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The Market Value of Standard-Setting Activities for Technology Providers

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Abstract
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Jelcodes:O32,L15

The Market Value of Standard-Setting Activities for Technology Providers[1]

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Abstract

In light of the increased demand for interoperability of products and technologies, fragmented ownership of intellectual property and initially high costs for communicating new technologies, standard-setting activities emerged as an important coordination and diffusion mechanism. Little is known about the value of standard setting activities for the providers of technologies. In this paper, we provide a large-scale empirical assessment of the value of standard-setting activities for technology sponsors. We show that there is a correlation between the economic value of technologies disclosed to standard setting organizations and the restrictiveness of licensing concessions. Disclosing standard relevant technologies appears to be more valuable when the disclosing firm itself further builds upon them in a cumulative way. Self-citations are positively correlated to the economic value of disclosed patents whereas external citations to standard relevant IP reduce company valuations.

JEL classification: O32, O34, L15

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1. Introduction

Standard-setting activities have become an increasingly important coordination mechanism in technology markets over the past decades (Besen and Farrell, 1994). This is due to two developments. At first, there is an increased demand for interoperability of products and technologies. Secondly, ownership of intellectual property has become more fragmented in the past which raises transaction costs, royalty stacking and the risk of hold-up (Shapiro 2001). In such a complex environment, standards define a set of technical specifications that seek to provide a common design for a product or process. Standard setting is supported by standard setting organizations (SSOs) which are public or private non-profit organizations that provide a legal framework for different technology owners to agree voluntarily and cooperatively on technology standards. They support technical coordination and lower the risk of standard wars and the occurrence of hold-up threats (Farrell et al., 2007).

Standards have been shown to contribute to national growth (Acemoglu et al., 2010, Blind and Jungmittag, 2008) and to support international trade flows (Swann et al., 1996). Stakeholders value the expected product variety and global outsourcing opportunities of standards (Blind et al., 2010). Standards codify technical knowledge and reduce communication costs (Bessen, 2012). This facilitates the adoption of new technologies and new product introductions especially when innovation is cumulative (Wen et al. 2011). Consumers can benefit from ongoing competition among providers of standardized products (Koski and Kretschmer, 2005). Empirical evidence for the returns to standard setting activities for technology providers is, however, missing so far.[2] On the one hand, technology sponsors can expect high returns from their participation in standard setting activities. Owning a technology that is declared to be essential for a standard can secure a stream of future licensing revenues. Standards can further decrease research and development (R&D) costs of the contributors as they share technological information and increase R&D costs for non-participating rivals (Salop and Scheffman, 1983). On the other hand, being involved in standard setting activities can incur substantial financial costs.[3] Coordination takes times and delays new product introductions (Farrell and Saloner, 1988, Simcoe, 2012). Standard setting activities further imply the threat that technologies disclosed to the SSO create knowledge

[2] Exceptions exist for management standards. Corbett et al. (2005) show that the ISO 9000 management certification lead to short term financial returns for the firms that applied it. Link and Naveh (2006) show that there is no impact of the environmental management standards ISO 14001 on firm business performance.

[3] Chiao et al. (2007) report that IBM spent half a million of dollars in 2005 on standard development which equals 8.5% of their total R&D budget (Rysman and Simcoe, 2008).

spillovers to competitors and grant them a competitive advantage on technology markets (Hunt et al. 2007). Patent protection might not be sufficient to protect intellectual property since disclosures to SSOs often involves additional information beyond the technical details publicly available in patent documents (Blind and Thumm, 2004). Furthermore, free-riding can occur in the sense that outsiders to the standard can benefit from the patented technologies involved in the standard without sharing their own essential patents (Aoki and Nagaoka, 2004, Schmalensee, 2009). The advantages and disadvantages of standard setting activities render the question on its returns for technology sponsors an empirical one.[4] In this paper, we provide for the first time large-scale empirical evidence on the returns to technology sponsoring to SSOs.

Providers of important technologies may engage in forum shopping when deciding to participate at a SSO (Lerner and Tirole, 2006). A firm with a high-quality invention is likely to be in the position of being able to make fewer concessions when sharing a technology, in terms of less restrictive licensing agreements with the SSO (Chiao et al., 2007). Accordingly, Blind and Thumm (2004) find that firms with higher patenting intensities are less likely to join cooperative standard-setting bodies.Large non-profit SSOs follow, however, an open, voluntary and consensus-based approach (Lemley, 2002). Members are discouraged, but usually not forbidden, to own IP in a standard althoughstandards formulations that do not infringe IPR are preferred. However, SSOs strive to develop high-quality technical specifications that become widely adopted. Trade-offs between a wide adoption and exclusive rights to superior patent-protected technology have to be taken into account during the standardization process. As SSOs lack formal enforcement power, the exclusive rights of technology providers have to be respected. SSOs' bylaws provide a legal framework that governs the treatment of members' intellectual property rights (Lemley, 2002, 2007). SSO members are consequentially required to disclose relevant IP and associated licensing intentions during the standard-setting process. Requested licensing terms can vary. For some standard technologies, licenses are royalty-free. For others, the owner provides licenses on reasonable and non-discriminatory (RAND) terms. Lastly, technology providers can sometimes refuse to waive their exclusive rights over intellectual property rights (IPRs) and

[4] So far, no empirical analysis on the value of technology sponsoring exists. The only indication we are aware of stems from a patent-level study by Rysman and Simcoe (2008). The authors find that once declared as essential for a standard patents receive more citations by future patents then a control group reflecting a value increase of the technology in the market.

command specific licensing terms. This essentially precludes approvals of infringing standards in open and consensus-based SSOs.

We investigate the value of standard-setting activities employing a market value approach (Griliches, 1981).[5] First, we analyze whether technology disclosures to SSOs affect firms' market value. Second, we distinguish between different required licensing terms (royalty-free disclosure, RAND disclosure and specific disclosure which do not comply with RAND licensing terms) and their impact of the firms' market value. Our analysis is based on a sample of publicly traded U.S. firms covering the period 1986 to 2006. The firm data is supplemented by firms' patent records using the firm-patent match provided by Bessen (2009). Information about firms' standard setting activities is taken from Rysman and Simcoe (2008). The data set by Rysman and Simcoe (2008) include disclosures to five major SSOs: the American National Standards Institute (ANSI), the Alliance for Telecommunications Industry Solutions (ATIS), the Institute for Electrical and Eletronic Engineers (IEEE), the International Telecommunications Union (ITU) and the Telecommunications Industry Association (TIA). Additional disclosure events at the European Telecommunications Standards Institute (ETSI), the Internet Engineering Task Force (IETF) and the International Organization for Standardization (ISO) have been searched. The standards we are investigating focus on the compatibility of technological components. We estimate pooled cross-sectional and panel models and find that technology disclosure events are not valued by financial markets beyond firms' R&D and patent stocks. Distinguishing between different types of licensing agreements associated to the disclosures, however, shows that more restrictive licensing terms are significantly higher valued. Irrespective of associated licensing terms, standard-relevant technology appears to be the more valuable the more firm's own further innovations builds upon standards, whereas the value of standard-relevant technology reduces to the firm when external cumulative inventions build upon it. These findings suggest that there is heterogeneity in the value of firm's standard-setting activities and that SSO's coordinative and communication cost-reducing function are important to foster own cumulative innovations.

