Essential Patents and Standard Dynamics

Justus Baron

Cerna, Centre d'économie industrielle. MINES ParisTech

Knut Blind

Berlin University of Technology, Chair of Innovation Economics

Fraunhofer Institute for Open Communication Systems

Rotterdam School of Management

Tim Pohlmann

Berlin University of Technology, Chair of Innovation Economics

Abstract: *This paper examines the impact of essential patents on standardization. In particular, we analyze the influence of patents on the rate of standard replacement. We investigate whether essential patents contribute to a "lock in" of outdated standards, or rather encourage investment and increase the pace of standardization. Building upon a comprehensive dataset of over 6.000 different standards and nearly 20.000 standard versions in the field of ICT, we evidence essential patents to reduce the likelihood of standard replacement. This effect takes place in the first years after the standard is issued. On the other hand, declarations of essential patents increase the likelihood of version replacement. We argue that these version upgrades do not entail replacement of standard components. The effect on versions reflects an increase in the firms' investment in standardization, while the reduced rate of standard replacement in early years reflects a stabilizing effect of patents on standardization.*

Introduction

The number of patents declared essential to technological standards has sharply increased over the last years (Simcoe, 2005). Essential patents are patents that are necessarily infringed by any implementation of the standard. Owners of essential patents have the right to impede the adoption of a standard. The rise in the number of these essential patents may thus have a direct impact on standardization and its main objectives, for instance to encourage the wide adoption of a technology and to create a common, generalized technological interface.

While there have been several recent contributions shedding light on the driving factors of the increasing number of essential patents (Simcoe, 2005; Bekkers et al. 2011), there have been less advances on understanding the consequences of this evolution for standardization. Several contributions raise the concern that the high number of patents could lead to patent thickets (Shapiro, 2001) and hamper standardization processes. Nevertheless, it is important to also see the potential benefits of essential patents in addressing inefficiencies in the collective investment into a standard. Allowing standard setting firms to include their proprietary technology into technological standards may indeed be an important incentive for firms to increase their investment in standardization. As a result, essential patents may actually accelerate the pace of standardization. It is the aim of this article to have a more comprehensive understanding of these mechanisms.

We examine empirically the effect of patents on standard replacement. In our analysis, standard dynamics face a tension between responding to an advancing state of the art, subject to innovation, and ensuring the main function of standardization, which is to fix a stable technological basis for implementation and new applications. Standard replacement induces costs for standardizing firms (standardization costs) and for users of the standard (adoption costs, and loss of network effects for users of the old standard), but is likely to improve the technology incorporated in the standard. In many cases, standardizing firms can choose between replacement and upgrade of the standard. While a standard upgrade only adds technological components to an existing standard, standard replacement replaces existing specifications. Only replacement allows fully integrating the advances in the state of the art, while standard upgrades are less costly for standard users. Based upon these insights, we investigate the rates of upgrade and replacement of standards including essential patents, as compared to other standards.

We rely upon a comprehensive database of ICT[1] standards released from 1992 to 2010 obtained from the international standards database PERINORM[2]. The database is limited to formal, international standards

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[1] According to the ICS (international classification of standards) standards classified as 33 (telecommunications, audio and video engineering) and 35 (information technology, office machines) represent all standards of ICT (information and

issued according to a comparable set of rules[3]. This dataset includes over 6.000 different standards and nearly 20.000 standard versions. These observations are richly informed in technical characteristics. We match the standards in our sample to a comprehensive database of patents declared essential. We furthermore match ICS classes of standards to IPC[4] classes based upon the declared essential patents[5] and inform for each standard class the speed of technological progress, as measured by the number of patent files in the field.

The aim is to estimate the effect of declarations of essential patents on the replacement of standards. This aim is complicated by the fact that essential patents are not randomly distributed over the 6.000 formal ICT standards, but are concentrated on important standards in specific technological fields. This paper presents two empirical strategies to deal with this potential source of bias. First, we construct an appropriate control sample in order to neutralize the effects of standard size, standard scope and technological field. Second, we estimate the hazard rate of standard replacement over time with tools of time-to-event analysis in a long-form data panel. The panel form of the data allows estimating the effect of a patent declaration on an existing standard, controlling year by year for relevant technological events. Regression results show that essential patents reduce the likelihood of standard replacement. This effect takes place in the first years after the standard is issued. On the other hand, declarations of essential patents increase the likelihood of version replacement. We argue that these version upgrades do not entail replacement of standard components and thus do not create costs for adaptors or a loss for IPR owners. Our findings support the argument that more frequent standard upgrade reflects an increase in the firms' investment in standardization, while the reduced rate of standard replacement in early years reflects a stabilizing effect of patents on standardization.

The remainder of this article is organized as follows. In the second section, we sketch a simple analytical framework of standard dynamics, and discuss the literature on essential patents. In the third and fourth section, we present our empirical methodology and sampling methods. In the fifth part, we present the results of a descriptive analysis of the database; and the sixth part includes the results from econometric analysis. The seventh part highlights paths for further research and concludes.

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telecommunication) technologies. As to Baron and Pohlmann (2011) 98 % of all essential patents can be found in ICT standards (ICS classes 33 and 35).

[2] PERINORM is a bibliographic database of formal standards and is updated by DIN, AFNOR and BSI.

[3] We used standards issued by all SSOs (Standard Setting Organizations) that are compliant with a general set of rules and publish their standards in the international standards database PERINORM. SSOs: ISO, IEC, JTC1, ISO, IEC, CEN/CENELEC, ITU-T, ITU-R, and IEEE.

[4] International Patent Classification.

[5] Companies declare their essential IPR to public available databases of the relevant SSO. We captured over 8.000 patent declarations and matched them to the relevant standards of our sample.

Analytical framework

Standard replacement

ICT technologies are subject to continuous innovation. Day by day new inventions are patented by many different actors. However, in most fields of ICT, network effects are strong, and technologies can only be successfully deployed when a large number of users share a common, stable technological basis. This technological basis is usually open to some improvements and extensions, and smaller technological contributions building upon the existing technological architecture are continuously brought to the market. However, substantial progress of the technological basis itself does usually not come gradually, but in a discrete number of "jumps", or "generations".[6] Standardization plays a crucial role in this process of deployment of ICT technologies. Standards set a common technological architecture, ensure compatibility and organize the common use of a wired or wireless network. The different generations of technology correspond to different standards, or generations of standards. The issuance and adoption of a new standard thus determine the common adoption of thousands of technological inventions[7]. This process can take place more or less often, and the technological progress incorporated in a standard with respect to its predecessor can be more or less important.

