pool.

The results of the 2SLS Instrumental Variable regression (Model 14) displayed in Table 9 confirm our previous Fixed Effect regression results presented in Table 7. The HHI index and the dummy for audiovisual technologies are very strong instruments for pool success. In the second stage of the regression, we confirm that pool announcements that are *ex ante* more likely to be successful induce a stronger increase in standard-related patenting. We see this finding as additional evidence for a causal effect of pool announcements on the incentives to file standard-relevant patents.

	(14)
	Fixed Effect 2SLS IV
	Early pools
	First stage: Launchplus012_membershare
Launchplus012	0.22285
	(34.73)
Launchminus012	0.40598
	(6.96)
Launchminus12_membershare	-0.24688
	(-14.33)
Standard age squared	-0.00111
	(-16.49)
Declarations_cumulative	0.0000394
	(17.88)
Newsfeed_cumulative	-0.000023
	(-12.49)
Launchplus_HHI_patents	-0.23454
	(-17.87)
Launchplus_audiovisual	0.10319
	(18.09)
	Second stage: Number related patents
Launchplus012_membershare	1377.88
	(2.22)
Launchminus012	-60.6403
	(-0.62)
Launchplus012	-150.13
	(-1.04)
Launchminus12_membershare	601.5189
	(1.84)
Standard age squared	2.1197
	(1.75)
Declarations_cumulative	0.06769
	(1.71)
Newsfeed_cumulative	-0.00281
	(-0.79)
Observations	4,767
Groups	227

t statistics in parentheses
Year fixed effects included but not reported

Table 9: 2SLS IV Regression results Model 14

4.5 Patenting vs. Innovation

So far, we estimated the effect of pool announcements on the number of new priority patent applications filed in the technological area of the standard. We do not consider the number of patents as an indicator of inventive activities. Indeed, the existence of a particular licensing mechanism, such as patent pools, can make it more attractive to file a patent for a patentable invention that its inventor may otherwise have kept secret or contributed to the public domain. It is quite plausible that patent pools have a more significant effect on the propensity to protect inventions by patents than on the propensity to invest in standard-related R&D.

Lampe and Moser (2010); Flamm (2013) use indicators of technological performance of the underlying technology to differentiate between the effects of patent pools on patenting and innovation incentives. While appealing, this strategy is only possible for studies confined to a single technological area, and does not allow to compare the contributions of different companies to a common technology standard. In our firm-level study of a comprehensive sample of different pools, we are confined to indicators of innovation that are generally available. As a first - albeit imperfect - approach, we use the number of new priority applications weighted by the number of forward citations received by the patent family[24].

	(15) Related patents, cit.wgtd. Early pools Fixed effect OLS	(16) Related patents, cit.wgtd. Early pools Fixed Effect 2SLS IV
Launch minus 1,2	56.88	51.48
	(0.64)	(0.56)
Launch plus 0,1,2	78.46	45.58
	(1.22)	(0.23)
Launch_minus_1,2_member	55.40	53.59
	(0.38)	(0.30)
Launch_plus_0,1,2_member	253.8	354.6
	(2.38)	(0.55)
Standard age squared	-0.471	0.0517
	(-0.46)	(0.10)
Declarations_cumulative	0.0385	0.737
	(1.15)	(7.78)
Newsfeed_cumulative	0.00128	0.000381
	(0.90)	(0.36)
Constant	245.3	
	(2.93)	
Observations	4851	4851
Groups	231	231

t statistics in parentheses
Year fixed effects included but not reported

Table 10: FE and 2SLS IV Regression results Model 15 and 16

In the regressions 15 and 16, we replicate two of the essential previous analyses (Model 7 and Model 10), and estimate the effect of a patent pool announcement on the innovation efforts of a prospective pool member. Model 15 is a Fixed Effect linear regression, whereas model 16 is a fixed effect 2SLS IV regression using the same instruments for pool membership as Model 10[25]. The results reported in Table 10 are not clear-cut. While the Fixed Effect OLS regression yields very similar results to the analysis unweighted patents, the IV regression does not provide significant results. While these preliminary analyses definitely do not rule out a positive effect of announced patent pools on innovation

[24] We remove duplicates and thus only count the number of different priority patent applications citing any patent in the family.

