Discussion Paper No. 13-060

The Value of Disclosing IPR to Open Standard Setting Organizations

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Non-technical summary

Open standard-setting organizations (SSOs) have emerged as important coordination and diffusion mechanism for information and communication technologies. Standards define a set of technical specifications which are intended to provide a common interface design among modules in a technological architecture. Open standards are developed in an open, voluntary and consensus-based process and licensed to anybody at reasonable and non-discriminatory terms. Economic and managerial literature has begun to study cooperative standard-setting only recently.

Little is known about the value of IP contributions to open standards for technology providers. On the one hand, the open availability of essential licenses facilitates entry and increases competitive pressure. Standard-setting codifies frontier technological knowledge and provides laggard firms access to technical experts. On the other hand, entry stimulation provides mix-and-match opportunities to customers and installs the user base of the standardization approach which might be served with compatible products by technology providers.

Open SSOs require their members to disclose upfront standard-essential IPR and associated licensing intentions. They are not required to search their patent portfolios for specific patents which might be essential. We employ a market value approach in order to investigate the valuation of financial markets for disclosing IPR to open SSOs. Our sample consists of large established companies which have been publicly-traded in the U.S. from 1986 to 2005. Pre-sample information shall control for unobserved firm heterogeneity. Citations prior to SSO disclosure shall control for the importance of disclosed patents.

We find that disclosure of standard-relevant IP ownership is positively correlated with company valuation if associated patent rights are referred to explicitly. This suggests that product market advantages from standardized technology outweigh the loss of exclusivity from contributed IPR. Prior literature suggests that firms with low R&D intensity benefit additionally from access to SSO expertise. This is not supported by our evidence. Disclosure of standard-relevant IP ownership without referring to a patent is negatively correlated with company valuation for firms with low R&D intensities. Hence, patents appear to signal the quality of technology contributions from firms with low R&D intensity.

Das Wichtigste in Kürze

Normen und Standards sind für die Verbreitung von Informations- und Kommunikationstechnologien entscheidend. Standards definieren einheitliche Schnittstellen, die die Kompatibilität verschiedener technischer Komponenten sicherstellen sollen. Standard-setzende Organisationen entwickeln diese in einem offenen, freiwilligen und konsensbasierten Prozess. Die ökonomische Literatur hat erst kürzlich begonnen, kooperative Standardisierungsprozesse näher zu untersuchen.

Offene Standards erleichtern den Marktzutritt und erhöhen den Wettbewerbsdruck. Sie kodifizieren die Grenze des technologischen Wissens und bieten technologieschwachen Unternehmen Zugang zu diesem. Offene Standards haben deshalb zumeist höhere Nutzerzahlen und ein breiteres Angebot kompatibler Produkte.

Standard-setzende Organisationen verpflichten ihre Teilnehmer dazu, essenzielles intellektuelles Eigentum und die dazugehörigen Lizensierungsabsichten offenzulegen. Die Teilnehmer sind allerdings nicht verpflichtet einzelne essenzielle Patentrechte offenzulegen. Diese Studie untersucht den ökonomischen Wert der Offenlegung essenziellen intellektuellen Eigentums. Dafür verwenden wir Daten großer, börsennotierter US-Unternehmen zwischen 1986 und 2005. Das durchschnittliche Markt-Buchwertverhältnis vor 1986 soll dabei für firmenspezifische Effekte kontrollieren. Die empfangenen Zitationen vor der Offenlegung sollen für die Wichtigkeit der offengelegten Patente kontrollieren.

Die Offenlegung essentiellen intellektuellen Eigentums ist positiv korreliert mit dem Unternehmenswert falls einzelne Patentrechte offengelegt wurden. Die Vorteile eines größeren Absatzmarktes bei offenen Standards scheinen also den Verlust exklusiver Patentrechte aufzuwiegen. Frühere Studien deuten an, dass der Zugang zu technischer Expertise für Firmen mit geringer FuE-Intensität besonders wertvoll sein könnte. Dafür finden wir allerdings keine Evidenz. Die Offenlegung essenziellen intellektuellen Eigentums durch Firmen mit geringer FuE-Intensität ist negativ korreliert mit dem Unternehmenswert falls einzelne Patentrechte nicht offengelegt wurden. Offengelegte Patentrechte scheinen also die Qualität des technischen Beitrags durch FuE-schwache Firmen zu signalisieren.

The Value of Disclosing IPR to open Standard Setting Organizations[1]

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August 2013

Abstract

Open standard-setting organizations (SSOs) have emerged as important coordination and diffusion mechanism for information and communication technologies. Open standards are developed non-discriminatorily and licensed to anybody at reasonable and non-discriminatory terms. Little is known about the value of IP contributions to open standards for technology providers. This paper provides a large-scale empirical assessment thereof. Our findings show that disclosure of standard-relevant IP ownership is valued positively by financial markets only if the disclosure refers explicitly to associated patents. The loss of exclusivity to IPR appears to be outweighed by the expected benefits from open standards. Patents appear to signal the technological quality of IP contributions from firms with low R&D intensities.

JEL classification: O32, O34, L15

Keywords: Open standards, IP disclosures, market value

[1] We thank Birgit Aschhoff, Bruno Cassiman, Dirk Czarnitzki, Georg Licht, Antonio Della Malva, Christian Rammer, Otto Toivanen, Reinhilde Veugelers for valuable comments. We thank also participants of the DRUID society conference 2012 and the Maastricht University PhD Workshop 2012. All remaining errors are our own. Research leading to this paper has been conducted at ZEW and University of Luxembourg (see www.zew.eu/fsc or www.zew.eu/khu for further information).

“At some level it is surprising that voluntary standard-setting works at all.”
(Schmalensee, 2009)

1. Introduction

Standards define a set of technical specifications which are intended to provide a common interface design among modules in a technological architecture (Baldwin and Clark, 1997). Open standard setting has become an increasingly important coordination mechanism for technology providers and users (Besen and Farrell, 1994). This is due to at least two developments. At first, there is an increased demand for interoperability of products and technologies. Telecommunications, computers and electronics industries have made extensive use of new information and communication technologies (ICTs) and share increasingly similar technology bases (Rosenberg, 1976; Bresnahan and Trajtenberg, 1995). Secondly, ownership of intellectual property has become more fragmented which raises the costs to secure intellectual property rights (IPR) for technology usage (Shapiro, 2001; Wen et al., 2012).

Standards may emerge as a result of market competition or from formal and informal coordination. This paper considers open standard setting organizations (SSOs). This particular type of standard setting has become increasingly important during the last decade (Simcoe, 2007; Funk and Methe, 2001; Cargill, 2002). SSOs are non-profit organizations which develop standards in an open, voluntary and consensus-based process. Any interested party may participate and contribute to the standard development process. Licenses for essential IPR of SSO standards shall be provided at reasonable and non-discriminatory terms to anybody. These organizations provide a neutral forum for technology owners to agree on standardized interface designs based on technical merit. The IP bylaws of open SSOs ensures the neutrality of the forum and limit antitrust concerns (Lerner and Tirole, 2006; Chiao et al. 2007, Gilbert, 2009).

Standards have been shown to contribute to national growth and to facilitate international trade flows (Swann et al., 1996; Blind and Jungmittag, 2008). Stakeholders value the expected product variety and global outsourcing opportunities (Blind et al., 2010). Consumers benefit from ongoing competition among providers of standardized products (Koski and Kretschmer, 2004). Technology users benefit from the open availability of standard-essential licenses (Gawer and Henderson, 2007; Fahri et al., 2005; Huang et al., 2013). Hence, standards facilitate entry of compatible products and increases competitive pressure (Wen et al, 2013). On the one hand, they codify technical knowledge which facilitates the diffusion and adoption of innovation (Acemoglu et al., 2010; Bessen, 2012). On the other hand, if the technology offers various applications for differentiated purposes, entry stimulation provides users further mix-and-match opportunities and installs the user base of the standardization approach (Gambardella and Giarrantana, 2012). Incentives to participate and contribute to open standards are, thus, ambiguous for technology providers (Lerner and Tirole, 2004; Strojwas et al., 2007; Feldman et al., 2009; Layne Farrar and Lerner, 2011).