In the next section, we review the existing literature on standard setting activities. Section 3 discusses the market value approach and describes our empirical specification. Section 4 describes our data and section 5 presents our econometric results. Section 6 concludes.

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[5] Surveys on this method being applied to evaluate firms' innovation activities are provided by Hall (2000) and Czarnitzki et al. (2006).

2. Literature Review

In the past decades, frequency and importance of standard-setting activities have grown tremendously (Simcoe, 2007). Standards define common technical specifications of products or components. Codified standards reduce the costs of communicating technical knowledge. Such specifications may be necessary to ensure minimum quality levels of products or may be necessary to ensure interoperability of different components of a technical system, the latter aspect being especially important in complex and multi-purpose technologies (David, 1990, Bresnahan and Traijtenberg, 1995). Interoperability and reduced communication costs can spur sequential and cumulative innovations in these technologies.

Standard setting processes are quite heterogeneous. The economic literature has predominantly focused on de facto standards (David and Greenstein, 1990). De facto standards occur when firms offer competing incompatible technologies and consumers gravitate to a particular technical solution (Farrell and Saloner, 1985). Farrell and Saloner (1988) have, however, shown that coordination among market participants can result in higher quality standards than standards emerging from market competition, at the cost of a delayed standard introduction though. De jure standards as the outcome of active coordination between technology owners enable multiple firms to participate in an open standard whereas de facto standards often result in single proprietary products (Shapiro, 2001).[6] De jure standards are typically supported by SSOs which are public or private non-profit institutions providing a forum for coordination. SSOs strive to achieve consensus on high-quality technical specifications that become widely adopted by defining sets of disclosure rules, negotiation rules and licensing rules (Farrell et al., 2007). SSOs have grown in importance since achieving an agreement on a standard can be particularly difficult in complex technologies where it is not uncommon that new products cover hundreds or thousands of patents (Lemley, 2007) and in technologies where technology providers have different business models (Aoki and Nagoaka, 2004, Simcoe et al., 2009).

SSOs policies regarding IPR disclosure, licensing and negotiation rules embody their role in resolving the tension between proprietary technology and a widespread standard adoption (Farrell et al., 2007). SSOs typically require their members to disclose any known IPR that

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[6] The implementation of the 2G standard, for instance, fostered entry, diffusion and within-standard competition in the mobile telecommunication sector (Koski and Kretschmer, 2005).

might be "essential" to the standard in a timely fashion. 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). The number of standard relevant IP disclosures has grown tremendously in the last decades by a rate surpassing that of patent applications (Simcoe, 2007). Disclosure requirements shall limit patent owners' ability to exploit opportunistically the market power conferred by being included in a standard.[7] Once adopted, standards exhibit a considerable degree of lock-in due to e.g. industry-wide specific investments in compliant equipment and machinery, development of cumulative, next-generation standards etc. Owners of essential patents that have not waived their right on exclusivity could, hence, expropriate substantial rents beyond the technological value simply because switching costs are that high.

SSOs' licensing and negotiation policies reflect such hold-up risks. Large SSOs typically require their members to license essential IPR on reasonable and non-discriminatory (RAND) terms, although licensing negotiations take place outside SSOs due to antitrust concerns (Gilbert, 2009). 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. Furthermore, royalty rates should be reasonable and non-discriminatory in view of available technical alternatives and in view of cumulative royalty rates when the standard reads on multiple, fragmented patents (Swanson and Baumol, 2005). SSOs thus provide a forum where their members commit themselves to provide licenses on RAND terms after the standard has been defined (Merges, 1998). Whether RAND licensing terms suffice to induce participation of important technology providers in standard setting, remains, however, subject to debate (Layne-Farrar et al., 2010).

The technical specifications formulated in standards largely determine which firms can effectively compete in new product markets (Katz and Shapiro, 1986, de Lacey et al., 2006, Bekkers et al., 2002). Technology providers form alliances to be in a better position for influencing the evolution of industry standards (Leiponen, 2008, Rosenkopf et al., 2001). Participation in standard-setting activities further signals technological capabilities which is especially important for young start-ups to access external funding (Waguespack and Flemming, 2009). Standards codify technical knowledge, i. e. technical knowledge is

[7] Although hold-up threats are reduced by disclosure requirements, they are not eliminated completely since SSO members are not legally required to search their patent portfolios for essential patents. For a discussion of further factors favoring hold-up within standard-setting, see Lemley (2007). 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).

converted into messages that can be processed as information by a large number of people (Cowan and Foray, 1997). Early standard generations formulate stable designs of complex technical systems that deliver satisfactory functional performance. Diffusion, adoption and further incremental refinements of technology are encouraged (Abernathy, 1978). In early stages of technology evolution, inventors sometimes freely reveal their knowledge (Allen, 1983, von Hippel, 1987, Lerner and Tirole, 2005, Harhoff et al., 2003, Bessen, 2012) in order to foster variation of compatible products, although royalty-free RAND licenses are usually conditioned on receiving reciprocal RAND terms (O'Mahony, 2003).

This suggests that participation in standardizing complex technologies may be valuable to technology providers because sequential and cumulative product innovations and incremental technology improvements increase the economic value of own technology contributions to the standard (Bessen and Maskin, 2009, Bessen, 2012). Research on cooperative standard-setting has so far mainly focused on the effectiveness of coordination efforts (Gilbert, 2009, Simcoe, 2012) and the restrictions on licensing terms imposed by RAND commitments (Swanson and Baumol, 2005, Salant, 2007). Much less is known regarding the returns of standard-setting to technology providers. The next sections of this paper will fill this gap in the literature.

3. Estimating the Market Value of Standard-Setting Activities

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 on company's valuation by financial markets (Griliches, 1981). The market valuation of companies is a forward-looking measure for financial market's expectations on 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 the `price' of the company (Hall et al., 2005, Czarnitzki et al., 2011, Sandner and Block, 2011). We follow Griliches (1981) by assuming a linear market value function that is additively separable in assets. According to (1)

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

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 recent empirical literature (Hall, 2000, Czarnitzki et al., 2011), we assume constant returns to scale, i.e. $\sigma_t=1$.[8] Equation (1) can then be rewritten as

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

The left hand side of the equation (2) is the log of Tobin's Q, defined as the ratio of the market value to the replacement cost of the firm's physical assets. γ represents the shadow value of investors for the ratio of knowledge capital to physical assets. j We use different variables to measure firm's knowledge assets K. First, we use the stock of firm's R&D expenses (Hall, 1993a). As R&D activities 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 skew (Pakes, 1986, Schankerman and Pakes, 1986, Harhoff et al., 1999, Deng, 2007, Gambardella et al., 2008), we further add the stock of forward citations within a 5-year citation window after the priority date as a measure for the importance of patents (Hall et al., 2005, 2006). Forward patent citations have been shown to correlate positively with patents' social as well as with its private value (Harhoff et al., 1999, Hall et al., 2005). They further reflect the economic and technological importance of patents as perceived by the inventors themselves (Jaffe et al., 2000) and the knowledgeable peers in the technology field (Albert et al., 1991).