The rate of standard replacement is subject to an important economic tradeoff: on the one hand, standard replacement is necessary in order to improve the technology at use and to integrate new functionalities. The more often a standard is replaced, the less the users have to wait for the improvements made possible by recent technological progress. In some cases, standardization can lock in a specific technology for an inefficiently long time (Farrell and Saloner, 1985). Once markets widely adopt the standard; switching costs and the risks of lock-in increase (Arthur, 1989). In some cases, standard replacement might thus be too slow and consumers would gain from a higher rate of replacement.

On the other hand, each standard replacement generates substantial costs for standardizing firms and for users of the technology. Adopters of the new standard version thus need to incur adoption costs (e.g. investment in new devices or in vintage-specific human capital) in order to benefit from the new technology, and manufacturers and service providers need to invest in new production chains and new services. These adoption costs can outweigh the benefits of the new technology. Therefore, some users will prefer to continue using the old technological generation. However, if a substantial number of users switch to the new standard, users of the old standard will suffer from smaller network size and loss of

[6] E.g. coding generations MPEG1 to MPEG7 and beyond, or generations of mobile technologies from 1G to 4G.

[7] For recent case studies of the interplay between standardization and innovation, see Bekkers and Martinelli (2010) and Fontana et al. (2009).

positive network externalities if the new generation is not fully backward compatible. The optimal rate of standard replacement thus strikes a balance between the costs of standardization and standard adoption on the one hand, and the opportunity cost of using an outdated technology on the other hand. The rate can deviate from the social optimum in both directions, yielding either excessive inertia (insufficient rate of standard replacement) or excessive momentum (excessive rate of standard replacement). Efficient standard dynamics thus strike the balance between the discrete costs of standard renewal and the opportunity cost of using outdated technology (Figure 1).

The issue of inertia and momentum in standard replacement has been addressed mainly in the theoretical economic literature (see for instance Farrell and Saloner, 1986). The role of IPR in generating excessive inertia has hereby been controversially discussed. On the one hand, Liebowitz and Margolis (1990) argue that some kind of ownership over a standard should rule out inefficient adoption patterns: "An owner with the prospect of appropriating substantial benefits from a new standard would have an incentive to share some of the costs of switching to a new standard"[8]. On the other hand, Clements (2005) finds that the incentives of an owner of a proprietary standard to have its standard adopted deviate from what would be socially optimal.

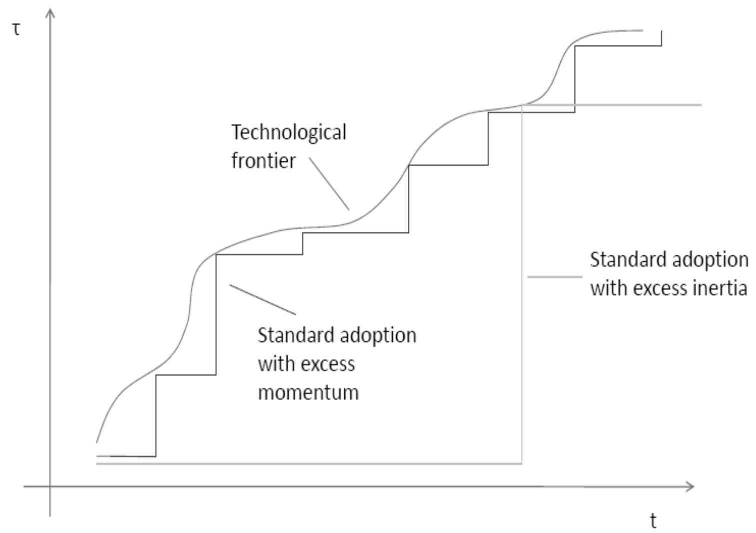

Figure 1: *Simple illustration of standard replacement with inertia or momentum*

In contrast to the common theoretical models which rely upon monopolistic technology supply in uncoordinated user markets, standard replacement in modern ICT industries mainly takes place in cooperative fora and Standard Development Organizations (SDO). These coordinative mechanisms are subject to a more recent literature on standard dynamics. In this analysis, standards face a tension

8 Liebowitz and Margolis (1990), p. 5.

between responding to an advancing state of the art, subject to innovation, and ensuring the main function of standardization, which is to fix a stable technological basis for creating compatible products and investing in applications and implementation (Egyedi 2005, Blind and Egyedi, 2008). A first empirical analysis that focuses on national standards bodies (Blind 2007) measures factors influencing the lifetime of standard versions in ICT industries. This paper has revealed that standard survival time decreases with the speed of innovation, as measured by patent files in ICT in the relevant country. Furthermore, the analysis firstly deals with cross-references between standards and standard size and its effects on standard survival.

We wish to take further the existing empirical literature and gain some understanding of the economic issues affecting the decision making process inside standard setting organizations. It is increasingly acknowledged that economic institutions have an important impact upon the outcome of standardization. Probably among the most important factors affecting standardization ranges the patent system. There is an increasing number of essential patents in standards, and the interplay between patents and standards is hotly debated. We wish to inform this debate by analyzing the role of essential patents in the process of standard replacement.

The role of essential patents

Essential patents can have an impact on these standard dynamics for various reasons. First, we argue that standardization entails a costly private investment in a public good and is therefore subject to free riding by standard takers. Kindleberger (1983) alleges that standards are public goods since every firm is free to implement the standards whether or not it contributed to standardization. Due to this externality, standard makers invest too little in standardization and consequently renew standards less frequently than what would be socially optimal. Strong IPR on standardized technology can help overcoming this inertia, as patent holders have a stronger private interest in renewing the standard version if they can recoup the standardization cost through licensing fees. Essential patents might furthermore signal commercial stakes in standards or that a standard is commercially relevant to a company. IPR can hereby help overcoming underinvestment in standards and socially inefficient inertia (Liebowitz and Margolis, 1990). The incentive to regularly upgrade a standard is particularly strong for owners of essential patents when the technological evolution in the sector generates pressure for standard renewal. In order to avoid standard replacement and the loss of exclusionary power over the standard, owners of essential patents can regularly invest in improving the standard through upgrades, which add technological components without replacing the existing ones.