The increasing evidence for user and consumer benefits from standards notwithstanding, evidence for the returns of technology providers to open standard setting activities is missing. On the one hand, technology sponsors can expect high returns from their participation in standard setting activities. Owning a patent-protected technology that is essential for a standard might for instance secure a stream of future licensing revenues. It may further increase the costs of rivals which are not participating in a standard (Salop and Scheffman, 1983). On the other hand, participation in SSOs involves significant financial costs (Chiao et al., 2007; Rysman and Simcoe, 2008).[2] Technology contributions to standard development processes may involve knowledge spillovers which threatens the competitive advantage from new technologies (Acemoglu et al., 2010; Bessen, 2012). This diminishes participation incentives of frontier technology firms since technology disclosures involve technical information beyond the details publicly available in patent documents (Blind and Thumm, 2004). Furthermore, technology sponsors have to waive their exclusivity if their patent-protected technology shall be included in open standards. They have to oblige themselves upfront to provide anybody licenses for standard-essential IPR on reasonable and non-discriminatory terms. This limits their attainable licensing revenues and diminishes incentives to participate (Chiao et al., 2007). The advantages and disadvantages of standard setting activities render the question on its returns for technology sponsors to SSOs an empirical one.

In this paper, we provide for the first time large-scale empirical evidence on the returns to sponsoring IP for open standards.[3] We focus on standard-relevant IP disclosures rather than on technologies that are already part of a standard. The reason is that the firm faces uncertainty about whether their contribution will become part of a standard or not at the time of disclosure. Contributing firms likely unveil additional technical details during the standard development process. Hence, the disclosure of standard-relevant IP and associated open

[2] Chiao et al. (2007) report that IBM spent 8.5% of the R&D budget for standard development in 2005.

[3] A study by Rysman and Simcoe (2008) that focuses on the patent level and on patent citations as a value correlate comes closest to ours. Rysman and Simcoe (2008) find that patents receive more citations once they have been disclosed as standard-relevant.

licensing intentions likely involves revealing technological knowledge along with uncertain prospects on the success of standardization.

We employ a market value approach in order to investigate the valuation of financial markets for disclosing and contributing IP to open SSOs (Griliches, 1981). Pre-sample information shall control for unobserved heterogeneity (Blundell et al., 1995; Aghion et al., 2005). Since there is considerable heterogeneity between SSOs ranging from de jure public bodies to private alliances and consortia, we focus on a specific type of SSO (Leiponen, 2008; Chiao et al., 2007). First, we only consider open SSOs. Open SSOs are open in the sense that anybody may contribute to and make use of the associated standards, but they are also partially closed by requiring reasonable and non-discriminatory licenses (Dahlander and Gann, 2010). Second, we only focus on compatibility standards. Such standards define technical specifications of interfaces in a technical system. Our sample consists of large established companies which have been publicly-traded in the U.S. from 1986 to 2005. All the firms are active in industries in which at least one firm disclosed once standard-relevant IP.

Our results from a market value approach show that disclosure of standard-relevant IP ownership is positively correlated with company valuation if associated patent rights are referred to explicitly. This suggests that product market advantages from standardized technology outweigh the loss of exclusivity from contributed IPR. The results show furthermore that technology providers with low R&D intensities appear to contribute important patents to standardization. Prior literature (Waguespack and Fleming, 2009) suggests that firms with a relatively weak technology portfolio benefit from access to SSO expertise. Our results show that IP disclosures of firms with low R&D intensities appear more valuable than those of R&D-intensive technology sponsors. However, this effect vanishes if the pre-disclosure importance of disclosed patents – as measured by citations that patents receive prior to SSO disclosure - is controlled for. Pre-disclosure citations account for the value of patents prior to SSO disclosure. Our finding does not support the conjecture that financial markets value the access to standard-setting technical experts by technologically lagging firms. It rather suggests that patents disclosed to SSOs by firms with a weak technology portfolio are of high technology value (Rysman and Simcoe, 2008). Disclosure of standard-relevant IP ownership without referring to a patent is negatively correlated with company valuation for firms with low R&D intensities. Hence, patents appear to signal the quality of technology contributions from firms with low R&D intensity.

The next section develops our hypothesis regarding the value of waiving exclusivity in standard setting. The first subsection discusses the various processes by which standards emerge. The second subsection discusses SSO's capacity to act as forum for non-discriminatory coordination, entry stimulation and diffusion of technical knowledge. Section 3 lines out the estimation approach (Griliches, 1981). Section 4 describes our dataset and the standard setting organizations in our sample. Section 5 presents econometric evidence and section 6 concludes.

2. Literature review and hypothesis development

2.1. Standard setting processes

Standards provide technical specifications for a common design of products or processes (Lemley, 2002). Compatibility standards specify interface designs which govern the interaction of components in a technical system. The formulation of a common technical design codifies frontier technical knowledge which stimulates the diffusion and adoption of technical knowledge (Bessen, 2012).

Standard setting processes are quite heterogeneous. The economic literature has focused predominantly on de facto standards. De facto standards result from competition among firms that offer competing incompatible technologies. Network externalities induce consumers to gravitate to one standardization approach (Farrell and Saloner, 1985). On the other extreme, de jure standards may be selected by public bodies which impose them by authority on industry participants (David and Greenstein, 1990). Besides administrative and pure market coordination, standards may result from a hybrid system of competition and voluntary coordination. Standards from cooperative coordination are likely to be of higher quality than those resulting from market selection; at the cost of a delayed introduction, though (Farrell and Saloner, 1988). Leiponen (2008) provides a typology of the various organizational forms of such forums. These may be private alliances, industry consortia or open standard setting organizations. We focus subsequently on the latter type of organization.[4]

SSOs develop standards for designated technological fields in open, voluntary and consensus-based processes.[5] This ensures pro-competitiveness of open that standard setting processes (Lemley, 2007). Inter-firm coordination shall be prevented while competitors remain excluded. Users, consumer and government representation in standard development processes

[4] If not expressed otherwise, the notion standard-setting organization (SSO) refers to open, voluntary and consensus-based organizations.

[5] A detailed description of the standard development procedure can be found in Appendix A.

shall prevent a too narrow focus on the interest of technology providers. In addition to open development processes, the use of standards shall be open. Standards shall be available to anybody without discrimination.

However, participation and IP contribution of technology providers is voluntary. Consensus-based decision making shall guarantee that standards are chosen on technical merit and that diverging interests are respected and incorporated. Open standards provide licenses to anybody but not necessarily royalty-free (Dahlander and Gann, 2010). In general, SSOs discourage intellectual property rights. Technology is standardized preferably if it is not patent protected or if non-discriminatory, royalty free licenses are available. If "technical reasons justify this approach" (ANSI 2011)[6], patent protected technology may exceptionally be standardized if and only if licenses will be granted on reasonable and non-discriminatory (RAND) terms. Important royalty demanding technology may be standardized if no adequate royalty free alternative is available. Prerequisite is that patent owners oblige themselves ex ante (i. e. before standards are approved) to demand reasonable and non-discriminatory licensing terms (Swanson and Baumol, 2005).

The IP bylaws of SSOs reflect the tension between formulating high-quality designs and guaranteeing a wide availability of standards (Farrell et al., 2007). As SSOs lack formal enforcement power, exclusive rights of technology providers have to be respected. IP bylaws provide a legal framework for the treatment of members' IPR (Lemley, 2002; 2007). SSOs require their members to disclose any known IPR that might be "essential" to a standard before it is approved. Patents are deemed "essential" if it is not possible for goods or services to comply with the technical standard specification without infringing that patent (ETSI, 2008).[7]

Disclosure requirements shall prevent owners of essential patents to exploit opportunistically the market power, which is conferred by standardization.[8] Once adopted, standards exhibit a considerable degree of lock-in. Industry-wide specific investments in standard-compliant machinery and equipment have been sunk, development of cumulative, next-generation standards may be underway etc. (Shapiro, 2001). Lurking owners of unanticipated essential

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[6] „Guidelines for Implementation of the ANSI Patent Policy" (2011), available at: http://publicaa.ansi.org/sites/apdl/Documents/Standards%20Activities/American%20National%20Standards/Procedures,%20Guides,%20and%20Forms/Guidelines%20for%20Implementation%20of%20ANSI%20Patent%20Policy%202011.pdf

[7] The ETSI Intellectual property rights policy is available at http://www.etsi.org/WebSite/document/Legal/ETSI_IPR-Policy.pdf.

[8] For a discussion of recent legal disputes regarding hold-up within standard-setting, see e.g. Shapiro (2001), Farrell et al. (2007) and Geradin and Rato (2006).

IPR might expropriate substantial rents simply because standard adopters would incur high switching costs if licenses are not secured.