Besides these established measures for firm's knowledge stocks, we further include the stock of firm i's announcements of standard-relevant IPR $Announce_{it}$ (orthogonalized by patent

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[8] As 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 cannot be rejected ad hoc.

stocks) in our estimations in order to test whether disclosing relatively more standard relevant patents to SSOs results in a market valuation premium.

$$\log Q_{it} = \log q_{it} + \log\left(1 + \gamma_1 \frac{R\&D_{it}}{A_{it}} + \gamma_2 \frac{PAT_{it}}{R\&D_{it}} + \gamma_3 \frac{CIT_{it}}{PAT_{it}} + \gamma_4 \frac{Announce_{it}}{PAT_{it}} + \gamma_5 \frac{Licensingterm_{it}}{Announce_{it}}\right) \quad (3)$$

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 announcements to SSOs, the estimated coefficient γ_4 is expected to be positive, showing a value-premium beyond firm's patent stock and its importance. Announcing IPR indicates (to varying degree) that the company owns exclusive rights to parts of a standard. Whether discussed technical specifications get approved as standard depends not the least on announced licensing terms. Licensing intentions can be categorized as reasonable and non-discriminatory (RAND), royalty-free and specific, non-RAND terms. Firms' stocks of IP announcements are split up according to these licensing terms. According to Chiao et al. (2007), SSOs that require fewer concessions from technology providers formulate standards of higher technical quality. We expect therefore that the valuation of standard contributions s increases in the restrictiveness of announced licensing terms, i. e. that the coefficient γ_5,which investigates the valuation of announced licensing terms relative tofirm's overall standard-setting activites, increases in the restrictiveness of considered *Licensing term*$_{it}$.

In equation (3), citations are used as indicators for the importance of the receiving patents. However, citations may convey further information on the process of knowledge diffusion (Jaffe et al., 1993). Standard setting shall reduce communication costs and thereby encourage cumulative and sequential innovation. When studying value creation and capture from standard-setting, citations' informative character regarding knowledge spillovers should not be disregarded, as the linkages between sequences of patents may be thought as materialization of cumulative innovations (Scotchmer, 1991). Citations may come from subsequent patents assigned to same entity as the cited patent or from any other applicants' patents. Whereas latter citations may reflect knowledge spillovers, former self-citations arguably capture *own* cumulative innovations with very different implications of subsequent innovations on firm value. Thus, Hall et al. (2005) find that self-citations are more valuable than citations from external patents. Belezon (2012) provides evidence that spilled knowledge in citations received from external patents might be reabsorbed, since external citations from patents which are subsequently cited again by own patents are positively related with firm value whereas external citations from patents not built upon are negatively related. Equation (4) seperates, therefore, the stocks of received citations from own and external patents. More importantly, we differentiate between self and external citations of disclosed patents associated with distinct licensing terms. This shall verify whether standard-setting activities are more valuable when they provide the platform for cumulative innovation.

$$\log Q_{it} = \log q_{it} + \log\left(1 + \gamma_1 \frac{R\&D_{it}}{A_{it}} + \gamma_2 \frac{PAT_{it}}{R\&D_{it}} + \gamma_{3a} \frac{SELFCIT_{it}}{PAT_{it}} + \gamma_{3b} \frac{EXTCIT_{it}}{PAT_{it}} + \right.$$
$$\left. + \gamma_4 \frac{Announce_{it}}{PAT_{it}} + \gamma_5 \frac{Licensingterm_{it}}{Announce_{it}} + \gamma_{6a} \frac{SELFCIT_{Licterm\ \ it}}{Licensingterm_{it}} + \gamma_{6b} \frac{EXTCIT_{Licterm\ \ it}}{Licensingterm_{it}}\right) \quad (4)$$

4. Data and Variables

4.1. Sample

Our sample consists of information on 609 publicly traded international companies between 1976 and 2006. These companies are traded on US capital markets, which can be regarded as well-functioning (Hall, 2000), and are in large parts large established firms. Our firms are active in industries in which at least one company announced standard-relevant IP to SSOs. These sectors include mechanical and electrical engineering, electronics, instruments, transport equipment,communications and holding companies in respective industries. Data on companies' market value, tangible assets and R&D expenditures have been retrieved from the Compustat database. This results in an unbalanced panel from 1986 to 2006 that consists of 7,103 observations. Information on company's portfolios of US patent applications has been added from NBER patent and citations dataset (Hall et al., 2001) based on a match to Compustat firms provided by Bessen (2009).

Standard-setting organizations encourage their members to disclose potentially relevant IPR for standard formulations (Lemley, 2002, 2007). This information is published on SSO websites. Building on the dataset by Rysman's and Simcoe's (2008), we checked SSO websites for additional company announcements of essential IPRs. Examples of important standards in our database are the different generations of mobile telecommunication standards (GSM, 3GPP), various applications and generations for network transport protocols (the IEEE 802 family including standards for LAN, WLAN technologies) or the MPEG coding standards for audiovisual digital data.

Announcements of standard-relevant IP differ in their scope. Some announcements declare broadly that they might possess IP to specific standards without specifying single patent rights whereas others include detailed information on specific patent rights. SSO members are usually not required to search their patent portfolio for standard-infringing IP, since standard-setting is an incremental process with various technical specifications proposed and discussed until agreement is reached.[9] IP announcements differ furthermore in the number of affected standards, as announced IPRs vary in their importance for technical specifications. Some intellectual property rights protect minor features that the technical committee can easily replace by a technical alternative. Technology for which alternative solutions are hard to find is likely to be frequently important as interface of elements in a large technical system. Announcements of respective IPRs are accordingly likely to refer to multiple standard specifications. In order to take into account their varying scope, IP disclosures have been weighted according to the number of affected standard formulations and the number of disclosed patent rights. This results in 5244 disclosure events at eight SSOs for our sample firms. Figure 1 depicts the evolution of these disclosure events. Their number has grown tremendously in the last decades by a rate surpassing that of patent applications (Simcoe, 2007).

Figure 1 about here

The eight considered standard-setting organizations are the largest SSOs among those that have (according to Lemley, 2002) a formalized IP policy, require disclosure of essential IP from their members and that do not require obligatory royalty-free licenses for IP-protected technology to be included in standard. These SSOs include the American National Standards Institute (ANSI), the Alliance for Telecommunications Industry Solutions (ATIS), the European Telecommunications Standards Institute (ETSI), the Institute of Electrical and

[9] Even if announcements include information on specific IPR, the possibility of consecutive drafts on a standardization problem precludes inferring that disclosed patents are essential for a specific standard. For umbrella organizations like ANSI or international organizations like ISO or ITU, it seems, however, not unreasonable to assume that disclosed patents read on some standards developed at a subordinated level. Standards defined by ISO, for instance, can be regarded as a final step in global standard setting efforts. Consequently, their developments require more coordination among (supra-)national standard setting bodies than coordination among intellectual property holders, since the latter's licensing intentions have already been included in national standard development processes. Information on essential IPR retrieved from ISO does consequently not include a disclosure date. Instead, announcements of essential IPR refer to the date of standard approval at the ISO.