Second, essential patents on formal standards can generate conflicts between standard makers regarding the shares of proprietary technology covered by the standard. In an interview on the effects of essential patents on standards the participating expert, a longtime practitioner in ICT standard bodies, stated: “There are cases where companies give inputs (IPR protected) which do not deliver useful technology for the standard. These companies would only agree to a certain standard, if they are allowed to integrate their technology.” He further emphasizes that “…this makes the standardization process more complex and time consuming and sometimes even introduces errors on products.”[9] Results from the survey of the “EU Study on The Interplay of IPR and Standards” show similar concerns on the inclusion of patents into standards (figure 2).

(1 = very negative, 5 = very positive)

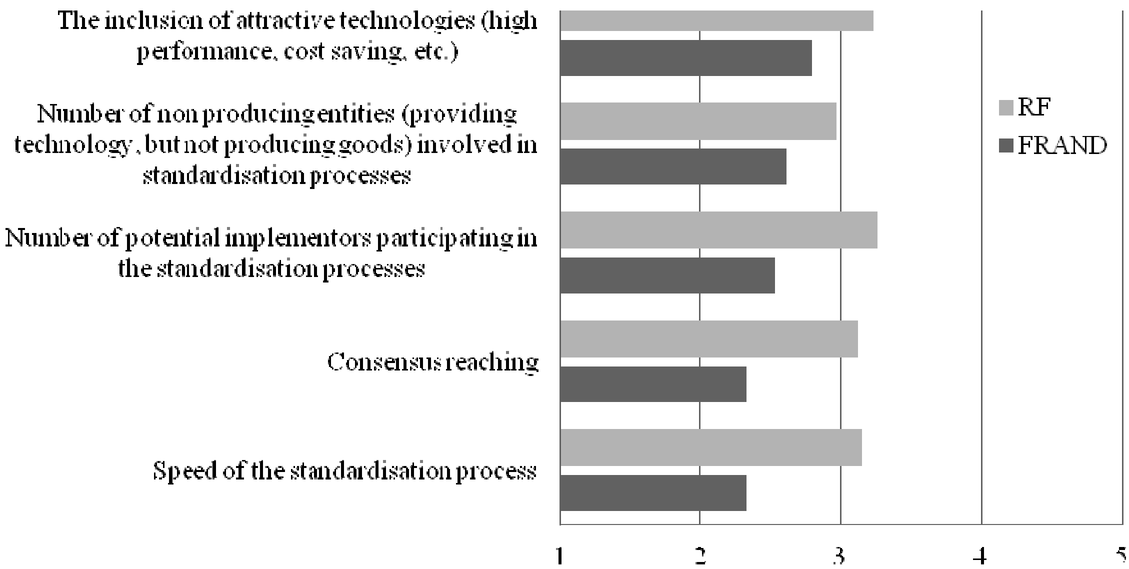

Figure 2: *Stakeholders views on the effect of IPR inclusion in standards. (N=108) (source: Blind et al., 2011)*

The survey result reflects a clear picture under FRAND conditions, where participants see consensus reaching and the speed of standardization processes to be the most negatively affected fields when essential IPRs are introduced to a standard. These findings support a string of literature that argues that a company’s preference for its own technological solution in standardization increases with the commercial stakes. Therefore essential patents can lead to a time-consuming « war of attrition » in building consensus

[9] The interview with Dr. Ivstan Sebestyen held in April 13th 2010 was conducted in the context of a fact finding.“EU study on the Interplay of IPR and Standards”. Ivstan Sebestyen has been involved in the worldwide multimedia standardization work for over 20 years including telecommunication standardization experience in CCITT, ITU-T, ISO/IEC, ETSI and DIN and ITU-T and still picture coding (JPEG, JBIG).

on a new standard (Farrell and Simcoe, 2009; Simcoe 2011). If standardizing firms need to build consensus for a standard replacing an existing one, they will furthermore face a conflict of interests between sponsors of the existing standard and owners of patents on technological components to be included. “Winners” of a standard replacement need to compensate the “losers”, who have otherwise a strong power to impede or at least delay standard renewal. Such a bail-out might be particularly difficult when the turnover in essential technology is high and when the contacts between standard makers are loose.

From the academic literature and practitioner statements, we thus draw the following hypotheses: first, essential patents allow some degree of internalization of standardization costs and therefore provide incentives for a more regular investment in standard replacement. Second, where standard replacement entails replacement of important technological components, property rights on technology incorporated in the standard are expected to delay standard replacement. The goal of our analysis is to empirically test these hypotheses and to deepen our understanding of the role of essential IPR in the dynamics of standardization.

Empirical methodology

We analyze the rate of standard replacement using a comprehensive database of international ICT standards drawn from PERINORM. We chose to include in our sample all ICT standards (ICS classes 33, 35, and 37) issued by the main international SDOs (CEN, CENELEC, ITU-R, ITU-T, IEEE, ISO, IEC, JTC1). We did not include ETSI or informal standard setting consortia, in order to concentrate upon standards issued according to comparable rules. We restrict the analysis to standards issued from 1990 to 2006, and we observe these standards until 2010. Standard versions that are still valid in 2010 are therefore right-censored. Draft standards, amendments and errata documents are excluded from the quantitative analysis. Overall, our sample comprises 6.296 standards, 18.476 standard versions and 50.883 version-year observations (47.931 observations for finalized standards).

For every standard version, the database gives precise dates of release and drawback. We can thus easily obtain the survival time, and the survival rate period by period, of standard versions. PERINORM also informs whether a standard version is replaced by a new version of the same standard, whether the standard is replaced by a new standard, or whether the standard is withdrawn without a direct successor. We consider that if a standard version is replaced by a more recent version of the same standard, the standard as such is kept in place, whereas if a standard version has no direct successor or if the successor is a different standard, the standard is withdrawn as a whole. We can thus differentiate between a version replacement (or standard upgrade) and standard replacement. We investigate the effects of our explanatory variables on the hazard rates of the different events using duration analysis. In the following analysis, we will separately investigate the survival rate of standard versions beginning with version release, and the survival rate of standards, beginning with the release of the first standard version.

The standards in our sample are matched to a database of essential patents in order to obtain the explanatory variable. Declarations of essential patents have been drawn from the websites of the SDOs. First, we identify the almost 700 formal standards for which there has been at least one declaration of essential patents. Overall, there are more than 8.000 patent declarations for the standards included in our sample. We can infer from our declaration data the number of patents claimed to be essential for the different standards in our sample. The patent declaration database generally informs the date of declaration, so that we can match each essential patent to its relevant standard at any time from the year of declaration. Patent declarations for which the date could not be informed have not been taken into account.