[25] In fact, as the included and excluded instruments are exactly the same as in Model 10, the first stage of the 2SLS regression is identical

incentives, we however note that we produce evidence for a positive effect of patent pools only on the un-weighted number of new patent applications.

5 Conclusion

In this article, we have analyzed how standard-related patenting is affected by pool announcement and creation. Several contributions have evidenced a decline in patenting after the creation of patent pools. We show that this decline must not be interpreted as causal effect of the pool creation, and that the most relevant effects of patent pools on patenting behavior occur before the creation of announced patent pools. We provide evidence that patenting increases in response to pool announcement. There is an important difference between pools announced before and after the policy change. While we find evidence for a positive reaction to patent pool announcement in the case of the earlier pools, there is no such reaction to announcements of more recent patent pools. This seems partly to be due to anticipatory behavior.

We use differences between firms as well as between technology standards to confirm that the observed increase in patenting after pool announcement is accountable to a causal effect of pool creation. We confirm that firms more likely to join a pool exhibit a stronger response to pool announcement, and the effect of pool announcement positively depends upon the chances of successful pool creation. Our findings overall support the prediction that patent pools have a positive effect on patenting. In particular, we confirm the hypothesis (discussed in length by Dequiedt and Versaevel (2013) that prospective pool creation is driving anticipatory innovation activities. Failing to take anticipatory behavior and the intrinsic life-cycle of each specific technology standard into account would lead to the mistaken conclusions.

Several limitations are inherent to our analysis. We do not observe an external measure of technological progress, but only a patent count. We cannot analyze to what extent our results are driven by an effect of patent pools on the propensity to patent, or reflect a positive contribution of patent pools to innovation incentives. A preliminary analysis using forward citations to weight the number of patents provides much weaker evidence for a positive effect of patent pools. Further research investigating the effect of patent pools on targeted R&D expenditures or a direct measure of technological progress could complement our analysis. Furthermore, our analysis relies upon a sample of relatively homogeneous patent pools. This excludes not only historical pools developed in a very different regulatory environment, but also contemporary patent pools in biomedical technologies.

Based upon the evidence we have reviewed in our study, we find empirical support for the idea that patent pools provide incentives to apply for additional patents. Furthermore, we show that this increase in patenting is attributable to prospective members of a pool, and that patenting increases more strongly in response to more successful pool launches. All these findings are consistent with the idea that patent pools provide an instrument to monetize standard-essential patents at a lower transaction costs, and hence make it more attractive for firms likely to join such a mechanism to file for additional patents. These findings do not reflect the full effect of patent pools on innovation or patenting, as we do not study the effect of patent pools on follow-up innovation, and we do not take into account the strategic responses of pool outsiders and licensees.

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Appendix 1

Matching methodology

We have identified 43 standards (aggregate projects or disaggregate technical specifications) related to patent pools. We match each patent pool to the full list of technical specifications covered by the included patents (this information is available either from the essentiality reports of the pool, or, e.g. in the case of LTE, we use a mapping of technical specifications to LTE built using data provided by 3GPP). We use information on declared standard-essential patents, as well as patents included in the patent pool (which is required to only include standard-essential patents). Overall, we use information on more than 20,000 different standard essential patent families to map specific standards documents to disaggregated CPC and IPC classes (8 digit classification)[26].