Electronics Engineers (IEEE), the Internet Engineering Task Force (IETF), the International Organization for Standardization (ISO)[10], the International Telecommunication Union (ITU) and the Telecommunications Industry Association (TIA). TIA is a private U.S. trade association that develops telecommunication standards particularly for wireless and cellular applications. IEEE is primarily a professional engineering association that is active in a variety of technology areas. However, it is also active in standard developments, particularly for local area networks. ANSI is the U.S. umbrella standard-setting organization. They certify other voluntary standardization organizations (like ATIS, TIA and IEEE) as being fair, open and consensus-based. At ETSI, participants at the standardizing process consist mainly of private companies that develop standards for mobile communication in the European marketplace. The IETF defines the specifications of internet transfer protocols whereby it takes an especially open approach of standard-setting activities with no formal membership requirements. The ITU(-T) and ISO are both international standardization bodies in which representatives of national standard bodies and private sector representatives coordinate their approaches. Whereas ISO is the umbrella organization for international standard development, the ITU-T is an U.N. organization in which delegates from member nations along with private-sector representatives participate.

All these organizations develop standards based on consensus among their members as they lack formal regulatory power to mandate the adoption of certain technical specifications (Funk and Methe, 2001). All considered SSOs are non-profit organizations that can be described (in different degrees) as open, voluntary and consensus-based. Antitrust concerns are thereby mitigated. Processes by which technical specification are developed are consequentially remarkably similar (Lehr, 1995). When a participant identifies a compatibility problem, she can submit a proposal to the SSO's administrative committees. When the proposal is approved because it is considered as technically feasible and desirable, the task of developing a technical specification is assigned to the appropriate working group. These working groups are composed of representatives from the various stakeholders at SSOs, i. e. representatives from governments, academia, customers and particularly companies. When the working group succeeds in developing a technical specification that reconciles internal disagreements regarding the merits of different versions, a draft specification is published and interested parties are invited to comment on it. Before the SSO approves the draft finally,

[10] More specifically, respective standard-setting efforts refer to activities of the Joint Technical Committee 1 ("JTC-1") of the ISO and the International Electrotechnical Commission (IEC). For a detailed discussion of the ISO standard-setting process, see Lemley and McGowan (1998).

comments have to be responded and reconciled with the draft which leads eventually to the publication of a new adopted draft. At this early stage of standardization, the general technical approach to solving the compatibility problem is agreed upon. Subsequently, working groups configure the technical components within the chosen technology path. After having reconciled or responded to internal or external disagreements and having received approval by the standard-setting body, adopters begin to implementing the standard in new products or processes. Unanticipated problems during standard implementation by their users can thereafter lead to final modifications of the standard specifications (cf. Layne-Farrar, 2011).

One major aspect of the standardization process is the clarification whether technical specifications read on exclusive patent rights. Bylaws of standard-setting organizations explicitly or implicitly oblige their members to disclose relevant patents and associated licensing intentions (Lemley, 2002). Member's acceptance of these bylaws permits SSOs to act as forum in which non-discriminatory coordination can take place. The obligation to disclose IP and associated licensing intentions permits standard-setting bodies to adjust draft specifications according to the availability of usage rights to technologies. Thus, during the process of commenting on draft specifications, standard-setting participants shall declare whether they regard some of their patents as potentially essential for the adoption of technical specifications. Figure 1 has shown the rapid growth of announcements of IPR deemed essential for technical specifications over time. Much of this growth in disclosure rates attributes to standard-setting efforts in mobile telecommunications, particularly at the ETSI. Roughly one half of IP disclosures take place at this SSO. With the exception of ATIS, disclosures at the remaining SSOs are quantitatively similar with shares ranging between 5 and 15 percent.

Table 1 about here

SSOs require disclosures in order prevent hold-up situations once a technical specification is agreed upon. They do, however, not require that IP owners waive their rights completely. In order to strike a balance between IP owners' legitimate reward entitlements and SSO's aim of widespread standard adoption, owners of essential IP are implicitly required to waive their right on exclusivity by committing on licensing terms that are reasonable and non-discriminatory (RAND). This is also reflected in our sample of disclosure events. Roughly 80 percent announce that they will license IPRs on RAND terms if their IP turns out to be essential for standard adoption. In 7 percent of disclosures, IP owners do not even require licensing fees. In 1 percent of cases, the IP owners deny granting licensing on RAND terms. In these cases, considered SSOs can essentially not include the protected technology in a standard.

Table 2 about here

Intellectual property that is announced as possibly essential to the standard differs in its importance. Forward citations are the most common proxy for the importance of patents. Figure 2 depicts the distribution of received citations within 5 years after priority for the 556 sample firm patents which have been disclosed to the eight SSOs. Citations for patents from 2001 onwards have been corrected for truncation in 2006 using Bessen’s (2009) truncation correction factors. Citation frequencies of disclosed patents are differentiated according to associated licensing intentions. Consistency of licensing intentions of single patents over various announcements at different SSOs has been checked manually. Based on a broad sample standard-setting organizations (ranging from research consortia to organizations that forbid IPR in their standards), Chiao et al. (2007) find that more technology provider-friendly SSOs request fewer licensing concessions are able to formulate standards of higher technical quality. In our sample of open, voluntary and consensus-based SSOs, it does not appear that high quality patents are associated with more restrictive licensing terms. Citation frequencies of all three licensing terms are highly skewed, although they are less skewed than citation frequencies of all US patents. Disclosed patents should therefore be on average of higher quality. According to Rysman and Simcoe (2008), higher quality patents are selected for disclosures at SSOs and incorporation into standards further increases their importance. Interestingly, skewedness of citation frequencies decreases with the restrictiveness of associated licensing terms. However, frequency distributions of royalty-free and specific licensing terms rest on fewer observations than citation frequencies of RAND patents.

Figure 2 about here

4.2. Variables

Our empirical analysis will be based on equations (3) and (4). According to equation (2), the dependent variable is Tobin's Q, the ratio of the market value of the firm to the replacement (book) value of its physical assets. Market value is defined as the sum of market capitalization (share price times the number of outstanding shares at the end of the year), preferred stock, minority interests, and total debt minus cash. The 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 of past and present annual R&D expenditures of the firm with a constant depreciation rate (δ) of 15 percent. We use the following formula for the R&D stock of firm i in year t

$$R\&D\ stock_{it} = (1-\delta)\, R\&D\ stock_{it-1} + R\&D_{it} \tag{5}$$

in which the annual R&D expenditures enter GDP-deflated. Patent stocks and patent citation stocks are constructed in the same way. A specialty arises for the calculation of the R&D stock since companies may have conducted R&D before entering our sample. Hence, we calculate a starting R&D stock is calculated as

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

This starting value assumes that R&D expenditures prior to the sample has been growing at a constant rate g. Following Hall and Oriani (2006) and Hall et al. (2007) an annual growth rate of 8 percent has been assumed. In order to take industry-, time period- and standard-specific factors into account, estimations will further include industry and year dummies as well as dummy variables for disclosures at specific SSOs in given years.