As explained in our analytical framework, we expect that standard renewals are determined by an evolving state of the art on one hand, and substantial discrete standardization and adoption costs on the other hand. We approximate the evolution of the state of the art using information drawn from essential patents. Building upon Baron and Pohlmann (2011), we use the technological classification of declared essential patents to match patent and standard classes in the field of ICT. We can thus identify how many patents are filed in fields that are potentially relevant for the standards in the different ICS (International Classification of Standards) classes. Thus we can inform for each standard class on a relatively disaggregate level the speed at which the state of the art evolves. Blind (2007) has shown that the replacement rate of national ICT standards increases with the number of ICT patent files in the respective country. In our data, we can identify innovation rates that are more closely related to specific standards. If the number of patent files in a standard related field increases by 100% with respect to the trend in ICT, the probability of replacement of the standards in the respective standard class increases by 50%.[10]

We furthermore wish to control for standard characteristics and events affecting the standard that are likely to have an impact on the probability of standard replacement. From PERINORM, we can draw a broad range of variables regarding standard characteristics. This information comprises characteristics that are constant over time and therefore are independent of the survival time of a standard or standard

[10] The link between our measure of standard related patenting trends and standard replacement is significant at 99%, see details in the appendix.

version. These constant characteristics include the issuing SSO, the technology as indicated through the ICS classification, the breadth of the technological scope, approximated through the number of ICS classifications, the number of pages, standard modifications, and references to prior standards. We inform also accreditations of the standard that have taken place before standard release (backward accreditations), when the standard has not been first issued by one of the SSOs we observe (for example if a national standard is accredited on international level).

Other standard characteristics relate to events occurring after standard release, and are therefore not independent of the survival time of a standard or standard version. Just as for patent declarations, standard modifications, references from other standards (forward references) and accreditations by other SSOs (forward accreditations) are matched to the panel over time and as they occur. These variables are likely to capture up to some extent downstream investment building upon the standard and the technological architecture in which it is embedded. Forward references and accreditations are thus likely to increase the cost of standard renewal, as changes in the central standard can require changes in the refereeing standard, and the accreditations need to be renewed.

We propose two different strategies to control for observable standard characteristics. In a first step, we will present descriptive statistics on the survival rate of standards over time, comparing standards including essential patents with standards that are a priori comparable, but do not include essential patents. This control sample is built up using Propensity Score Matching (PSM). We calculate the ex ante propensity of standards to include essential patents, based upon fixed standard characteristics. Each standard including essential patents is then matched to a standard without essential patents, but with a very similar propensity score.

We can thus construct a sample of standards that have, based upon observable characteristics, the same propensity to include essential patents than those that actually include such patents. If standards including patents behave differently than the standards in this control sample, this difference is not due to observable factors such as the characteristics of a technological field or SDO policies. We can on the other hand not rule out that there is an unobservable common factor affecting the likelihood of a standard to include essential patents and the survival of this standard and its versions. This is particularly true for the various aspects relating to the commercial relevance of a standard for technology holders. Our findings can therefore not indicate the effect of allowing for patents as a particular appropriation mechanism. Similar to Simcoe (2011), they rather highlight the effects on standards when there are greater commercial interests of technology holders at stake.

However, sampling is not effective to control for time-variant factors of standardization dynamics. Therefore we will propose in a second step a multivariate panel analysis, where standard characteristics are included as control variables. Standard replacement is explained through a Cox model. In this methodology, the likelihood of an event is estimated period by period, and explanatory variables are allowed to vary over time. Time-variant characteristics are matched to the data over time as they occur.

The Cox model is a semi-parametric model: there is no restriction on the baseline hazard of the explained event (standard or version replacement), except that the baseline hazard is common to all observations. Fixed standard characteristics are time-invariant in the model, and are therefore modeled to have a constant effect over time. This assumption could be problematic for important factors affecting the life cycle of standards. The SDO of issuance is important, as the different bodies may differ as to their standardization procedures. Furthermore, the life cycle of standards is likely to depend upon the technological field. We do not want to impose that the effect of the issuing SSO is constant over time. Therefore, all our results are based upon stratified analysis, estimating the baseline hazard rate individually for each SDO. In stratified analysis, we allow the baseline hazard rate to be different among the strata (groups of observations), and we only impose that the effect of the explanatory variables is common to all observations. Stratifying according to SDO or ICS class therefore adequately controls for time-variant effects of these factors.

Sampling

It is the objective of our analysis to compare standards including essential patents with the other standards. However, essential patents are not randomly distributed over the standards in ICT. For instance, essential patents play a much greater role in some technological fields than in others. Furthermore, it can be argued that institutional factors relating to the issuing SSO can encourage or inhibit declarations of essential patents. But also the year of issuance, the size, the technological scope, the international dimension and the novelty of the technological content of the standard are all likely to play a role in explaining which standards include proprietary technology. Many of these factors are also likely to have an impact on the duration until standard upgrade and replacement.

We therefore have to construct an appropriate control group in order to be able to present meaningful descriptive statistics. We carry through a propensity score matching based upon a broad range of observable fixed standard characteristics. We apply a very strict matching restricted to the next neighbors in propensity score. Observations of standards without essential patents are allowed to be matched to more than one standard including essential patents. This specification reduces sample size, but increases accuracy. We furthermore impose a maximum propensity score difference of 0.03, thus also eliminating some observations of standards including essential patents (off support). These are standards presenting so many characteristics related to essential patents, that it is impossible to find a close enough sibling standard that does not include essential patents. Once again, we thereby sacrifice sample size for greater accuracy. Figure 1 sketches the distribution of propensity scores in the samples of standards with and without essential patents and indicates the observations eliminated because of the absence of a sufficiently close neighbor.