Standard essential patents claim an invention that must be used by any company to comply with a technical standard. However, declared standard essential patents only represent a small share of all patents that are technologically related to standards. The number of declared essential patents furthermore depends upon strategic interactions and policy rules, leading to a higher or lower declaration propensity (Bekkers et al., 2012; Baron et al., 2014). While the number of declared standard-essential patents would thus be a poor measure of investment in standards, essential patents nevertheless indicate the CPC/IPC classes that are relevant to the standard. Therefore, we identify a standard's relevant technological field by using the CPC/IPC classification of declared standard essential patents as well as patents included in the patent pools. The goal is to describe the technological content of standardization projects related to pools using 3,000 different CPC/IPC technology classes.

In a first step we gather all available information on standard-essential patents from the lists of patents declared as standard essential and the lists of patents included in a patent pool. Next, we use the PATSTAT database to match patent numbers to a patent family identifier (INPADOC family ID). Each INPADOC family ID describes a single invention (priority application). We remove duplicate observations per family ID (resulting for instance from patents being filed in different countries), and obtain 22,745 unique patent families (8,891 declared standard-essential patent families and 13,854 patent families included in patent pools). We retrieve the CPC/IPC classification of these patent families from the Patstat database. Only in cases where the CPC classification was not available, we make use of the IPC classification[27].

We then assign weights to classes for each INPADOC family ID depending upon whether a class is a primary classification. We compare three weighting methods. A weight of 0 means that all classifications are treated equally (the primary CPC class is given the same weight as each extended CPC class), a primary-weight of 1 means that only the primary classification is taken into account, and a weight of 0.5 means that half of the weight is assigned to the primary class and the remaining half is distributed among

[26] The Cooperative Patent Classification (CPC) is a more recent classification system supplementing the International Patent Classification (IPC). CPC is a more detailed classification system, but has the same roots as the IPC classification.

[27] CPC and IPC classifications can be used together up to a level of disaggregation a the 8-digit level.

all classes of the patent family[28]. Subsequently, we sum the weights over all patents for each class and standard pair for the 8 digits CPC or the 4 digit CPC level. Finally, for each standard-class combination we remove duplicates to keep unique standard-class observations.

In a next step we count all patents filed from 1992 to 2014 by our sample of 190 companies. The sample includes all companies that have declared at least one patent as standard essential[29] to any of the standards in the sample. We retrieve the patents by searching the company names as well as alternative designations (e.g. 'International Business Machines' or 'IBM') in the PatStat database and by using the company assignee merging methods of Thoma et al. (2010). This patent extraction yields 13 million patent documents. For each patent number we retrieve the patent family identifier (INPADOC family ID) and the CPC/IPC primary classification. Additionally we compute the number of forward citations for each patent. We aggregate the citation and CPC/IPC information by INPADOC family ID and then remove duplicate observations to keep only one observation per patent family. In a next step we compute different importance weights to account for heterogeneity in patent value. The *family weighted* count multiplies patent weights by the number of forward citations and the *citation weighted* count multiplies patent weights by the number of citations[30]. As a final point, we aggregate counts and weighted counts over all patents for each firm, class and year. Afterwards we remove duplicates to keep unique firm-class-year combinations.

Finally, we compute for each company the number of patent files in the technological field of a standard. We therefore multiply the number of patent applications per firm, year and class by the relevance of each particular class for a particular standard. For each firm, standard and year, we sum this product over all technology classes, and then remove duplicates to keep unique firm-standard-year observations. In creating our sample of company-standard pairs for the econometric analysis, we consider three different sample restrictions: 1. We only consider pool members and companies that declared a standard essential patent. 2. For each standard, we consider all pool members, all firms that have declared standard-essential patents, and the top ten companies that file patents in the identified standard-relevant IPC/CPC classes[31]. 3. We consider all firms in our sample.

Validation

The approach of matching patent data and standards data is a novel way of measuring standard-specific innovation activities, and we therefore compare different weighting, counting and aggregation options. We apply general criteria to discard methods that appear to result in a poor match between patents and standards (details will be published in a forthcoming paper). We find that including the extended classification of patents clearly

[28] E.g. for a patent with one primary and 4 extended classifications, the primary class receives 0.6 weight, and each of the extended classes receives 0.1 weight.