4.3. Descriptive Statistics

Table 3 shows descriptive statistics for the sample and for firms that participate in standard-setting only. Table 4 presents correlation coefficients between variables. The sample includes overwhelmingly medium-sized and large companies. All observations are active in R&D and applied for patents. Average Tobin's Q is well above one. Market valuation of sample firms is thus beyond replacement value of tangible assets on average. The extent of firms' R&D activities, the size of their patent portfolios, received citations as well as standard-setting activities are all highly skewed in absolute as well as in relative terms. Only 6 percent of sample firms participate in standard-setting activities. The stock of announcements reaches its maximum 181 announcements per company. The majority of these announcements refers to reasonable and non-discriminatory licensing terms. Normalizing stock of licensing announcements over announcement stocks does not qualitatively change relative frequencies among announcements of different licensing terms. Furthermore, relative and absolute frequencies among different licensing announcements resemble the pattern of overall disclosure activities described in section 4.2. Overall, the extent of standard-setting activities is, however, low. On average, we observe 3.8 announcements per 100 patents.

Table 3 about here

The second half of Table 3 shows the descriptive statistics of the 653 observations that announce standard-relevant IP during 1986-2006. Participants in standard-setting in our sample are large and very large companies with higher stocks of tangibles assets, more R&D activities and larger patent portfolios. Standard-setting firms have on average a stock of 4.6 announcements of standard-relevant IP in which RAND announcements again dominate in absolute as well as in relative terms. In order to take into account a possible selection of important patents, citations to disclosed patents which have been received before their first disclosure year are separated from total citation stocks. Standard-active firms' essential patents receive on average 41.8 citations before they get the first time disclosed at SSOs. 1125 predisclosure citations is the maximum stock in our sample. Besides being an indicator for the importance of patents, citations also provide information on knowledge diffusion processes. Citations received from patents of third-party applicants can reflect competitive cumulative innovations based on knowledge spillovers whereas self-citations reflect own cumulative innovations. Citations to disclosed standard-relevant technologies are therefore separated from total citation stocks and differentiated between self and external citations. As is the case for citations to entire patent portfolios, citations to standard-relevant patents originate in larger parts from external applicants than from own subsequent patent applications, irrespective of associated licensing terms.

5. Market Value Estimations

We estimate the relation between firms' market valuation and disclosures to SSOs (equation (3)) using nonlinear least squares. Table 5 reports the estimated coefficients. We start with a model that includes R&D over assets only and then sequentially add stocks of patents, citations, disclosures to SSOs and announced licensing terms. All specifications include year and industry dummies as well as year-fixed effects for announcements to different SSOs. R&D, patent and citations stocks are positively and significantly related to Tobin's Q in all specifications. Increasing the extent to which IP is disclosed to SSOs do not appear to contribute to the firm value. Including furthermore either stocks of royalty-free, RAND or specific, non-RAND licensing intentions does also not show significant valuation effects that may be due to the high correlations among various announced licensing terms. Significant valuation effects do show up in estimations, then, that include all possible licensing terms for standard-relevant IP. We find a strong positive valuation announcing licensing intentions that do not comply with SSO's RAND encouragements. Furthermore, we find that announcements of royalty-free licensing intentions reduce strongly firm valuation conditional firm's other knowledge stocks. Conditional on firm's knowledge stocks and their importance measured by citation stocks, mere widespread adoption of own technology in standards without royalties does not seem to be value-creating firm strategy. The positive valuation effects of specific licensing announcements may, however, indicate that diffusion and adoption due to cooperative standardization can be difficult, since these licensing terms essentially precludes the technology to be included in standards set by open, voluntary and consensus-based standards.

With respect to the various SSOs in which firms may be active, we do not find significant effects of SSO dummies in most of the cases. Only disclosure activities to ISO show consistently negative valuation effects. Standards defined by ISO can be regarded as a final step in global standard setting efforts. It seems not unreasonable to assume that disclosed patents read on some standards developed at a subordinated level as inclusion to a standard is more likely the larger the installed customer based of products containing the technology (Weiss and Sirbu, 1990). ISO standards may, thus, not refer to cutting-edge technologies. ISO's negative stance towards intellectual property for long time could also be reflected in this negative coefficient.

Table 5 about here

The positive valuation of announcing specific licensing terms for standard-relevant IP might be driven by unobserved heterogeneity of respective IP. Rysman and Simcoe (2008) provide evidence that formulating technical design specifications in standards increases citation rates to standard-relevant patents but that these patents have pre-disclosure citation rates that are higher than comparable patents of the same age in the same technology. SSOs identify or attract apparently more important technologies. For the 556 disclosed standard-relevant patents in our sample, we calculate therefore the number of citations received before it has been disclosed the first time as standard-relevant to any SSO and re-estimate specification (8) of Table 5 using pre-disclosure citation stocks in order to control for possible selection effects.[11] Table 6 shows a large, strongly significant additional effect of pre-disclosure citations. The effects of announcing licensing intentions remain, however, qualitatively unchanged in their magnitudes and levels of significance. Column (2) of Table 1 investigates whether value effects of pre-disclosure citations differ by announced licensing terms to associated patents. There is no indication that the valuation of licensing intentions changes with pre-disclosure citation rates of associated patents.

Table 6 about here

The codification and coordination of interface designs in standards fosters their diffusion and adoption. Sequential and cumulative innovations are thereby facilitated. Own cumulative innovations building on standards could further leverage the contributions to standard setting efforts whereas rival incremental innovations could compete innovation rents away. Table 7 investigates whether there is evidence for leveraging standard-setting contributions by sequential and cumulative innovations. Citations to standard relevant IP are distinguished between citations accruing from subsequent patents of the same company and citations from patents of external applicants. It is studied whether self and external citations of patents to be licensed under different terms contribute to company value in addition to licensing announcements. They are therefore orthogonalized by the stock of respective licensing announcements. The effects for royalty-free, RAND and specific licensing announcements remain qualitatively unchanged although the negative valuation of royalty-free licensing announcements becomes slightly significant in estimations unconditional on other

[11] Please note that overall citation stocks are corrected by the number of separated citations in these and following estimations in order avoid double-counting biases.

contributions. We find a strongly significant value contribution of self-citations to patents that are licensed royalty-free or under RAND licensing terms in estimations conditional and unconditional on alternative licensing announcements. Third party citations to patents which are licensed royalty-free or under RAND terms lower contrarily company valuation at high levels of significance. Whereas external citations for patents which are not standard-relevant seem to measure technological importance, this appears not to be case for standard-relevant ones. Their negative valuation indicates that external cumulative innovations might dissipate the value that contributors to standards could appropriate. Own cumulative innovations, on the other hand, seem to reinforce value capturing efforts of technology providers to standards.

With regard to self and external citations of standard-relevant IP which is licensed under specific, non-RAND terms, regressions conditional and unconditional on remaining licensing contributions deliver conflicting results. Unconditional regressions appear to be in line with prior results. External citations reduce slightly the value of specific licensing intentions which speaks for capturing value by own commercial exploitation. Conditional on other licensing announcements, it appears that standard-relevant IP, which is licensed under terms that do not conform to be RAND, creates value from its blocking power to external innovations. Subsequent regressions will have to further investigate these conflicting results.