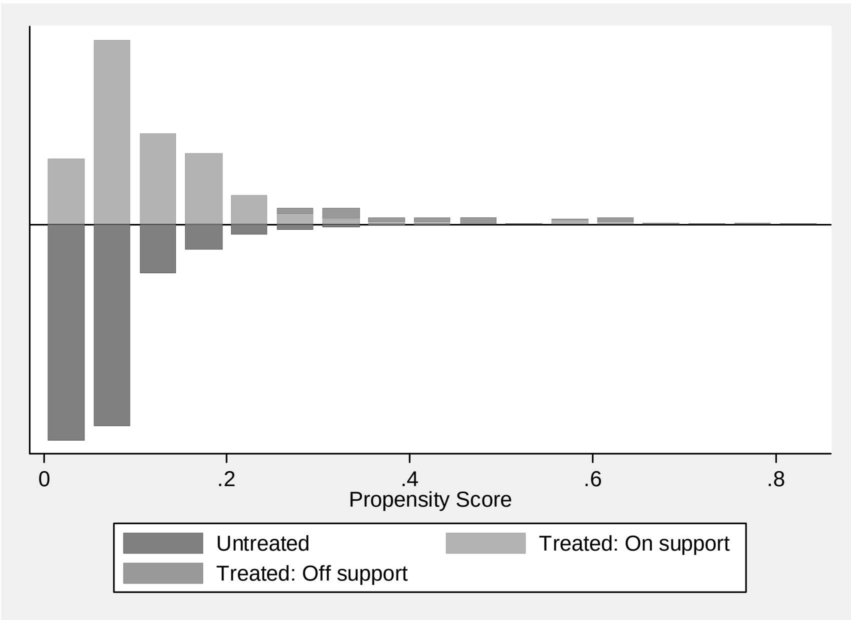

Figure 3: *Propensity scores for standards with (above) and without (below) essential patents*

Table 1 provides descriptive statistics on the main standard characteristics in the samples of standards including and not including essential patents; both before and after propensity score matching. We can see that there are significant differences between the samples of standards with and without patents, most importantly with respect to the technological field (ICS class) and the issuing SDO. For instance IEEE standards are much more likely to include essential patents, while IEC standards are much less likely to include essential patents than the average in the sample. After propensity score matching, there are no remaining significant differences between characteristics of the standards in the two samples.

		Mean			% reduct. bias	t-test	
Variable	Sample	Treated	Control	% bias		t	p> |t|
Date of first release	Unmatched	14470	13903	28,2	43,7	4,45	0,000
	Matched	14472	14791	-15,9		-2,00	0,046
Number of Pages	Unmatched	106,27	54,742	41,0	66,7	8,19	0,000
	Matched	99,419	116,6	-13,7		-1,28	0,200
Backward references	Unmatched	7,4306	6,7001	7,5	-64,9	1,14	0,254
	Matched	7,333	8,5376	-12,3		-1,31	0,191
Citation backlag	Unmatched	32,394	30,26	3,7	-260,4	0,53	0,596
	Matched	31,863	39,556	-13,3		-1,42	0,157
Number of ICS classes	Unmatched	2,0961	2,1571	-2,3	29,5	-0,36	0,719
	Matched	2,1004	2,1434	-1,6		-0,19	0,853
Prior accreditations	Unmatched	0,13523	0,1341	0,3	-1802,1	0,05	0,962
	Matched	0,1362	0,1147	5,2		0,60	0,548
ITU-T	Unmatched	0,5089	0,4354	14,7	46,4	2,39	0,017
	Matched	0,51254	0,47312	7,9		0,93	0,353
JTC1	Unmatched	0,23132	0,27453	-9,9	33,6	-1,57	0,117
	Matched	0,23297	0,26165	-6,6		-0,78	0,433
IEC	Unmatched	0,03203	0,13583	-38,1	93,1	-5,02	0,000
	Matched	0,03226	0,02509	2,6		0,51	0,613
IEEE	Unmatched	0,14235	0,06273	26,4	86,5	5,09	0,000
	Matched	0,1362	0,14695	-3,6		-0,36	0,716
ISO	Unmatched	0,08541	0,09151	-2,1	-17,5	-0,34	0,732
	Matched	0,08602	0,09319	-2,5		-0,30	0,767
ICS dummies	20 class dummies, reported in the appendix						

Table 1: *Sample statistics, matched and unmatched samples*

The average standard version is active for 3.5 years. The average standard lasts just a bit longer, 3.72 years. It has to be noticed that this information is right-censored. This information has been retrieved in November 2010; standards still active at that time are not considered for calculating the average survival time. While 11.047 standard versions have been withdrawn, only 8.336 of these versions belong to standards that have been replaced. As the period of observation is relatively short, average survival times are not informative, especially with respect to the survival of the whole standard. Even for a first descriptive analysis of standard replacement, it is therefore preferable to rely upon the tools of duration analysis. We will thus present stylized facts on the dynamics of standard and version replacements in our samples. We further present statistics on version replacement, i.e. the replacement of a version by another document, either a new version of the same standard, or a different standard.

Descriptive Analysis

Figure 2 presents the survival estimates of standard versions by SDOs. Survival estimates are the likelihood that an observation will "survive" for a specific time. At each time, only observations that have been observed are taken into account. The following statistics are therefore not subject to truncation problems. These survival estimates furthermore only take into account finalized standards, and exclude drafts, errata and modifications. Version survival rates differ strongly between the different SSOs. For example, less than half of the JTC1 standard versions are active for more than 3 years, while this is true for well above 90% of ITU-T standard versions. These differences need to be explicitly addressed in the following econometric analysis.

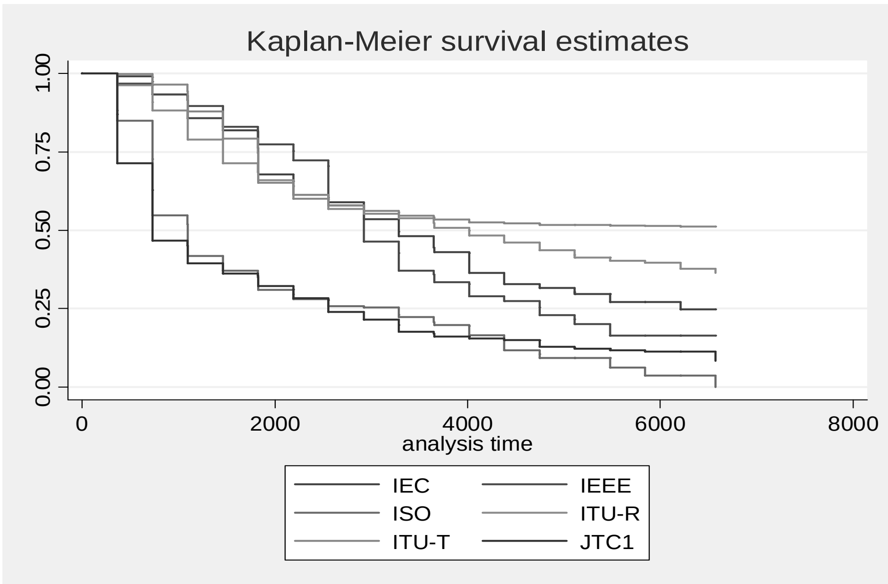

Figure 4: *Kaplan-Meier survival estimates of standard versions by SDO*

The following figure 5 shows the evolution of the survival rate of version replacement over time, comparing standards including patents with appropriate. Figure 5 shows that the survival rate of standard versions is higher for standards including patents than comparable matches at any time, but that the hazard rate evolves similarly over time for both groups of standards.