[29] According to data provided by IPLytics

[30] We divide the number of citations by the average number of citations for patents with this priority year in order to address truncation effects. This approach is used e.g. in the NBER patent database (see Hall et al., 2001).

[31] We consider the cumulative count of patent up to the date of pool launch

improves the matching method (and hence discard the primary weight 1)[32], and that family weighting schemes result in a poorer fit than unweighted or citation-weighted patent counts. In the analysis we ensure that our results are robust to all remaining specification choices that are not discarded by clear and general criteria. We use three different criteria to assess the performance of our methodology. First, we assess to what extent peaks in patenting in the classes identified as *standard-relevant* coincide with the timing of standard development. Second, we analyze whether declarations of standard-essential patents for this standard coincide with peaks in patenting in the identified *standard-relevant* classes. Finally, we assess whether the companies holding the largest portfolios of declared standard-essential patents for this standard are also identified as being among the largest patent holders in the relevant standard-relevant classes. In the following, we present analyses confirming that our selected methodologies reliably identify technology classes that are indeed closely related to the specific standard.

Timing

To test the different choices of how to map patents to standards we cumulate the preferred measure over time up to the year of standard release. We then compare the timing of patent files to the development of a standard's life time. Once a standard is set and published, the main technology development of the standard is completed and we would thus expect decreasing investments in the technology standard. A good standard related patent measure would thus suggest an increase of patenting up to standard release and a decrease thereafter. We regress the number of identified *standard related patents* on a full set of standard age dummies (each dummy represents a number of years since or up to standard release), controlling for other time effects by including an overall count of patent files per year, and including company-standard pair fixed effects.

The graphs in Figure 1 show the normalized coefficients of regressing standard age dummies over the full sample (left), pool members, declaring companies and top 10 patent holders (center) and for pool members and declaring companies only (right). The comparison of the different weightings of primary or extended CPC/IPC reveals that a weight of 0.5 shows a development that is most closely related to the standard lifetime developments. In figure 2-4 we illustrate that using a primary weight of 0.5, both unweighted and citation-weighted patent counts as well as the different groupings of company standard pairs display an increase of patenting prior to a standard release and a decrease of patenting thereafter. The differences between the different selected methods seem to be relatively insignificant.

Succession of standard generations

We can illustrate the correlation of our computed measure of standard-related patenting with standard development by comparing different generations of standards in the same

[32]This finding is in line with Benner and Waldfogel (2008), who suggest using all IPC classifications of patents, not only the primary classification, and at a relatively aggregate level. In contrast to Benner and Waldfogel (2008), we however find that the method is improved by assigning a higher weight to the primary IPC class.