Table 7 about here

Table 8 - Table 10 in the appendix re-estimate preceding models using an alternative estimation approach that allows to control for fixed effects based on pre-sample information for the dependent variable (cf. Blundell et al., 1995). This approach includes fixed effects as the average value of the dependent variable in the period 1976-1985, which is included as an additional regressor. It has the further advantage that it does not require strict exogeneity of the rightern-side variables. Czarnitzki and Dhaene (2011) show that the pre-sample fixed effects approach is consistent and efficient for non-linear least squares regressions and show that the original regression results of Hall et al. (2005) hold still if pre-sample fixed effects are taken into account. This approach shows that a large part of firm valuations is explained by unobserved firm-specific effects. It further reveals that the estimation results discussed above are not driven by unobserved heterogeneity. Royalty-free licensing intentions remain negatively valued whereas specific licensing terms still contribute to firm valuation. Conditional heterogeneities in company valuation, announcing standard relevant IP to be licensed under RAND terms shows strongly significant valuation effects in estimations conditional and unconditional on alternative IP contributions (Table 8). Pre-disclosure

citations do not further contribute to company valuation when heterogeneities in profitability are controlled for. The negative effect of pre-disclosure citations to standard relevant IP to be licensed royalty-free indicates the negative valuation of royalty-free IP announcements increases the more important the respective technology is (Table 9). Table 10 reports valuation effects of self and external citations when unobserved firm heterogeneities are controlled for. The estimations confirm above results regarding contributions of self and external citations to standard relevant IP in regressions unconditional on remaining licensing contributions to standards. In estimations including all terms of licensing announcements, self and external citations to standard relevant IP show significant valuation only with respect to IP licensed under RAND terms. The positive value contribution of external citations and the negative valuation of self-citations to patents which are licensed under specific, non-RAND terms are not significant anymore when unobserved firm heterogeneity is controlled for. The resembling valuation of blocking power to external cumulative innovations in Table 7 seems to be driven by firm heterogeneities, like heterogeneities in IP strategies.

In order to get an indication of the economic magnitude of estimated effects, we present semi-elasticities of Tobin's Q with regard to the explanatory variables in Table 11 based on estimated coefficients in Table 10.[12] With respect the variables of main interest, we find that a conditional increase in the share of specific, non-RAND licensing intentions increases company valuation relatively more than increasing the share of RAND licensing announcements. An one-unit change of the ratio of announced royalty-free licenses from 0 to 1 would lower company valuation, ceteris paribus, by 41 percent. One-unit changes in the ratios of RAND (specific, non-RAND) announcements would increase company valuations, ceteris paribus by 16 (33) percent. Using the standard deviations as a more realistic change in the magnitudes of licensing announcements, we find that announcing 5 percentage points more specific, non-RAND licensing intentions and 5 percentage points less royalty-free licenses avoids a decrease in company valuation by 2.1 percent and contributes a further increase of 1.6 percent. Thus, 5 percentage points more specific licenses and a corresponding share less royalty-free licensing intentions increases company valuation by 3.7 percent. An

[12] In comparison to Hall et al.s' (2005) results for the market value of R&D and patenting, we find a lower impact of R&D on company value and larger impact of firm's patent stocks. Hall et al.s' (2005) results refer to pooled estimations in manufacturing for the period 1979-1988 whereas our dataset focuses on machinery and electronics-related sectors from 1986-2002. Hall (1993) reports that particularly in those industry sectors in our sample 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.

additional external citation per announcement of standard relevant IP reduces company valuation by 0.5 percent for royalty-free and RAND IP, whereas external citations to specific, non-RAND IP reduce it by 3.5 percent, respectively. An additional self-citation per announcement increases company valuation by 2.3 (1.6) percent for royalty-free (RAND) announcements. The focus of royalty-free contributions on diffusion and adoption instead of licensing revenue renders subsequent innovations, apparently, more important for capturing value from standardized technology.

Table 11 about here

6. Conclusion

The importance of voluntary standard-setting organizations (SSOs) has grown tremendously in recent decades. In many cases, compatibility standards developed by these informal organizations supplanted standard-setting approaches in formal national or international standard development bodies (Cargill, 2002). SSOs provide a forum for cooperative and pro-competitive coordination on standards in an open, voluntary and consensus-based manner. Standards foster diffusion, adoption and cumulative innovations of new technologies (Bessen, 2012). Standardization of new technologies contributes thereby to economic growth but these positive effects get alleviated by business-stealing effects from rival incremental innovations (Acemoglu et al. 2010). Empirical evidence for the returns of standard-setting activities to technology providers is, however, missing so far. In view of their importance for firm’s competitiveness (e. g. de Lacey et al., 2006), this is surprising.

In order to fill this gap, we follow Griliches (1981) and Hall et al. (2005) by employing a market value approach for a sample of 609 publicly traded companies covering the period 1986 to 2006. Data on firm’s standard-setting activities have been retrieved from eight major SSOs. These organizations follow an open, voluntary and consensus-based policy. They permit standards to include patent-protected technology if licenses are granted on reasonable and non-discriminatory (RAND) terms and “technical reasons justify this approach” (ANSI 2011, p.7). Technical specifications which can be adopted without entailing royalties are, however, preferred as standard. Standard-setting bodies require their members to disclose standard relevant IP and associated licensing intentions upfront during the standardization process. We have investigated whether these announcements of standard relevant IP contribute to firm’s market value in addition to their R&D and patents. We do not find that these technology disclosure events are valued by financial markets. Controlling for unobserved heterogeneity and distinguishing between different types of licensing intentions, we do, however, find positive and strongly significant contributions to firm value by standard relevant IP and licensing it under RAND and specific, non-RAND terms.

In view of the increasing importance of IP for business strategy (e. g. Kline and Rivette, 2000), standard-setting bodies have to reconcile their objective of widespread standard adoption with their objective of providing standards of high technical quality. Licenses on RAND terms for essential patents shall strike this balance in cases for which inclusion of proprietary technology is justified. Licenses on RAND terms may, however, be insufficient to induce participation of technology providers. Technology providers may insist on their right on exclusivity and command licenses on specific, non-RAND terms. Cooperative standard specifications that read on this technology are essentially blocked and cannot be approved by open and consensus-based SSOs. In these cases, the right to exclusivity is apparently more valued the increasing number of technology adopters due to standardization. The higher importance of exclusive technology should then then be reflected in associated valuations of licensing announcements. Estimated semi-elasticities of technology disclosures indeed show that the value contribution of IP announcements increase in the restrictiveness of licensing terms (conditional at each time on other types of licensing intentions).