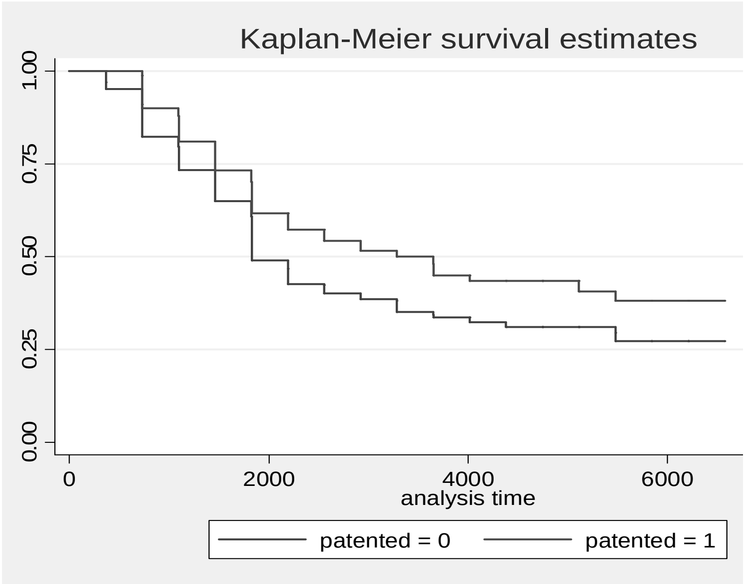

Figure 5: *Kaplan-Meier survival estimates of standard versions, comparing standards including patents with appropriate matches*

As discussed in the methodological section, we have aggregated standard versions to standard observations. We can also run survival analysis on these standard observations, considering that standard survival is the time until a standard is replaced by a different standard. We argued that it is very important to distinguish between a standard upgrade, whereby a version is replaced by an ulterior version of the same standard, and a standard replacement, whereby a standard version is replaced by a different standard.

Figure 6 shows the time estimated for a standard to last until standard replacement. The curve is extremely flat in the tail. Therefore, the risk of standard replacement is highest during the first years after the release of a standard version. Only standards issued by ISO and IEEE face a sustained risk of replacement up to 15 years after release. Comparing standards including essential patents with appropriate matches (but also with all ICT standards in our sample) reveals that standards including patents have a higher survival rate. This difference arises in the first years of the lifetime of a standard, and does not cancel out over time. This difference is particularly striking when comparing standards including patents with the overall sample. Indeed, an important number of standards (around 25%) is withdrawn during the first three years after release. This pattern is not verified for standards including patents, and it is less strong for matched standards. Nevertheless, the hazard rate of standard replacement does not seem to be significantly different between the different samples after this initial period.

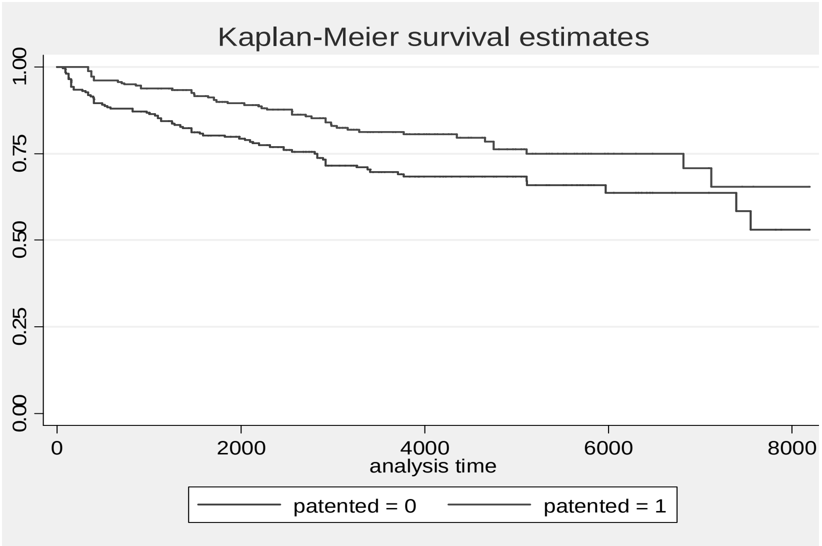

Figure 6: *Kaplan-Meier survival estimates of standards, comparing standards including patents with appropriate matches*

In the following Table 2, we corroborate the graphical analysis using statistical tools. For instance, we check whether differences between the different samples of standards are statistically significant and robust to different specifications. For instance, we wish to make sure that standards including patents do not behave differently only because they are mainly issued by specific SDOs, or because they are concentrated in specific technological sectors. Therefore we test for the statistical significance of the differences between the samples also in a stratified analysis, whereby we compare only standards issued by the same SDO or classified into the same ICS class.

	Standard survival				Version survival			
	Comparison with sample		Comparison with PSM matches		Comparison with sample		Comparison with PSM matches	
	Events observed	Events expected	Events observed	Events expected	Events observed	Events expected	Events observed	Events expected
Patented	Log-rank test for equality of survivor function							
0	1901	1850,33	77	60.30	3544	3536,59	184	160,44
1	78	128,67	50	66,70	294	301,41	115	138,56
Chi2/Pr>chi2	22,19	0,0000	8,84	0,0029	0,21	0,6433	8,09	0,0045

Patented	Wilcoxon (Breslow) test for equality of survivor functions							
0	1901	1850,33	77	60,30	3544	3536,59	184	160,44
1	78	128,67	50	66,70	294	301,41	115	138,56
Chi2/Pr>chi2	37,46	0,0000	11,65	0,0006	8,17	0,0043	10,58	0,0011
Patented	Log-rank test, stratified by SDO							
0	1901	1858,17	77	63,35	3544	3577,15	184	168,41
1	78	120,83	50	63,65	294	260,85	115	130,59
Chi2/Pr>chi2	18,25	0,0000	6,31	0,0120	5,32	0,0211	4,05	0,0443
Patented	Log-rank test, stratified by ICS class							
0	1901	1844,33	77	67,67	3544	3538,18	184	173,77
1	78	1347,67	50	59,33	294	299,82	115	125,23
Chi2/Pr>chi2	36,53	0,0000	5,26	0,0219	0,19	0,6611	2,85	0,0915

Table 2: *Tests of statistical significance of differences between samples*

The statistical tests confirm the graphical analysis. Comparing standards including essential patents with appropriate matches, we notice strongly significant differences in both version and standard survival. Both standards and standard versions including patents are replaced less frequently than matched standards. In a comparison with the overall sample, standards including patents also have a higher survival rate. Standard versions have, depending upon the test specification, a higher, a lower or a statistically non-significantly different survival rate.