The disclosure, licensing and negotiation rules of IP bylaws reflect this hold-up problem. SSOs oblige their members to disclose any known IPR which might be essential for standards. Furthermore, members are obliged to disclose their licensing intentions for essential IPR. Their ex ante commitment to reasonable and non-discriminatory licenses limits the hold-up power of essential IP owners and is prerequisite for the patent-protected technology to become standardized. Agreeing on RAND licensing terms does not oblige to specific licensing terms. It does, however, oblige to licensing negotiation that are conducted in good faith without deceiving SSO participants into ex-post hold-up. Royalty rates should be reasonable and non-discriminatory taken into account the technical alternatives and cumulative royalty rates for standards (Swanson and Baumol, 2005; Gilbert, 2009).

Although IP bylaws impose obligations which are partially implicit, they do a fairly well job in preventing hold-up (Lemley, 2002; Geradin and Rato, 2006). Providers of essential technology commit themselves to negotiate RAND licensing terms in good faith after the standard has been defined (Merges, 1996). Hence, open standards can be regarded as certification that technology users will not be squeezed ex post (Farrell and Gallini, 1988; Fahri et al., 2005; Huang et al., 2013).

2.2. The value of contributing IPR to open standards

The voluntary contribution of IPR to open standards reveals that technology providers expect the lost benefits from exclusivity to be offset by the benefits from open standards. Licensing revenues from open standards are unlikely the primary motivation for IP contributions to open standards (Garud and Kumaraswamy, 1993). It does not seem accidental that open SSOs proliferate in those industries in which complex technologies offer a multitude of differentiated applications and in which demand for interoperability is high (Lemley, 2002; Simcoe, 2007). If interfaces are standardized, components from different suppliers and products from different market segments may be combined to form a larger technical system. The limited risk of open standards to be held up improves the attractiveness for producers to offer compatible products (Gawer and Henderson, 2007; Fahri et al. 2005; Huang et al., 2013). In turn, the available variety of complementary and compatible products improves the attractiveness of the standardization approach for customers (Katz and Shapiro, 1985). Expanding user bases stimulates the attractiveness of one standardization approach even further; for users and as well as for complementary product suppliers. A positive feedback is generated which reinforces and installs the increasing market shares. Markets tend to tip to one dominant standard in such industries (Katz and Shapiro 1986, 1994; Shapiro and Varian, 1999). A large user base early on is, thus, crucial for standards to become entrenched by increasing returns to adoption.

Network externalities provide powerful incentives for industry participants to coalesce around a single dominant standard (Schilling, 1998). Widespread adoption is more likely for open standardization approaches than for closed proprietary ones (Simcoe, 2007). Giving momentum to technology adoption and initiating a bandwagon of complementary product entry should be a major motivation for the contribution of IP to open standards. On the other hand, open and cooperative standards are subject to intensified competition which renders it harder for technology providers to capture value and sustain competitive advantages. This tension between cooperation and competition is inherent in standard setting processes. Although the consensus-driven approach to standardization emphasizes cooperation, participants compete fiercely to align standards with private benefits (Suarez, 2004). However, cooperation and open licensing is likely if the technology offers various applications to differentiated markets and if no single technology provider is able to block standardization due to a missing substitute technology (Barnett, 1990; Layne-Farrar et al., 2010; Layne-Farrar and Lerner, 2011; Gambardella and Giarratana 2012).[9] In summary, we expect that financial markets value IP sponsoring to open standards positively on average. IP contributions to open standard setting activities might be an indication for future profit of IP sponsors if open standards succeed to proliferate.

Technology providers are usually not obliged by SSOs to indicate specific patent rights in their disclosure statement on essential IPR. General statements on the possession of essential IPR and the associated licensing intentions suffice to fulfill their obligations from IP bylaws. The reference to specific patents clarifies, however, technology ownership and elucidates the value of disclosed IP. It facilitates an assessment of the chance that the patent-protected technology will be standardized.

Following the resource-based theory, Hsu and Ziedonis (2013) provide supporting evidence for patents to provide a dual advantage (Penrose, 1959; Wernerfelt, 1984). They provide a quality signal for potential investors in addition to their role as legal safeguard for the

[9]Coordination is especially difficult if technology providers are heterogeneous (Simcoe, 2012). Temptations to split off from coordinated standards are high for specialized technology suppliers. As they lack revenues from downstream product markets, their participation has to be rewarded by licensing premiums (Schmalensee, 2009; Gilbert, 2009). In contrast, vertically-integrated incumbents adopt standards themselves in downstream markets. Licensing revenues play only a minor role for them. Coordination among vertically-integrated firms should be easier as profits are made largely downstream.

commercial use of standardized technology (O'Mahony, 2003). The quality of IP contributions and the likelihood that the sponsored technology will actually become part of a standard are difficult to judge for financial markets. Investors and other market participants typically face an informational disadvantage as compared to firm insiders (Hall and Lerner, 2010). IP disclosures which refer explicitly to the associated patent rights might signal financial markets the quality of contributions. These contributions might provide additional value as quality signal that improves the terms of trade in financial markets for the contributing firm (Stuart et al., 1999). Hence, disclosure of relevant IP ownership, which explicates associated patent rights, should achieve higher valuations from financial markets than generally held IP statements.

We summarize the preceding discussion regarding the benefits from contributing IPR to open ICT standards and regarding the different statements of standard-relevant IP ownership in subsequent hypotheses:

H1a: Disclosure of standard-relevant IP ownership is positively valued by financial markets

H1b: Disclosure of standard-relevant IP ownership is more valuable if the associated patent rights are revealed.

During phases of turbulent technology evolution, the quality of technologies is particularly difficult to judge for financial markets (Stuart et al., 1999). SSO adjudicate the process of technology evolution by providing technology sponsors a forum for coordination (Rosenkopf and Tushman, 1998). Consortia and alliances are formed among technology providers in order to promote their technical approaches for standardization (Leiponen, 2008). In these situations of uncertainty, the endorsement by standard developing technical experts signals financial markets the quality of contributions to standardization (Corbett et al., 2005; Simcoe and Waguespack, 2011). The strategic and economic importance of IP contributions to open standards is illustrated by increasing citation rates of disclosed patents (Rysman and Simcoe, 2008). It is also reflected by the distributional conflicts and the associated slowdown in open standard setting processes (Simcoe, 2012). Hence, the open, consensus- and merit-based development of standards certifies the quality of standardized technology contributions (Lerner and Tirole, 2006).

Participation in SSOs permits furthermore to establish and cultivate relationships with peers in the technology domain. The endorsement of high status technical experts and the participation in alliances with established technology providers increases the visibility and reputation of contributing firms (Lerner and Tirole, 2002). The selection of technologies based on technical merit provides opportunities for exchange, feedback and learning (King et al., 2005). SSO participation facilitates monitoring and staying abreast of technological evolution (Waguespack and Fleming, 2009).

Hence, firms with low R&D intensities, which lack a large technology portfolio that allows them to make favorable deals in bargaining negotiations, should benefit from SSO participation additionally due to accessing important external knowledge (Acemoglu et al., 2010; Bessen, 2012). The endorsement of technology contributions by technical experts should be particular important for those firms for which R&D activities indicate limited technological quality. IP disclosures to SSOs should, thus, be particularly valuable for firms with low R&D intensities. This is summarized in the following hypothesis:

H2: Disclosure of standard-relevant IP ownership is more valuable for firms with low R&D intensity.