Besides firms that command royalties for their IP to be included in standards, others waive these rights. Forgoing licensing revenues seems puzzling and should be negatively valued by financial markets. Indeed, we find evidence for a negative valuation of royalty-free licensing announcements. Firms might, nevertheless, capture value from their technology contributions due to an increased standard adoption. Subsequent cumulative innovations could be one mechanism to profit from a wide standard adoption. In line with this argument, our evidence has indicated that self-citations to IP contributed to standards are more valuable when it has been licensed royalty-free than when it is licensed under RAND terms. When sequential standard-compatible innovation is conducted by rivals, the extent to which value can be captured from the standard should decrease. We find, accordingly, a negative valuation effect of third party citations to own standard relevant IP, irrespective of associated licensing intentions. There has been some indication that specific, non-RAND licensing intentions might increase in value with third party citations to respective patents. This could have indicated a valuation of blocking power. Such valuation effects are, however, not found any more when we control for unobserved firm heterogeneities.

This paper has provided evidence on the value of standard-setting activities for technology sponsors. The sources of value creation from cooperative standard setting remain, however, unclear. SSOs could create value because they clear mutually blocking patent rights, prevent royalty stacks and the risk of hold up and/or because standards facilitate leveraging demand and production complementarities. Future research has to clarify the roles of these different dimensions in value creation from standard-setting.

7. Data Appendix

Figure 1 Announcements to SSOs over time

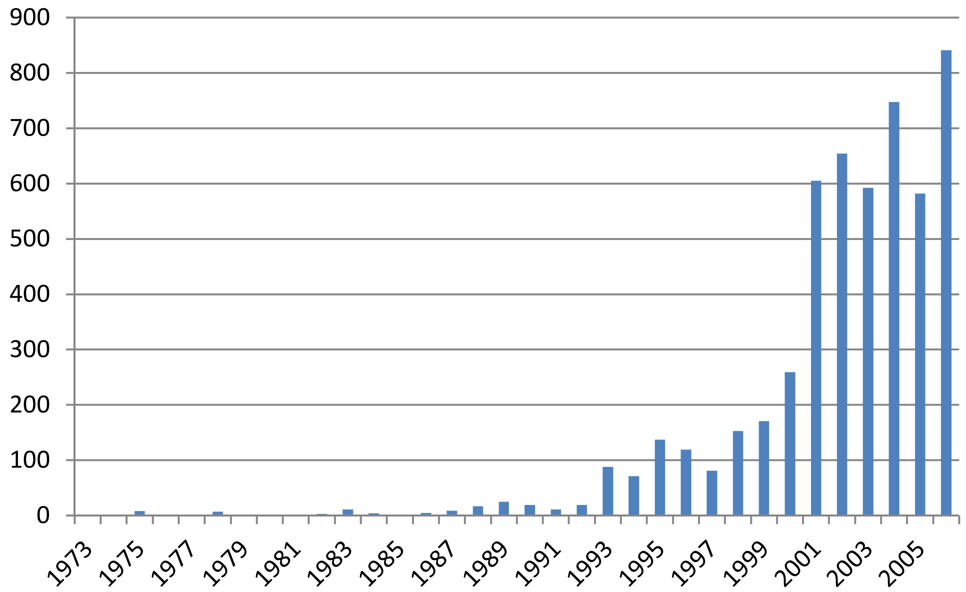

Table 1 Disclosure events by SSOs

Standard-setting Organization	Disclosures	Percent
ANSI	275	5
ATIS	62	1
ETSI	2483	47
IEEE	351	7
IETF	706	13
ISO	466	9
ITU	691	13
TIA	210	4
	5244	

Table 2 Disclosed licensing intentions

Licensing Terms	Number	Percent
Free of Royalties	341	7
RAND	4165	79
Specific Licensing terms	61	1
No information provided	677	13
Total	5244	

Figure 2 Citations frequencies of disclosed patents

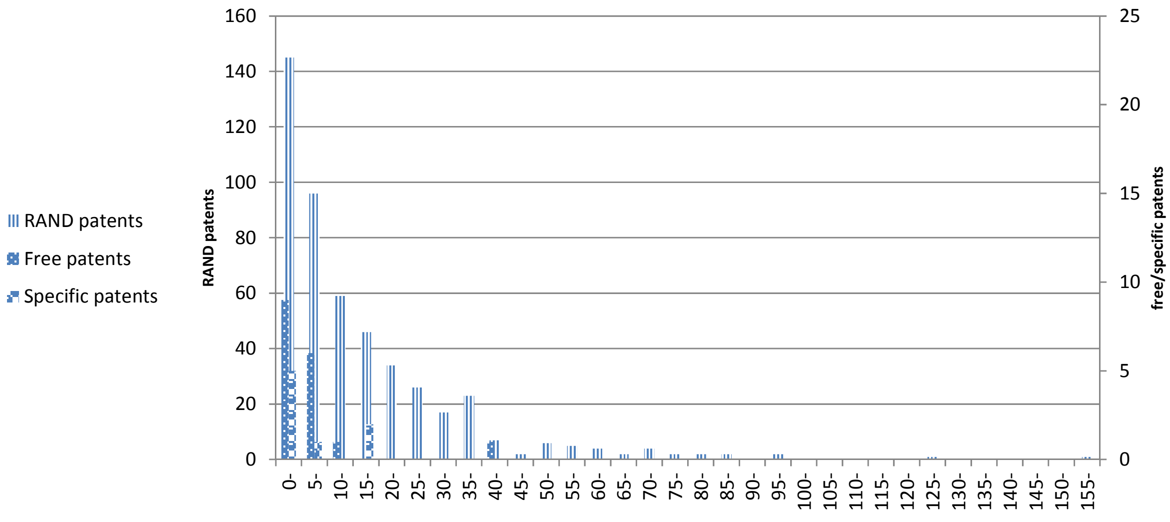

Table 3 Descriptive Statistics

	Sample			Standard-active firms		
	Mean	Median	Std.dev.	Mean	Median	Std.dev.
TobinQ	1.23	0.77	1.68	1.17	0.80	1.59
Market value	2866	146	11468	18274	8463	30849
Tangible assets	3087	177	10743	21174	11923	26006
R&D stocks	817	40	3069	5863	2804	7693
Patent stocks	288	12	1170	2278	790	3123
Citation stocks	3001	97	13928	24761	8598	39033
Predisclosure citation stocks	3.92	0	42.24	41.84	0	133.38
Selfcitation stocks	0.80	0	8.28	8.56	0	26.05
External citation stocks	3.46	0	36.25	37.03	0	114.10
Announcement stocks	0.42	0	4.59	4.60	0.72	14.50
Royalty-free Announ.	0.02	0	0.22	0.22	0	0.69
RAND Announ.	0.30	0	4.16	3.24	0	13.38
Specific Announ.	0.01	0	0.17	0.12	0	0.56
Selfcitations to royalty-free patents	0.05	0	0.87	0.48	0	3.77
External citations to royalty-free patents	0.23	0	4.47	2.34	0	20.34
Selfcitations to RAND patents	0.68	0	7.42	2.23	0	8.03
External citations to RAND patents	3.24	0	35.33	10.27	0	30.08
Selfcitations to specifically-termed patents	0.01	0	0.30	0.05	0	0.44
External citations to specifically-termed patents	0.05	0	1.09	0.20	0	1.58
d_ANSI	0.005	0	0.074	0.060	0	0.24
d_ATIS	0.001	0	0.036	0.014	0	0.117
d_ETSI	0.003	0	0.057	0.035	0	0.18
d_IEEE	0.002	0	0.047	0.025	0	0.15
d_IETF	0.004	0	0.062	0.041	0	0.20
d_ISO	0.010	0	0.098	0.106	0	0.31
d_ITU	0.011	0	0.105	0.121	0	0.33
d_TIA	0.001	0	0.036	0.012	0	0.11
No. of Obs.		7103			653	