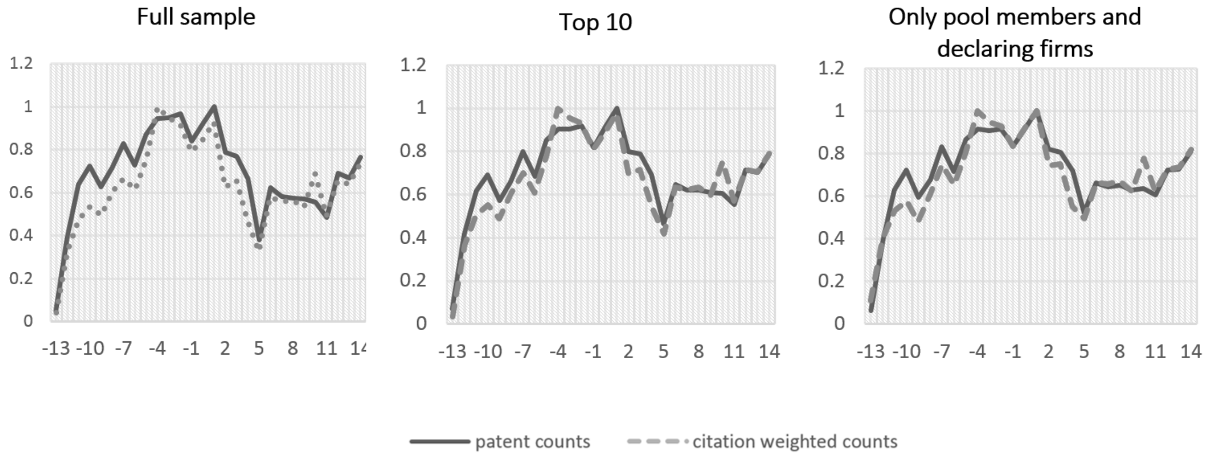

Figure 2: Normalized coefficients of standard age dummies before and after standard release

technical field. We can compare telecommunication standards, which evolved from 2G (GSM) to 4G (LTE). Therefore we compare the patenting of citation-weighted patent counts for all company standard pairs over time for GSM and LTE.

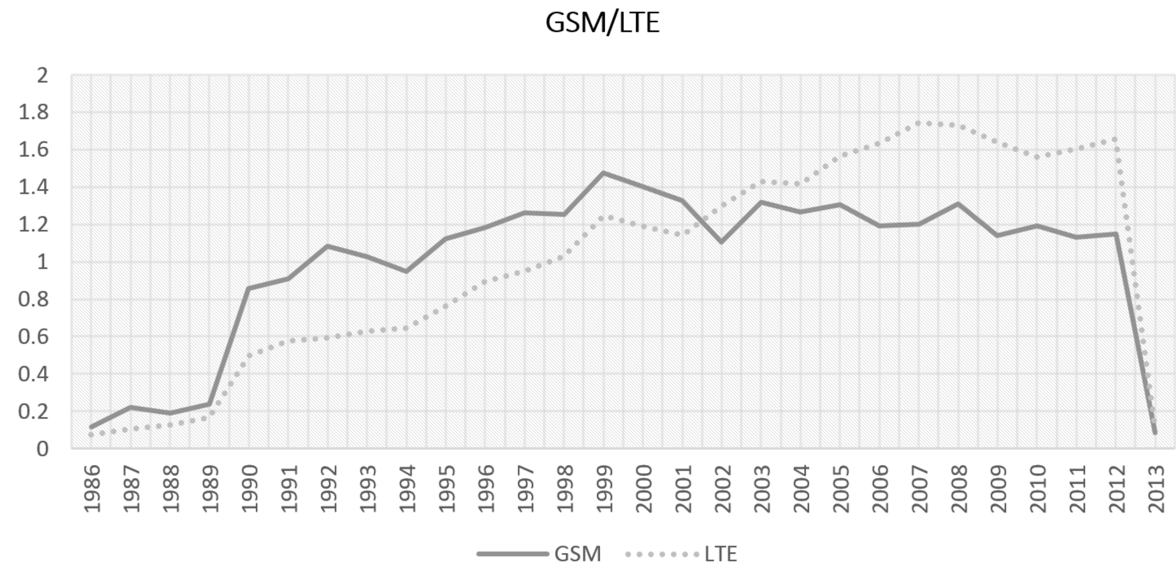

Figure 3: Normalized levels of patenting over time

We replicate the analysis for different generations of the audio/video coding standards developed by the Moving Picture Expert Group (MPEG): mp3 (MPEG1 Audio), MPEG2, MPEG 4 Visual and AVC. Both examples of standard generations show that our measure very well measures the timing differences. Patents filed for GSM decrease after 2000, while LTE patents increase thereafter and peak around 2008. The same is true for the audio/video coding standards, where mp3 related patents are filed in early years of the 90ies and AVC patents in late 2000, whereas patenting for MPEG2 and MPEG4 visual peaks in between these dates. These time trends clearly mirror the different steps in the progress of the different technological fields.