Even though the comparison with appropriate control standards reveals statistically significant differences, it is too early to conclude on a causal effect of patent declarations. The main concern is a potential endogeneity problem. Many essential patents are declared with considerable delay after grant of the patent and release of the standard (see Baron and Pohlmann, 2011). It is therefore possible that some standards are therefore found not to include essential patents, because the standards were replaced before the patents were declared. This problem is especially worrisome regarding standard versions, as many essential patents are essential for several versions of the same standard, and are therefore indiscriminately declared to the whole standard regardless of the version.

Nevertheless, this descriptive analysis already provides some insights into the interplay between essential patents and the survival rate and replacement probabilities of standards and standard versions. Until now, we tested the hypothesis that standards including essential patents generally face different hazard rates of upgrade or replacement than other standards. In the following multivariate analysis, we will adopt a slightly different approach. We estimate how a patent declaration impacts the hazard rate of upgrade or replacement over time. We have organized the data into a panel dataset, and information is tracked over time. Most importantly, patents are allowed to have an impact on standard dynamics only after they have been declared. The results are therefore no longer subject to doubts about the direction of causality. Furthermore, we can now not only distinguish between standards including essential patents and the other standards, but also test for the effect of the number of patents declared, and for the number of declaring firms.

Multivariate Panel Analysis

It is the aim of this section to evidence an effect of essential patent declarations on the survival of standard versions. We will therefore rely upon semi-parametric survival analysis, using a Cox model. In this methodology, the likelihood of drawback is estimated year by year, conditional upon the fact that the version has not already been withdrawn. The model infers from the data a baseline hazard rate of renewal. This baseline hazard rate is multiplied by the explanatory variables and controls, and the coefficients are estimated in order to match the observed renewal rate. As described in our methodological section, our data are in panel form, meaning that the explained variables, and for instance patent declarations, are fed into the model over time.

We carry through two types of controls. First, we introduce control variables for technological characteristics of the standard, and for instance for the variables mentioned in the methodological part. We therefore construct a large panel of references among standards and accreditations of standards by different SSOs, and feed in the count of references and accreditations over time. Time-invariant standard version characteristics, number of pages, backward references and prior accreditations are also taken into account.

Second, we wish to make sure that we really adequately control for two crucial factors: standard renewal dynamics are likely to vary from one SSO to the other, and among technological fields. Introducing dummy variables is not likely to adequately control for these differences: control variables in a Cox model are only allowed to have a linear effect on the survival rate. This means that a control variable can control the idiosyncratic effect of a technological field or SSO when the likelihood of standard renewal is higher or lower by a given coefficient *at any time*. Our descriptive analysis has revealed that renewal rates at some SDOs (for instance ISO and JTC1) are very high in the first years, and low in the following years. In order to control for this kind of time-varying effects, we propose stratified survival analysis. In stratified survival analysis, the baseline hazard rate is allowed to vary between the strata, but the effect of the explanatory variables is the same in all strata. We stratify jointly by SDO and ICS class, and introduce linear controls for all the other factors.

The effect of patents can be estimated in various ways. In a first model, we estimate the effect of the first patent declaration, meaning that we give a dummy to every standard observation including at least one essential patent. This variable captures differences that generally arise between standards including essential patents and those that don't. Second, we introduce a second dummy variable, indicating that at least a second firm has declared essential patents on the standard. We introduce this variable in order to capture possible effects resulting from conflicts of interest between different IPR holders. The second model furthermore includes a count variable of patent declarations, simply capturing the linear effect of the number of essential patents. Finally, we also test a third model, in which we allow the effect of including essential patents to vary over the lifetime of a standard. We wish to confirm the descriptive finding that essential patents seem to make a difference primarily in the first years after standard release. All the three models are tested against the data to explain two different events: version replacement and standard replacement. In the first case, the unit of observation is the standard version, observed from version release until version drawback. In the second case, the unit of observation is the standard, observed from the release of the first version until the drawback of the last standard version. The results of the six estimations are presented in Table 3.

Model 1: Duration analysis of version replacement, stratified by ICS and SDO
Model 2: Duration analysis of version replacement, stratified by ICS and SDO
Model 3: Duration analysis of version replacement, stratified by ICS and SDO
Model 4: Duration analysis of standard replacement, stratified by ICS and SDO
Model 5: Duration analysis of standard replacement, stratified by ICS and SDO
Model 6: Duration analysis of standard replacement, stratified by ICS and SDO

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Patented	0.924 (-0.52)	0.859 (-0.85)	1.008 (0.03)	0.701** (-2.12)	0.597** (-2.52)	0.464** (-2.75)
Second firm		1.120 (0.40)			1.506 (1.23)	
Patent declarations		1.005** (2.55)			1.003 (1.07)	