3. Estimation Approach

Publicly traded companies can be regarded as bundles of tangible and intangible assets whose value is determined by financial markets. As market prices for intangible assets are usually not observable, hedonic pricing models are used to assess the contributions of various assets to firm value (Griliches, 1981). The market valuation of companies is a forward looking measure for financial market's expectations on the returns from investments in different assets. If financial markets work efficiently, it can be assumed that financial markets value various assets simultaneously according to their discounted value of expected cash flows. A number of recent empirical studies use the market value approach to assess the contributions of tangible and intangible assets to firm value (Hall et al., 2005; Czarnitzki et al., 2011). We follow Griliches (1981) by assuming a linear market value function that is additively separable in assets. According to (1),

$$V_{it}\left(A_{it}, K_{it}\right) = q_{it}\left(A_{it} + \gamma K_{it}\right)^{\sigma_t}$$
$$\text{or} \quad \log V_{it} = \log q_{jt} + \sigma_t \log A_{it} + \sigma_t \log\left(1 + \gamma \frac{K_{it}}{A_{it}}\right) \qquad (1)$$

the value V_{it} of company i in year t is given by the sum of physical assets A_{it} and knowledge assets K_{it}. The parameter γ_{it} represents the marginal value contribution of an one-unit increase in the ratio of knowledge capital to physical assets. The current valuation coefficient q_{jt} captures factors that affect firm value multiplicatively, like time- and industry-specific effects. σ_t indicates the returns to scale of factor inputs. Following the empirical literature (Hall, 2000; Czarnitzki et al., 2011), we assume constant returns to scale, i.e. σ_t=1.[10] Equation (1) can then be rewritten as

$$\log Q_{it} = \log \frac{V_{it}}{A_{it}} = \log q_{jt} + \log\left(1 + \gamma \frac{K_{it}}{A_{it}}\right) \tag{2}$$

The left hand side of the equation (2) is the log of Tobin's Q, defined as the ratio of market value to replacement cost of physical assets. γ represents the shadow value of investors for the ratio of knowledge capital to physical assets. We use different variables to measure firm's knowledge assets K. First, we use the stock of firm's R&D expenses (Hall, 1993). As R&D expenses measure the input into highly uncertain activities, we use additionally the stock of patent applications as a measure for successfully finished R&D activities (e.g. Blundell et al., 1999). Since previous literature has shown that the distribution of patent value is highly skewed (Pakes, 1986; Schankerman and Pakes, 1986; Harhoff et al., 1999; Deng, 2007; Gambardella et al., 2008), we further add patent citations as a patent quality indicator to the specification (Hall et al., 2005). Forward patent citations have been shown to correlate positively with patents' social as well as with its private value (Trajtenberg, 1990; Harhoff et al., 1999; Hall et al., 2005). They further reflect the economic and technological importance of patents as perceived by inventors and knowledgeable peers in the technology domain (Albert et al., 1991; Jaffe et al., 2000).

Besides these well-established measures for firm's knowledge stocks, we further include the stock of firm i's disclosures of standard-relevant IP ownership. Members are required to disclose known patent rights which might be relevant for discussed standards.

$$\log Q_{it} = \log q_{it} + \log\left(1 + \gamma_1 \frac{R\&D_{it}}{A_{it}} + \gamma_2 \frac{PAT_{it}}{R\&D_{it}} + \gamma_3 \frac{CIT_{it}}{PAT_{it}} + \gamma_4 \frac{Disclosure_{it}}{PAT_{it}}\right) \tag{3}$$

Proxies for firm's knowledge stock enter the estimation equation in a cascading specification. Each variable is normalized by the preceding one. $Disclosure_{it}$ enters othogonalized by firm's patent stock. The coefficients in this cascading specification have to be interpreted as a premium or a discount on the former variable. Regarding our variable of main interest, the stock of disclosures, the estimated coefficient γ_4 is expected to be positive, showing a valuation premium beyond firm's patent stock and conditional on the valuation premium of

[10]We find a significant coefficient of approximately one for regressions of $\log A_{it}$ on $\log V_{it}$ in the cross-section. The assumption of constant returns to scale seems therefore reasonable.

patent citations. According to hypothesis 1b, revealing associated patent rights in disclosures of standard-relevant IP ownership might signal financial markets the quality of technological contributions. We will investigate this hypothesis by separating the disclosure stocks between those indicating associate patent rights and the remaining general ones. These distinct stocks will enter equation (3) separately.

4. Data

4.1. Sample

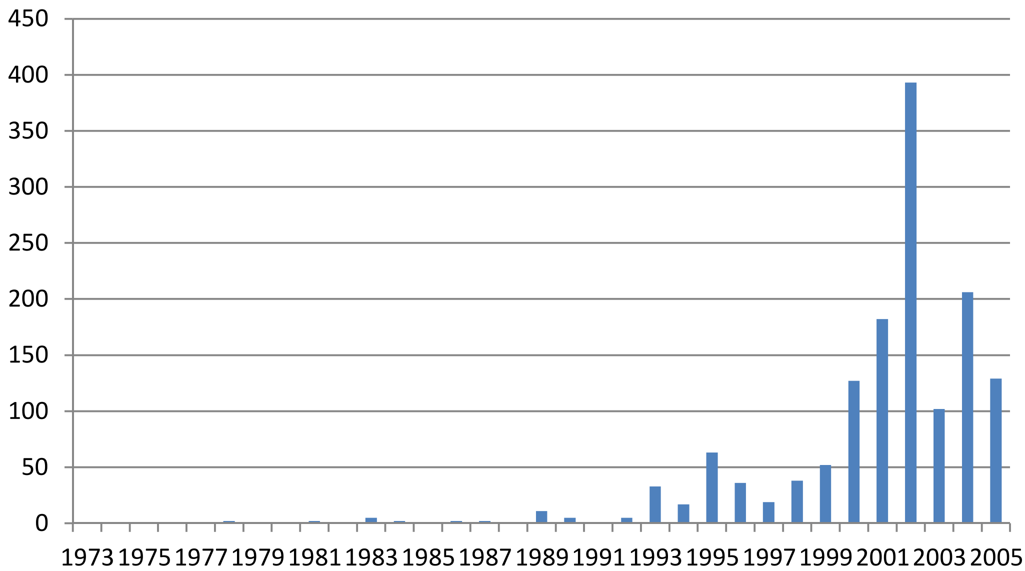
Our sample consists of yearly firm-level information on 609 publicly traded companies during 1976 and 2005. These companies are traded on US capital markets and consist in large parts of large incumbent firms. They are active in industries in which at least one company disclosed standard-relevant IP to the considered SSOs. These are mechanical and electrical engineering, electronics, instruments, transport equipment, communications as well as holding companies in respective industries. Data on market value, tangible assets and R&D expenditures of the companies have been retrieved from the Compustat database. This results in an unbalanced panel of 7,095 observations. Information on US patent applications has been retrieved from the NBER patent and citations dataset (Hall et al., 2001). The match to Compustat firms is provided by Bessen (2009).

Information on technology disclosures to eight SSOs has been gathered. These organizations are the American National Standards Institute (ANSI), the Alliance for Telecommunications Industry Solutions (ATIS), the European Telecommunications Standards Institute (ETSI), the Institute of Electrical and Electronics Engineers (IEEE), the Internet Engineering Task Force (IETF), the International Organization for Standardization (ISO) and the Telecommunications Industry Association (TIA). All these organizations have installed a formalized IP policy, require disclosure of essential IP and allow royalties to be charged for essential IP in exceptional cases. Although these non-profit organizations differ in degree of openness and have various definitions of consensus, heterogeneity among them can be characterized as "accidental" (Lemley, 2002). In the 1990s and 2000s, their activities have been dominated by the digital transition of telecommunication networks and the convergence between information and telecommunication technologies.[11]

[11]Appendix 1 provides an overview of major standards developed by these eight organizations.

SSOs require their members to disclose eventually standard-relevant IPR. This information is published on SSO websites. Disclosures of relevant IP at ANSI, ATIS, IEEE, ITU and TIA have been retrieved from Rysman's and Simcoe's dataset (2008).[12] IP disclosures at ETSI, ISO and IETF have been retrieved from their websites. Disclosures at ESTI refer predominately to digital telecommunications (GSM, UMTS). Unfortunately, information on the standard for which disclosed IP might be essential is only available for ETSI and ISO. Disclosures at TIA should refer predominately to the competing CDMA approach. Sample firms' disclosures to ATIS occur from the midst of the 1990s until the beginning of the 2000s. They should refer to US standardization efforts for 3G. ISO standards refer overwhelmingly to different MPEG generations. IEEE standards refer presumably in its majority to WiFi technology. In view of ANSI's interface function to international standard bodies, disclosures to ANSI should reflect telecom standards as well as standards for information technologies. ITU standards may, in parts, refer to the discussed US and European telecommunication standards. However, they reflect surely technology contributions to standards in other world regions, too.

Figure 1 Evolution of sample disclosures



We have found 1446 disclosures events for sample firms. Table 1 shows that most of them refer to disclosures of IP ownership which are relevant for ETSI standards. Some disclosure statements indicate that the IP owner does not agree on licensing at reasonable and non-

[12]Available at http://www.ssopatents.org.

discriminatory terms. This is the case for eleven disclosures by our sample firm. These observations are not included in disclosure stocks since these technologies are essentially precluded from incorporation in open and consensus-based standards. The remaining events disclose reasonable and non-discriminatory licensing intentions if the associated IP is essential to standards. RAND licensing terms may entail royalties or not. Figure 1 depicts the evolution of these disclosure events. Increasing disclosure numbers reflect the general trend of surging disclosure rates (Simcoe, 2007). Peaking disclosure activities in 1995 reflect intense standardization activities with respect to US CDMA technology. High rates in 1993 and escalating disclosures at the beginning of the 2000s reflect standardization of the second and third generation of digital telecommunication at ETSI.