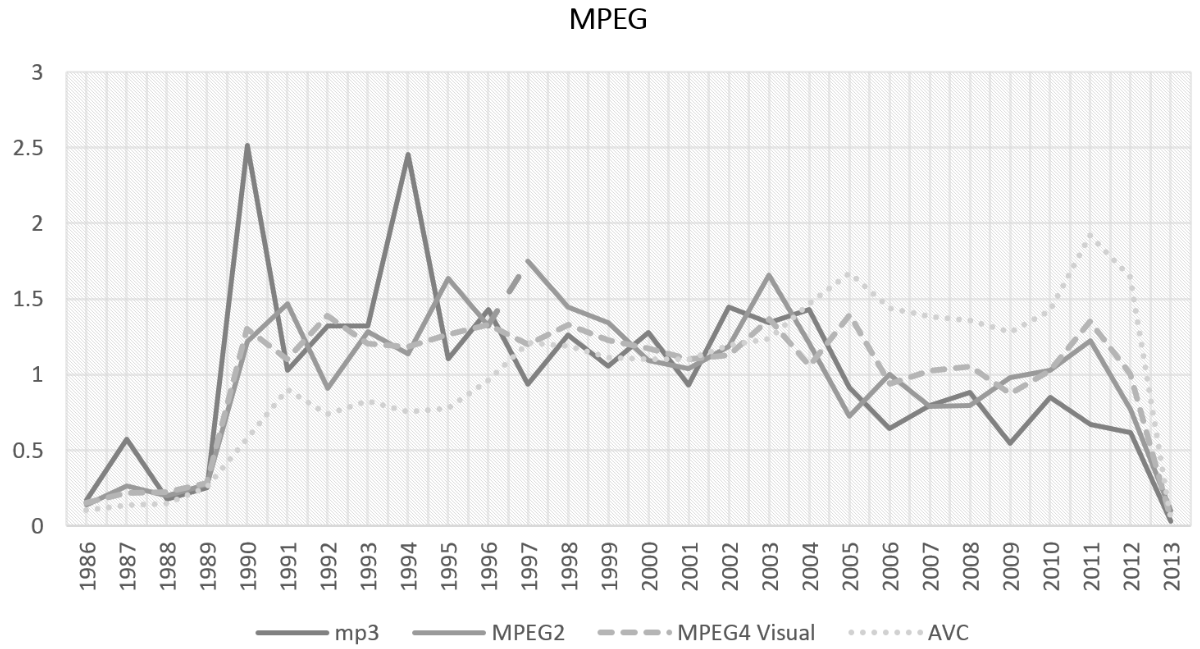

Figure 4: Normalized levels of patenting over time

Identification of largest patent holders

We use the calculated cumulative number of patent files by company-standard pairs at the time of patent launch to establish a ranking of the largest patent holders. We compare these lists of top patent holders with the lists of pool members and companies declaring standard-essential patents in order to assess if our counting methods actually reveal relevant patent files of a particular company for a particular standard[33]. We picked four large patent pools representing four different technology fields, and we compare the list of top patent holders. We find that almost all identified top patent holders also declared to own standard-essential patents for this standard. In the case of AVC or the two DVD patent pools, most of the significant patent holders have also been pool members at least at some time over the period of observation. This is not the case for the WiFi and GSM standards. In the case of DVD, Thomson, which was known to be a significant pool outsider, is identified as a relevant patent holder for this standard. In the case of GSM, we find that the ranking of patents in the field is quite representative of the number of declarations. This is not the case for AVC and WiFi, which were developed at SSOs that allow companies to declare to own standard-essential patents without specifying specific patent numbers.

[33]By picking the largest patent pools in their respective fields, we also pick pools for which we had a higher number of patent observations to establish the matching. The matching works "less well" for smaller standards, where the number of observations is lower.