Patented_age			0.983 (-0.32)			1.000** (1.98)
Patent Intensity	0.808 (-1.05)	0.805 (-1.06)	0.806 (-1.06)	1.434* (1.75)	1.428* (1.73)	1.441* (1.78)
Backward references	0.996 (-0.91)	0.996 (-0.92)	0.996 (-0.90)	0.988** (-2.42)	0.987** (-2.49)	0.988** (-2.42)
Number of pages	1.000 (1.20)	1.000 (0.97)	1.000 (1.20)	1.001*** (3.29)	1.001*** (3.14)	1.001*** (3.27)
Number of modifications	1.038 (0.73)	1.007 (0.13)	1.039 (0.74)	0.959 (-0.47)	0.923 (-0.88)	0.950 (-0.58)
Number of version releases	n./a.	n./a.	n./a.	0.878** (-2.51)	0.878** (-2.49)	0.867*** (-2.71)
Forward references	1.000 (0.25)	1.001 (0.34)	1.000 (0.24)	0.987 (-1.44)	0.987 (-1.49)	0.986 (-1.52)
Ulterior accreditations	0.921*** (-4.99)	0.922*** (-4.98)	0.922*** (-4.99)	0.742*** (-14.19)	0.742*** (-14.19)	0.743*** (-14.10)
Year	1.053*** (2.85)	1.053*** (2.78)	1.054*** (2.85)	1.014 (1.53)	1.013 (1.48)	1.014 (1.58)
Standard age	0.999 (-1.18)	0.999 (-1.33)	0.999 (-1.18)	0.998*** (-5.13)	0.998*** (-5.14)	0.998*** (-5.05)
Standard age squared	1*** (3.07)	1*** (3.23)	1*** (3.08)	1 (1.90)	1 (1.94)	1 (1.78)
Version age	.251	1.826	.242	n./a.	n./a.	n./a.
Position controls	YES	YES	YES	n./a.	n./a.	n./a.
Observations	15386	15386	15386	34594	34594	34594
No. of Subjects	2166	2166	2166	3662	3662	3662
No. of Failures	1054	1054	1054	1106	1106	1106
Log Likelihood	-2942.488	-2945.867	-2945.816	-3578.483	-3576.726	-3576.618
LR chi2	306.45	299.69	299.79	463.52	467.04	467.25

* 10% significance, ** 5% significance, *** 1% significance

Table 3: Results of the multivariate panel analysis

On the one hand, the econometric results seem to confirm one of our descriptive findings. Essential patents indeed seem to reduce the likelihood of standard replacement. We have exposed two different theoretical arguments that could explain this finding. In contrast to standard upgrades, standard replacements involve changes that can exclude technological components from a standard. Based upon this argument, we can argue that essential patents on a standard raise the standardizing firms' resistance to radical changes to the standard, at least before the investment into the incorporated technology has been amortized. This argument is in line with the low rate of standard replacement during the fifteen years following release of a standard version including essential patents, and it seems to corroborate suspicions that essential patents increase inertia of technological standards.

Nevertheless, this increased inertia is potentially beneficial for standard users, as it reduces the cost of implementation. If this argument is true, essential patents could provide a signal to standard users that a standard is less likely to be replaced rapidly, and therefore provide important incentives to invest in sunk costs derived from implementation. It is important to notice that the difference between standards including essential patents and the other standards mainly arises in the first years after standard release, and does not increase over time. In coherence with the descriptive findings, we find that this effect decreases over the lifetime of the standard (as indicated through the positive coefficient on the interaction term of the patented dummy and the standard age variable). Furthermore, there is no significant effect of patent declarations on standard survival if these first years are excluded from the analysis[11]. Essential patents do not seem to lock-in standards for a very long time after release.

On the other hand, we do not corroborate our descriptive finding that standard versions including essential patents have a higher survival rate. Taking into account the timing of patent declaration, there is no significant difference between standard versions including essential patents and those that don't. This finding is coherent with our concerns that the previous descriptive finding is vulnerable to endogeneity biases. The longer a standard version is in place, the higher is the likelihood that it will at some point receive declarations of essential patents. Our econometric findings are not subject to this concern, as patents are only allowed to have an effect after they have been declared. Proceeding this way, we find the number of patent declarations to increase the hazard rate of version replacement. While having one patent instead of no essential patent does not make a difference for version replacement, having many patents seems to accelerate the rhythm of version replacement. We can interpret this result in light of our theoretical analysis. Regular standard upgrades are costly for standardizing firms. Firms are more inclined to accelerate the rhythm of standard upgrade and therefore to reduce the life-time of single standard versions, when the standard involves important commercial stakes. A higher number of essential patents could indicate important commercial stakes, providing sufficient incentives for firms to invest in

[11] Results available from the authors upon request

standardization, or they could indicate fierce technological rivalry among firms pushing the standard in order to promote their technologies.

The analysis of the control variables reveals that our model is able to capture key aspects of our analytical framework. Intensive patenting in the field is positively associated with the likelihood of standard replacement. This indicates that standard replacement indeed responds to progress in the field of the art. There is no significant association of patent intensity to version replacement; once again revealing the importance of distinguishing between both types of events. Downstream investment building upon a standard delays the replacement of a standard version. The accreditation of a standard version by a different SSO significantly delays both version and standard replacement. References from ulterior standards only delay standard replacement, and this result is not statistically significant. Variables capturing the size and scope of the standard (such as the number of ICS classes and the number of pages), are significantly and positively associated with a higher likelihood of version replacement.

Conclusion

We have presented an empirical analysis of the effects of essential patents on the duration of standard and standard version activity until replacement. Essential patents reduce the likelihood of standard replacement. A standard including essential patents is therefore less likely to be replaced by a different standard. This effect is consistent with several hypotheses on the effect of patents on standard dynamics. For instance, we have argued that owners of essential patents oppose to changes in the standard that exclude their IPR from the standard.

Nevertheless, we did not find evidence that essential patents induce excessive inertia in standardization. While standard versions including essential patents also have a higher survival rate than comparable standards, econometric analysis suggests that this difference is not due to a causal effect. Indeed, essential patents seem to have a positive effect on the rate of standard upgrades. We have argued that these standard upgrades do not entail replacement of standard components, explaining why essential patents could induce standardizing firms to substitute standard upgrades for standard replacements. Our second finding indicates that essential patents not only induce standardizing firms to substitute version for standard replacements, but also to overall increase the number of replacements. The latter part of the finding can be explained by the cost of standardization: standard changes are costly for standardizing firms, who are unable to internalize all the benefits of the improved standard. Essential patents generate licensing revenue that is dependent upon the value of the standard. They therefore provide incentives for at least some standardizing firms to regularly invest into the standard. Furthermore, regular standard upgrades can be a means of avoiding standard replacement. Indeed, by adding technological components to a standard, owners of essential patents can reduce the competitive pressure from new, alternative technologies.

The descriptive analysis seems not to support concerns of excessive inertia, as the effect of essential patents on standard replacement takes place over the first years after the release of the standard version. Rather than locking in outdated standards, essential patents therefore appear to stabilize standards in an early period, and may even reduce socially inefficient excessive momentum.

In the light of our results, essential patents do not seem to lock in standards for an inefficiently long time, and their effects are potentially beneficial for standard users. Essential patents stabilize standards in the first years after standard release, encourage standard upgrades rather than replacements and accelerate the rhythm of incremental changes. These are attractive features, as they reduce uncertainty for standard implementers regarding future technological changes, without preventing the standards from keeping up with an advancing state of the art.

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