Table 1 about here

Disclosures of standard-relevant IP ownership differ in scope. Some disclosures declare broadly that the disclosing firm might possess relevant IP without specifying single patent rights. Other disclosures reveal specific patent rights which might be standard-relevant. In order to take into account their varying scope, IP disclosures have been weighted according to the number of disclosed patent rights. Roughly half of the disclosure events in our sample reveal specific patent rights. Disclosure events indicating specific patents occur overwhelmingly at ETSI. General disclosures are relatively seldom at ETSI. Generally-held IP disclosures are more frequent than patent-indicating disclosures at the remaining SSOs.

4.2. Variables

Our empirical analysis is based on equation (3)(3). The dependent variable Tobin's Q is defined as the ratio of firm's market value to the replacement (book) value of its physical assets. Market value is the sum of market capitalization (share price times the number of outstanding shares at the end of a year), preferred stock, minority interests, and total debt minus cash. Book value is the sum of net property, plant and equipment, current assets, long term receivables, investments in unconsolidated subsidiaries and other investments. All explanatory variables of equation (3) are based on stock variables. Except for tangible assets for which financial stock information is available, we follow Griliches and Mairesse (1981) by calculating the stocks for the remaining explanatory variables as perpetual inventory.

We use the following formula for the R&D stock of firm *i* in year *t*

$$R\&D\ stock_{it} = (1-\delta)\,R\&D\ stock_{it-1} + R\&D_{it} \qquad (4)$$

in which the annual R&D expenditures enter GDP-deflated and a constant depreciation rate (δ) of 15 percent is assumed.

Patent, citation and IP disclosure stocks are constructed accordingly. IP disclosure stocks are further distinguished between disclosures of standard-relevant IP ownership, which refer explicitly to associated patent rights, and generally-held disclosures which do not indicate the associated patent rights. The stock of citations which disclosed patents receive prior to their first disclosure has been calculated in order to proxy for the importance of contributed technology.

A specialty arises for the calculation of R&D stocks since companies may have conducted R&D before entering our sample. Hence, we calculate a starting equilibrium R&D stock as

$$R\&D\ stock_{i0} = \frac{R\&D_{i0}}{\delta + g}.$$

This starting value assumes that R&D expenditures prior to the sample have been growing at a constant rate g. Following Hall and Oriani (2006) and Hall et al. (2006) an annual growth rate of 8 percent has been assumed.

4.3. Descriptive statistics

Table 2 shows the descriptive statistics of the sample and firms that contribute IP to SSOs. The descriptive statistics illustrates that our sample includes overwhelmingly medium-sized and large companies. All firms in our sample have positive R&D and patent stocks. Average Tobin's Q is well above one. Market valuation of sample firms is larger on average than the replacement value of tangible assets. R&D activities, patent portfolio size, citations as well as standard-setting activities are highly skewed in absolute and relative terms. Only five percent of observations have disclosed relevant IP to SSOs. The second half of Table 2 provides descriptive statistics for these 334 observations. The distribution of industry sectors appears similar between the total sample and standard setting firms. Technology providers to SSOs are mostly large and very large companies. On average, they have larger stocks of tangibles assets, more R&D activities and larger patent portfolios than the control group. The median value for Tobin's Q is slightly higher than for the average control firm. Disclosure stocks reach their maximum at 148 disclosures of RAND licensing intentions. RAND licenses may involve royalties or may be royalty-free. Eight observations have been excluded that show more than ten disclosures per patent.

Companies which contribute IP to SSOs receive similar citations per patent than the control group. Prior literatures has shown that IP contributions for standardization are among the more valuable technologies (Rysman and Simcoe, 2008). This is reflected in the number of received citations prior to their first disclosure to any SSO. Firms receive, on average, 12 citations per patent in their portfolio. In contrast, they receive, on average, 19 citations per IP disclosure.

5. Market Value Estimations

Table 3 reports the coefficients from nonlinear least squares estimations for equation (3). The first panel in Table 3 (model (1)-(4)) presents estimations including firm's total disclosure stock. The second panel (model (5)-(8)) distinguishes between disclosures of IP ownership which refer explicitly to associated patents or not. The first model in each panel (model (1) and model (5)) shows cross-sectional results. The second model in both panels (model (2) and model (6)) controls for unobserved firm-specific effects. We follow Blundell et al. (1995) and Aghion et al. (2005) in using pre-sample information as control for unobserved firm-specific effects. Average Tobin's Q in the pre-sample period is included as additional regressor in model (2) and (6).

The third model in both panels (model (3) and model (7)) controls for pre-disclosure citations. The stock of received citations until the first disclosure of the patent as standard-relevant shall control for the selection of more important IP to be disclosed as standard-relevant (Rysman and Simcoe, 2008). In order to avoid double-counting, citation stocks are corrected by pre-disclosure citations. The last models in each panel (model (4) and model (8)) show the results for a specification that incudes pre-disclosure citations and pre-sample means. All specifications include year and industry dummies.

Table 3 about here

Table 3 shows that our results are robust with regards to the different specifications. The proxies for firm's knowledge stock – R&D, patent and citation stocks – are positively and significantly correlated with Tobin's Q (Hall et al., 2005; 2006). As regards to the variable of main interest, disclosure of standard-relevant IP ownership, model (1) in Table 3 shows a positive sign for overall IP disclosures which is statistically significant at the 5% level. This effect vanishes if the pre-sample mean of Tobin's Q or the normalized pre-disclosure citation stock is added (models (2)-(4)). This finding does not support hypothesis 1a.

Models (5)-(8) present estimation results if disclosure of standard-relevant IP ownership is separated in disclosures indicating specific patent rights and generally-held disclosures. The positive coefficient for generally-held IP disclosures is weakly significant only if firm-specific effects or the importance of disclosed patents is not controlled. This does not indicate that financial markets value disclosures of standard-relevant IP ownership without revealing the associated patent rights. The coefficients for IP disclosures, which specify associated patents, are positive and statistically significant at the 5% level in all models (5)-(8). The disclosure of standard-relevant patents is still positively correlated with firm valuation if firm-specific effects or the importance of disclosed patents are controlled. The benefits from contributing IPR to open ICT standards appear to outweigh the costs of lost exclusivity. Hypothesis 1b, hence, receives support.

In order to get an indication of the economic magnitude of the estimated effects, Table 4 reports semi-elasticities of Tobin's Q with regard to its explanatory variables. The semi-elasticities are calculated using the median values of explanatory variables.[13] Estimated semi-elasticities for IP disclosures indicate that an increase from 0 to 1 of the disclosure-patent ratio would increase the log of Tobin's Q by a range of 7.4 to 8.9 points. The standard deviation of the disclosure-patent ratio (=0.23%) provides a more realistic order of magnitude. A one standard deviation change yields a change in market value between 1.7 and 2.1 percent. Hence, the benefits from contributing IPR to open ICT standards appear to outweigh the cost of lost exclusivity.

Table 4 about here

Table 5 and Table 6 re-estimate models (1)-(8) for split samples of lowly or highly R&D-intensive firms. Median R&D intensity of industry sectors is chosen to divide the sample into firms of low and high R&D intensity. Overall disclosures of relevant IP ownership do not show significant effects for firms with low R&D intensity (columns (1)-(4) of Table 5). For firms with high R&D intensity, the coefficient of overall IP disclosures is positive and

[13]In comparison to Hall et al.s' (2005) results for the market value of R&D and patenting, we find lower values of R&D semi-elasticities and larger values of patent semi-elasticities. In contrast to Hall's sample, which refers to manufacturing sectors from 1979 to 1988, our sample focuses on machinery and electronics-related sectors from 1986-2002. Hall (1993) reports that in those particular industries, the value of R&D declined in the 1980s. As knowledge assets have been found to be of lower values in computing and electrical sectors (Czarnitzki et al. 2006), it seems not unreasonable that the value of R&D assets has further declined in our sample period.

significant only if firm-specific effects or the importance of disclosed patents are not controlled.