	AVC			DVD		IEEE 802.11			GSM		
	Company	Pool	Decs	Company	Pool	Company	Pool	Decs	Company	Pool	Decs
1	Hitachi	Y	0	Sony	Y	Ericsson	N	1	Ericsson	N	57
2	Philips	Y	3	Canon	N	Siemens	N	0	Nokia	Y	1,425
3	Sony	Y	11	Thomson	N	Nokia	N	51	Siemens	N	205
4	Siemens	Y	5	Samsung	Y	Sony	Y	1	Qualcomm	N	553
5	Samsung	Y	2	Philips	Y	Philips	Y	11	Motorola	N	1,682
6	IBM	N	32	Hitachi	Y	LG	Y	4	NEC	N	102
7	NEC	N	3	Toshiba	Y	Motorola	N	8	Sony	N	0
8	Fujitsu	Y	3	NEC	N	Thomson	N	1	Samsung	N	53
9	Toshiba	Y	3	Sanyo	Y	Nortel	N	5	Philips	N	167
10	Intel	N	3	LG	Y	Intel	N	10	Toshiba	N	9
11	Thomson	N	55	Fujitsu	N	IBM	N	5	Hitachi	N	0
12	LG	Y	3	Sharp	Y	NEC	N	1	Bosch	N	18
13	STMicro	N	0	Intel	N	Huawei	N	3	Thomson	N	0
14	Motorola	N	25	Siemens	N	Samsung	N	0	Canon	N	0
15	Seiko	N	0	Mitsubishi	Y	NTT	Y	3	Nortel	N	10

Table 11: Top patent holders in the field of selected pools

Appendix 2

Standard	Patent share	Aggregate	AV	Telecom	HHI patents
AGORA-C		1	0	0	
AMR		0	0	1	
AMR-WB+	0.0086	0	0	1	0.0580
AMR-WB/G.722.2	0.0599	0	0	0	0.0604
ATSC	0.0992	1	1	0	0.1649
AVC	0.6118	0	1	0	0.0549
BluRay	0.7891	1	1	0	0.1002
CDMA-2000		1	0	1	
DAB	0	1	1	0	0.0568
DECT	0	1			0.1365
DVB-H	0	0	1	0	0.3055
DVB-MHP	0.1456	1	1	0	0.4660
dvb-t	0.0223	1	1	0	0.0631
dvb-t2	0.1265	1	1	0	0.0646
DVD	0.6081	1	1	0	0.1107
Digital Radio Mondiale	0.1343	1	1	0	.4788
G 711.1	0.2107	0	0	1	0.1301
G 723.1	0.1178	0	0	1	0.1115
G 729	0.0038	0	0	1	0.5385
G 729.1	0.0957	0	0	1	0.5085
H.264 SVC		0	1	0	
IEEE1394	0.2947	1	0	0	0.0817
IEEE802.11	0.2510	1	0	0	0.0485
LTE	0.0634	1	0	1	0.0604
mp3		0	1	0	0.0647
MPEG Surround	0.3232	0	1	0	0.3602
MPEG2	0.2379	0	1	0	0.5449
MPEG2 AAC	0	0	1	0	
MPEG4 Audio	0.2930	0	1	0	0.0681
MPEG4 SLS	0	1	0	0	
MPEG4 Systems	0.2285	0	1	0	0.0672
MPEG4 Visual	0.7369	0	1	0	0.0934
MPEG7	0	0	1	0	0.1428
MVC	0.3461	0	1	0	0.0759
NFC	0	1	0	0	0.2550
OCAP		0	1	0	
GSM	0.0292	1	0	1	0.0508
TOP Teletext	0	0	1	0	
TV Anytime	0.5341	1	1	0	0.3503
UHF-RFID	0.0762	1	0	0	0.0611
VC-1	0.7202	0	0	0	0.1853
W-CDMA	0.3876	1	0	1	0.0571
WSS	0	0	1	0	0.4199

Table 12: Patent pools by success rate (patent share), technological category, HHI