Table 5 and Table 6 about here

Estimated coefficients for IP disclosures, which refer explicitly to patents, are positive and significant for firms of high and low R&D intensity (models (5)-(8) of Table 5 and Table 6). Table 4 reports the respective semi-elasticities for split samples. For R&D intensive firms, estimated semi-elasticities indicate that a change of one standard deviation in the IP disclosure-patent stock ratio yields 2.0% to 4.3% higher market values. For firms of low R&D intensity, the corresponding change in market value ranges from 2.6% and 3.3%.

The marginal disclosure effect for firms with low R&D intensity is significantly higher than the marginal disclosure effect for R&D-intensive firms only in model (5) which does not control for pre-disclosure citations or firm-specific effects. Tests for R&D intensive firms to have higher semi-elasticity values cannot be rejected for models (6)-(8). The higher valuation of patent disclosures for firms with low R&D intensities in model (5) appears to reflect the importance of their specified IPR contribution to open standards. This suggests that firms with low R&D intensity contribute important IPR to standardization. However, it does not support hypothesis 2 for higher marginal disclosure effects on the valuation of firms with low R&D intensity. The results do not suggest a valuation premium due to accessing technological knowledge in open standard setting processes.

Disclosure of standard-relevant IP ownership without revealing associated patent rights shows a significant positive sign for firms with high R&D intensity, if firm-specific effects or the importance of disclosed patents are not controlled (model (5) of Table 6). Generally-held IP disclosures are not significantly correlated with the valuation of R&D-intensive firms if pre-disclosure citations or firm-specific effects are controlled. Disclosure of IP ownership without revealing associated patent rights is negatively correlated with the valuation of lowly R&D-intensive firms. This holds irrespective of firm-specific effects or pre-disclosure citations (models (5)-(8) of Table 7). This suggests that disclosure of standard-relevant IP ownership without revealing associated patent rights signals financial markets a low quality of the contribution to standardization. Patents appear to signal financial markets the technological quality of contributions from firms with low R&D intensity.

6. Conclusion

Open standards, set by organizations in which technology providers cooperate voluntarily, have gained significant importance in the last decades. These organizations have considerable impact on market and technology evolution and supplanted formal public SSOs in many cases (Funk and Methe, 2001; Cargill, 2002). Recent economic studies on cooperative standard setting emphasize coordination problems (e.g. Schmalensee, 2009; Layne-Farrar et al., 2010). Large-scale empirical evidence on the returns of sponsoring IPR to open standards is missing so far. When firms disclose IPR to SSOs, they face the risk of revealing technical knowledge during the standard development process without knowing whether the respective technology will become part of a standard or not. Even in case the technology becomes part of the standard, it cannot be taken for granted that open standards will proliferate or the benefits thereof outweigh the costs, e.g. in terms of giving up exclusivity for universal RAND licensing conditions.

We employ a market value approach in order to investigate the valuation of disclosing standard-relevant IP ownership. The sample consists of large established companies which have been publicly-traded in the US during 1986 to 2005. Information on firm's IP contributions to eight major SSOs has been retrieved. These contributions reveal that the IP owner is prepared to grant reasonable and non-discriminatory licenses for essential IPR.

The results show that IP contributions to open standards are positively correlated with company valuation if they refer explicitly to associated patents. We do not find that the positive value correlation of patent disclosures vanishes if firm-specific effects or the selection of more important patents is controlled. The benefits from contributing IPR to open ICT standards appear to outweigh the loss from waiving exclusivity.

SSOs adjudicate the process of technology evolution (Rosenbloom and Tushman, 1998). They are important venues for learning, producing, exchanging and promoting technical knowledge (Waguespack and Flemming, 2009). Standardization codifies frontier technical knowledge and support the diffusion and adoption of new technologies (Bessen, 2012; Acemoglu et al., 2010). Hence, firms with comparably low R&D intensities might be expected to benefit additionally from access to frontier technical knowledge. Endorsement from technical experts might signal financial markets the quality of their contributions (Corbett et al., 2005; King et al., 2005).

IP disclosures of firms with low R&D intensity appear to be more valued by financial markets. However, this effect vanishes if the pre-disclosure importance of disclosed patents is controlled for. This suggests that firms with low R&D intensities may contribute important

IPR to standardization. However, we do not find evidence for higher marginal disclosure effects on the valuation of firms with low R&D intensity. This does not suggest that their access to frontier technological knowledge is valued additionally.

Disclosure of standard-relevant IP ownership without revealing associated patent rights is negatively correlated with the valuation of lowly R&D-intensive firms. Generally-held IP disclosures are not significantly correlated with the valuation of R&D-intensive firms. This suggests that patents signal financial markets the quality of IPR contributions from firms with low R&D intensity. Further research should study the motives to disclose IPR ownership without referring to associated IP. Information on participation in standard-setting meetings and further information on the scope of IPR or standards might provide further insights on knowledge sourcing and IP strategies.

This study provides evidence for positive valuation effects of IPR contributions to open standards. The benefits from contributing IPR to open standards appear to outweigh the loss of exclusivity. The provided evidence refers to large established companies which participate in open SSOs; and particularly in standard-setting at the ETSI. It has to be kept in mind that incentives to participate to open standards might be different for specialized technology suppliers.

The importance of strong exclusive rights is frequently emphasized for gaining competitive advantage from new technology. This study suggests a more nuanced view that management should carefully evaluate whether to follow temptations to insist on exclusivity if the competitive environment is characterized by strong network effects. To the extent that the correlation of market value and disclosure of IP ownership represents a causal effect, our results show that the benefits from technology contributions to open standards may outweigh associated costs, e. g. due to lost exclusivity. Identification of causal effects requires estimation of the counterfactual situation. We have focused on a comparison between disclosing and non-disclosing firms for lack of an experimental setting. Therefore, it cannot be ruled out entirely that the correlation of market value and IP disclosure results from unobserved heterogeneities although we do not find evidence for it.

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Appendix A Sample SSOs

Multiple and partially incompatible standards have been in operation in Western Europe during the era of analog telecommunication. In order to promote an integrated market, the European Commission mandated a single harmonized standard for digital telecommunication. Simultaneously, telecommunications operations have been deregulated (Besen, 1990). Standard development has been delegated to ETSI. The worldwide success of European standards for digital telecommunication is attributed to the early coordination efforts and the large market size for harmonized standards (Funk and Methe, 2001; Gandal et al., 2003). Major ETSI standards are GSM, UMTS and LTE. GSM is ETSI's successful 2G standard. UMTS is its next generation successor. When success of ETSI's UMTS approach for 3G standards became conceivable, standardization of mobile telecommunications have been transferred to the international 3GPP consortium. 3GPP is an international collaboration with ATIS and SSOs from Japan and Korea. At the end of our sample period, first standardization efforts began for LTE as the 4G telecommunication standard.

In contrast to the European approach, US regulators have chosen not to mandate unified telecommunication standards. Committee T1 is responsible for network reliability and interoperability of all equipment accessing the US telecommunications network (de Lacey et al., 2006). They collaborate with the Alliance for Telecommunications Industry Solutions (ATIS) in order to fulfill this task. Fundamental differences between competing technical approaches have made it difficult to reach consensus. Furthermore, the fiercest competitor of European GSM standards, Qualcomm and its CDMA technology, has chosen a very closed and misleading licensing approach. Qualcomm's CDMA approach has been promoted by TIA (Rosenkopf et al., 2001). ETSI and TIA can, therefore, be considered as competing organizations in the standardization of digital services. When US firms started coordinative efforts to accelerate decision making processes at ATIS, ETSI's GSM standards have already been introduced to the marketplace (Steinbock, 2003).

In comparison to other considered SSOs, the Internet Engineering Task Force (IETF) follows particularly open standardization processes. IETF develops standards for protocols and procedures that are used in or by the Internet, as for instance the TCP/IP which routes data between computers (Simcoe, 2012). Along with rapid growth and commercialization of the Internet during the 1990s, IETF transformed from an open network of computer scientists to the primary forum for Internet standardization. Inherited conventions of openness among software developers have been retained. Participation to standard setting processes is not restricted. Any individual may join and monitor this process by subscribing to an email list. Standard setting processes at the Institute of Electrical and Electronics Engineers (IEEE) can also be considered as particularly open. IEEE is primarily a professional engineering association. Its standard-setting subdivision is open to corporations as well as to individual members. IEEE's major contributions to the ICT domain are the standards for wireless local area networks (WiFi).[14]

Telecommunication standards are predominately developed by corporate representatives sent to SSOs. In order to mitigate antitrust concerns, an US forum of technical coordination may apply for certification by ANSI. ANSI is the US umbrella standard-setting organization that certifies voluntary standardization organizations as being fair, open and consensus-based. ATIS and TIA are, for instance, accredited by ANSI. ANSI is an interface for US standardization efforts to the International Organization for Standardization (ISO). ANSI promotes internationally the standards developed by certified SSOs.

ISO is the international umbrella organization of national standard setting organizations. It develops compatibility standards in cooperation with the International Electrotechnical Commission (IEC) in the Joint Technical Committee (JTC). ISO has prohibited traditionally intellectual property ownership on standards (Lemley and McGowan, 1998). This has changed recently in recognition that proprietary products may become de facto standards. The danger to lose touch with current technological developments is particularly acute in markets that are characterized by strong network effects. In order to keep ISO standardization processes current with ICT markets, ISO standards may, in the meanwhile, rely on intellectual property if technical reasons justify such a step and worldwide RAND licenses will be granted.[15] Disclosures of relevant IP at ISO refer in large parts to standards developed by the Moving Picture Experts Group (MPEG). This working group developed several standard generations for audio and video compression and transmission. The MPEG LA patent pool emerged as a result of this standardization process (Merges, 2001).

ITU-T is another international standard setting body. It is an U.N. organization in which delegates from member nations participate. The historic preeminence of ITU in setting international telecommunications standards has been increasingly threatened by the emergence of regional SSOs (Besen and Farrell, 1991). In response to this development,

[14]For a discussion of WiFi standards and their development, we refer to de Lacey et al. (2006).

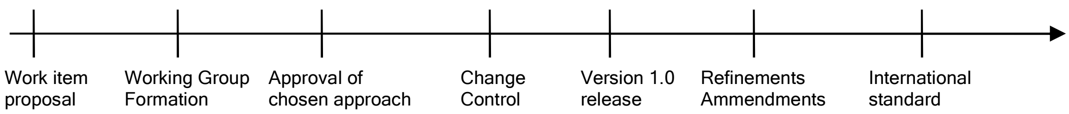
[15]See ISO/IEC Directives, Part 2, "Rules for the structure and drafting of International Standards", available at: http://www.iso.org/iso/standards_development/processes_and_procedures/iso_iec_directives_and_iso_suppleme nt.htm

commercial enterprises have greater opportunities to submit technical proposal now. Voting rights are, however, still reserved to national government representatives.

Appendix B Standard Development Procedures

The development process of technical specifications for standardization is in large parts similar across different consensus-based organizations (Lehr, 1995; Layne-Farrar, 2011). Figure 2 sketches this process. If a compatibility problem is identified or emerges from new technical opportunities, members may submit a work item proposal to the SSO boards. If the proposal is approved because it is considered as technically feasible and desirable, the task of developing a technical specification is assigned to an appropriate working group. Working groups consist of technical experts delegated from governments, academia, customers and companies. The Moving Pictures Expert Groups is an example for such a working group formed by ISO (International Organization for Standards).[16] When internal disagreements regarding the merits of different versions are reconciled, the boards have to approve the chosen technical approach. Subsequently, a draft specification is published and interested parties are invited to comment on it.

Figure 2 The process of developing standards



Source: Authors' own illustration; based on Leiponen (2007), Simcoe (2012) and Layne-Farrar (2008)

During the process of commenting on draft specifications, SSO participants are obliged to reveal essential proprietary technology of which they are aware. Clarification whether technical specifications read on exclusive patent rights is essential to standardization. Bylaws of SSOs explicitly or implicitly oblige their members to disclose relevant patents and associated licensing intentions (Lemley, 2002). Members' acceptance of these bylaws allows SSOs to act as forum of non-discriminatory coordination. The obligation to disclose IP and its licensing intentions permits standard setting bodies to adjust draft specifications according to

[16]http://mpeg.chiariglione.org/

the availability of exclusion rights. Participants shall reveal IP if it may be essential to the adoption of standards. They are, however, not obliged to search their portfolios for eventually infringing patents. General statements that they might possess relevant IP suffice to comply with the disclosure requirement.

Before a draft can be approved, comments have to be responded and reconciled with the draft. This may result in new draft versions. After formal change requests have been responded and consensus is reached, a first standard version can be released. A general technical approach is agreed upon in this early stage of the standardization process. Strategic maneuvering is often intense here as path and direction of further technology evolution is largely predetermined by the chosen technical approach in the first standard version (Suarez, 2004; Layne-Farrar, 2011). Coalitions are restructured to align positions and gain supporters for technical approaches. When the general technological path is agreed upon, working groups define specifications for components of the chosen technical systems. The process of consensus-finding, board approval and change control start anew for these technical designs. Strategic maneuvering should be less intense in these later stages. Coalitions which gained majority for a general technical paradigm are stable during these phases of incremental change (Rosenkopf and Tushman, 2002). Updated standard versions refine or amend technical specifications. User knowledge is incorporated into standardization. Market competition selects among various technical approaches proposed by different (supra-) national SSOs.

International standard setting starts in the shadow of this competition. International standard bodies often do not propose single standards to solve a compatibility problem. They usually certify important standards in different world regions. When efficiency and effectiveness improvements of a technical approach to standardization have reached the limits of feasibility, new standard generations begin to loom and the process of strategizing begins anew, although already installed bases may put incumbents at advantage.

Appendix B Tables

Table 1 Disclosure of standard-relevant IP ownership

SSO	*Identified IP disclosed*	*General Disclosures*
ANSI	15	53
ATIS	0	11
ETSI	599	196
IEEE	45	0
IETF	30	49
ISO	27	125
ITU	19	103
TIA	6	156
	741	693

Table 2 Descriptive statistics

	Sample					Standard-active firms				
	Mean	Median	Std.dev.	Min	Max	Mean	Median	Std.dev.	Min	Max
TobinQ	1.22	0.77	1.68	0.00	29.79	1.17	0.78	1.86	0.08	29.49
Market value	2867	145	11474	0.00	280367	26664	15338	38979	136.51	280367
Tangible assets	3088	177	10749	0.14	137756	32581	23345	30781	64.13	126986
R&D stocks	817	40	3071	0.01	33932	9283	5547	9279	35.02	33932
Patent stocks	289	12	1171	0.01	18355	3540	1866	3761	0.85	18355
Citation stocks	3005	97	13936	0	274483	39663	17529	48618	0	274483
R&D stocks / Assets	1.36	0.65	2.93	0.00	54.69	1.48	0.94	1.50	0.07	9.05
Patent stocks / R&D	0.63	0.33	1.11	0.00	30.85	0.37	0.32	0.28	0.00	1.83
Citation stocks / Patents	12.20	8.12	18.67	0	432.63	12.37	10.73	7.31	0	47.94
IP disclosures	0.17	0	3.36	0	153.50	3.53	0.71	15.14	0.00	153.50
General discosures	0.19	0	1.38	0	26.55	4.11	2.37	4.94	0.00	26.55
IP disclosures / Patents	0.00	0	0.002	0	0.16	0.00	0.00	0.010	0.00	0.16
General discosures / Patents	0.00	0	0.09	0	3.17	0.07	0.00	0.40	0.00	3.17
Predisclosure citations	3.92	0	42.27	0	1125.22	69.41	11.17	171.65	0	1125.22
Predisclosure citations / Patents	0.02	0	0.63	0	32.00	0.40	0.00	2.88	0	32.00
Machinery and Computer equipment	0.29	0	0.45	0	1	0.29	0	0.45	0	1
Electric and electronic equipment	0.29	0	0.46	0	1	0.43	0	0.50	0	1
Transportation equipment	0.07	0	0.26	0	1	0.01	0	0.12	0	1
Instruments	0.27	0	0.45	0	1	0.08	0	0.27	0	1
Communications	0.01	0	0.09	0	1	0.08	0	0.27	0	1
Business Services	0.06	0	0.24	0	1	0.11	0	0.32	0	1
Observations			7095					334		

Table 3 Valuation for disclosure of standard-relevant IP ownership

Dependent: *ln* (TobinQ)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
R&D/assets	0.070 ***	0.020 ***	0.070 ***	0.020 ***	0.070 ***	0.020 ***	0.070 ***	0.019 ***
	(0.013)	(0.008)	(0.013)	(0.008)	(0.013)	(0.008)	(0.013)	(0.008)
Patents/R&D	0.105 ***	0.071 ***	0.105 ***	0.072 ***	0.105 ***	0.072 ***	0.105 ***	0.072 ***
	(0.022)	(0.017)	(0.022)	(0.017)	(0.022)	(0.017)	(0.022)	(0.017)
Citations/Patents	0.004 ***	0.001 *	0.004 ***	0.001 *	0.004 ***	0.001 *	0.004 ***	0.001 *
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Disclosure/Patents	1.067 **	0.124	0.076	-0.148				
	(0.536)	(0.176)	(0.243)	(0.131)				
IP disclosure/Patents					8.169 **	9.005 **	9.742 ***	9.364 ***
					(3.6)	(3.524)	(3.488)	(3.462)
General disclosure/Patents					0.979 *	0.106	-0.084	-0.194
					(0.523)	(0.172)	(0.116)	(0.119)
Predisclosure Citations/Patents			0.223 ***	0.064 **			0.254 ***	0.074 **
			(0.081)	(0.028)			(0.086)	(0.032)
presample mean *ln* (TobinQ)		0.403 ***		0.402 ***		0.403 ***		0.402 ***
		(0.014)		(0.014)		(0.014)		(0.014)
Observations				7095				

***. **. * indicates a 1%. 5%. 10% level of significance

Table 4 Marginal disclosure effects

Dependent: *ln* (TobinQ)	Full Sample				Low R&D-Intensity				High R&D-Intensity			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
R&D/assets	0.063***	0.019***	0.063***	0.019***	-0.021	-0.099***	-0.021	-0.098***	0.049***	0.026**	0.049***	0.026**
	(0.012)	(0.007)	(0.012)	(0.007)	(0.046)	(0.034)	(0.046)	(0.034)	(0.014)	(0.010)	(0.014)	(0.010)
Patents/R&D	0.094***	0.068***	0.095***	0.068***	0.018	-0.009	0.018	-0.009	0.447***	0.394***	0.448***	0.395***
	(0.019)	(0.016)	(0.019)	(0.016)	(0.015)	(0.011)	(0.015)	(0.011)	(0.057)	(0.051)	(0.058)	(0.051)
Citations/Patents	0.004***	0.001*	0.004***	0.001*	0.007***	0.003**	0.007***	0.003**	0.003***	0.002**	0.003***	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.007)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
IP disclosure/Patents	7.348**	8.597**	8.765***	8.939***	23.870**	17.103**	23.341**	17.135**	7.753*	10.836**	8.885***	11.118**
	(3.236)	(3.362)	(3.136)	(3.303)	(9.673)	(6.211)	(10.056)	(6.936)	(3.963)	(5.335)	(3.751)	(5.221)
General disclosure/Patents	0.881*	0.101	-0.076	-0.185	-20.014***	-18.293***	-19.625***	-18.319***	0.833**	0.174	-0.015	-0.137
	(0.47)	(0.164)	(0.104)	(0.114)	(3.745)	(3.058)	(4.320)	(3.764)	(0.415)	(0.170)	(0.112)	(0.107)
Predisclosure Citations/Patents			0.229	0.070**			-0.418	0.029			0.197***	0.078**
			(0.077)	(0.030)			(2.081)	(1.982)			(0.064)	(0.031)
presample mean *ln* (TobinQ) included	*no*	*yes*	*no*	*yes*	*no*	*yes*	*no*	*yes*	*no*	*yes*	*no*	*yes*
Observations	7095				3300				3795			

***. **. * indicates a 1%. 5%. 10% level of significance

Table 5 Valuation for firms with low R&D intensities

Dependent: *ln* (TobinQ)	Low R&D-Intensity							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
R&D/assets	-0.021	-0.095 ***	-0.021	-0.095 ***	-0.022	-0.096 ***	-0.022	-0.096 ***
	(0.048)	(0.032)	(0.048)	(0.032)	(0.048)	(0.032)	(0.048)	(0.032)
Patents/R&D	0.019	-0.009	0.019	-0.009	0.019	-0.009	0.019	-0.009
	(0.016)	(0.01)	(0.016)	(0.01)	(0.016)	(0.01)	(0.016)	(0.01)
Citations/Patents	0.007 ***	0.003 *	0.007 ***	0.003 *	0.007 ***	0.003 *	0.007 ***	0.003 *
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
Disclosure/Patents	-4.594	-5.727	-4.590	-5.707				
	(2.802)	(1.449)	(2.706)	(1.434)				
IP disclosure/Patents					25.064 **	16.729 ***	24.508 **	16.761 **
					(10.146)	(6.062)	(10.55)	(6.773)
General disclosure/Patents					-21.015 ***	-17.894 ***	-20.607 ***	-17.919 ***
					(3.944)	(2.988)	(4.548)	(3.68)
Predisclosure Citations/Patents			-0.790	-0.303			-0.439	0.029
			(2.205)	(1.93)			(2.185)	(1.939)
presample mean *ln* (TobinQ)		0.491 ***		0.491 ***		0.491 ***		0.491 ***
		(0.018)		(0.018)		(0.018)		(0.018)
Observations				3795				

***. **. * indicates a 1%. 5%. 10% level of significance

Table 6 Valuation for firms with high R&D intensities

Dependent: *ln* (TobinQ)	High R&D-Intensity							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
R&D/assets	0.062 ***	0.030 **	0.061 ***	0.030 **	0.062 ***	0.030 **	0.062 ***	0.030 **
	(0.019)	(0.012)	(0.019)	(0.012)	(0.019)	(0.012)	(0.019)	(0.012)
Patents/R&D	0.559 ***	0.462 ***	0.560 ***	0.463 ***	0.559 ***	0.462	0.560 ***	0.463 ***
	(0.084)	(0.068)	(0.084)	(0.068)	(0.084)	(0.068)	(0.084)	(0.068)
Citations/Patents	0.004 ***	0.003 **	0.004 ***	0.003 **	0.004 ***	0.003 **	0.004 ***	0.003 **
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Disclosure/Patents	1.111 **	0.225	0.115	-0.113				
	(0.524)	(0.204)	(0.231)	(0.135)				
IP disclosure/Patents					9.689 *	12.698 **	11.100 **	13.025 **
					(4.966)	(6.259)	(4.703)	(6.126)
General disclosure/Patents					1.041 **	0.204	-0.019	-0.161
					(0.519)	(0.199)	(0.14)	(0.126)
Predisclosure Citations/Patents			0.219 ***	0.080 **			0.246 ***	0.091 **
			(0.075)	(0.032)			(0.08)	(0.036)
presample mean *ln* (TobinQ)		0.334 ***		0.333 ***		0.335 ***		0.333 ***
		(0.021)		(0.021)		(0.021)		(0.021)
Observations				3300				

***. **. * indicates a 1%. 5%. 10% level of significance

Table 7 Correlation matrix

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
TobinQ	(1)	1												
R&D stocks/assets	(2)	0.23 ***	1											
Patents/R&D stocks	(3)	0.04 ***	-0.10 ***	1										
Citations/Patents	(4)	0.15 ***	0.19 ***	-0.07 ***	1									
IP discosures/Patents	(5)	0.02	0.00	-0.02 **	0.00	1								
General discosures/Patents	(6)	0.10 ***	0.04 ***	-0.02	0.02 *	0.05 ***	1							
Predisclosure citations/Patents	(7)	0.08 ***	0.03 ***	-0.02	0.02 **	0.00	0.71 ***	1						
Machinery and Computer equipment	(8)	-0.08 ***	-0.05 ***	0.04 ***	0.01	-0.03 **	-0.02 *	-0.02 *	1					
Electric and electronic equipment	(9)	-0.05 ***	-0.05 ***	0.01	-0.01	0.00	0.05 ***	0.05 ***	-0.41 ***	1				
Transportation equipment	(10)	-0.06 ***	-0.09 ***	0.01	-0.07 ***	0.00	-0.01	-0.01	-0.18 ***	-0.18 ***	1			
Instruments	(11)	0.12 **	0.01	-0.01	0.01	-0.03 ***	-0.02 *	-0.02	-0.39 ***	-0.40 ***	-0.17 ***	1		
Communications	(12)	0.00	-0.02	-0.04 ***	-0.03 **	0.31 ***	0.02	0.00	-0.05 ***	-0.06 ***	-0.02 **	-0.05 ***	1	
Business Services	(13)	0.07 ***	0.27 ***	-0.05 ***	0.08 ***	0.00	-0.01	-0.01	-0.17 ***	-0.17 ***	-0.07 ***	-0.16 ***	-0.02 *	1

***. **. * indicates a 1%. 5%. 10% level of significance