All financial data in mln US$

Table 4 Correlation Matrix

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
TobinQ	(1)																
R&D/assets	(2)	0.234 ***															
Patents/R&D	(3)	0.040 ***	-0.099 ***														
Citations/Patents	(4)	0.150 ***	0.188 ***	-0.073 ***													
Predisclosure citations/Patents	(5)	0.089 ***	0.046 ***	-0.018	0.026 **												
Self Citations/Patents	(6)	-0.008	-0.004	-0.025 **	-0.008	0.040 ***											
External Citations/Patents	(7)	0.089 ***	0.046 ***	-0.018	0.027 **	1.000 ***	0.025 **										
Announ./Patents	(8)	0.031 ***	0.066 ***	-0.019	-0.002	0.113 ***	-0.002	0.113 ***									
Free Announ./Announ.	(9)	-0.014	0.014	-0.007	0.001	-0.003	0.023 **	-0.002	-0.003								
RAND Announ./Announ.	(10)	0.018	0.034 ***	-0.042 ***	0.013	0.206 ***	0.122 ***	0.205 ***	0.097 ***	0.272 ***							
Specific Announ./Announ.	(11)	-0.001	-0.006	-0.008	-0.001	-0.002	0.018	-0.002	-0.003	0.538 ***	0.169 ***						
Self Citations to Free Patents/Free Announ.	(12)	-0.009	-0.005	-0.014	-0.003	0.001	0.061 ***	0.001	-0.001	0.106 ***	0.120 ***	0.107 ***					
External Citations to Free Patents/Free Announ.	(13)	-0.010	-0.004	-0.013	-0.002	0.001	0.056 ***	0.001	-0.001	0.094 ***	0.112 ***	0.104 ***	0.947 ***				
Self Citations to RAND Patents/RAND Announ.	(14)	-0.007	0.002	-0.017	-0.003	0.014	0.249 ***	0.011	-0.003	0.070 ***	0.416 ***	0.039 ***	0.284 ***	0.251 ***			
External Citations to RAND Patents/RAND Announ.	(15)	-0.016	0.002	-0.023 *	-0.009	0.061 ***	0.226 ***	0.058 ***	-0.001	0.057 ***	0.486 ***	0.014 *	0.096 ***	0.097 ***	0.806 ***		
Self Citations to Specific Patents/Specific Announ.	(16)	-0.008	-0.003	-0.012	0.001	0.001	0.045 ***	0.001	-0.001	0.068 ***	0.124 ***	0.136 ***	0.811 ***	0.868 ***	0.186 ***	0.092 ***	
External Citations to Specific Patents/Specific Announ.	(17)	-0.007	-0.002	-0.011	0.002	0.001	0.041 ***	0.001	-0.001	0.070 ***	0.130 ***	0.124 ***	0.729 ***	0.848 ***	0.161 ***	0.088 ***	0.963 ***

Table 5 Base estimations

Dependent: *ln* (TobinQ)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
R&D/assets	0.077 ***	0.087 ***	0.083 ***	0.083 ***	0.083 ***	0.083 ***	0.083 ***	0.083 ***
Patents/R&D		0.087 ***	0.098 ***	0.099 ***	0.099 ***	0.099 ***	0.098 ***	0.098 ***
Citations/Patents			0.006 ***	0.006 ***	0.006 ***	0.006 ***	0.006 ***	0.006 ***
Announ./Patents				0.015	0.015	0.015	0.015	0.015
Free Announ./Announ.					-0.261			-0.580 ***
RAND Announ./Announ.						0.000		0.025
Specific Announ./Announ.							0.155	0.536 ***
d_ANSI	0.048	0.058	0.055	0.059	0.075	0.059	0.050	0.059
d_ATIS	0.160	0.168	0.161	0.154	0.149	0.153	0.157	0.152
d_ETSI	0.166	0.165	0.168	0.155	0.149	0.155	0.157	0.144
d_IEEE	-0.126	-0.119	-0.123	-0.123	-0.124	-0.123	-0.126	-0.139
d_IETF	-0.012	-0.013	-0.006	0.002	0.007	0.002	0.001	0.007
d_ISO	-0.293 ***	-0.289 ***	-0.288 ***	-0.296 ***	-0.294 ***	-0.296 ***	-0.296 ***	-0.293 ***
d_ITU	-0.025	-0.016	-0.014	-0.012	-0.005	-0.012	-0.010	0.000
d_TIA	0.262	0.272	0.279	0.278	0.280	0.278	0.279	0.282
Industry- and Timedummies included								
Observations	7103							

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

Table 6 Estimation of patent selection effects

Dependent: *ln* (TobinQ)	(1)	(2)
R&D/assets	0.079 ***	0.083 ***
Patents/R&D	0.098 ***	0.098 ***
Citations/Patents	0.006 ***	0.006 ***
Announ./Patents	0.004	0.014
Free Announ./Announ.	-0.549 ***	-0.587 ***
RAND Announ./Announ.	-0.050	0.082
Specific Announ./Announ.	0.552 ***	0.528 ***
Pre-Disclosure Citations/Patents	0.338 ***	
Pre-Free Disclosure Citations/Free Announ.		-0.001
Pre-RAND Disclosure Citations/RAND Announ.		-0.001
Pre-Specific Disclosure Citations/Specific Announ.		-0.006
d_ANSI	0.090	0.069
d_ATIS	-0.411	0.167
d_ETSI	0.118	0.125
d_IEEE	-0.147	-0.142
d_IETF	0.034	-0.002
d_ISO	-0.263 ***	-0.295 ***
d_ITU	0.036	0.004
d_TIA	0.320	0.330
Industry- and Timedummies included		
Observations	7103	

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

Table 7 Self and external citations to disclosed patents

Dependent: *ln* (TobinQ)	(1)	(2)	(3)	(4)
R&D/assets	0.073 ***	0.073 ***	0.072 ***	0.074 ***
Patents/R&D	0.098 ***	0.096 ***	0.097 ***	0.096 ***
Announ./Patents	0.002	0.002	0.002	0.002
Self Citations/Patents	0.466	0.232	0.418	0.249
External Citations/Patents	0.313 **	0.314 **	0.316 **	0.307 **
Free Announ./Announ.	-0.268 *			-0.540 ***
RAND Announ./Announ.		-0.026		-0.011
Specific Announ./Announ.			0.161	0.519 ***
Self Citations to Free Patents/Free Announ.	0.047 ***			0.079 **
External Citations to Free Patents/Free Announ.	-0.008 ***			-0.015 **
Self Citations to RAND Patents/RAND Announ.		0.022 ***		0.022 ***
External Citations to RAND Patents/RAND Announ.		-0.006 ***		-0.006 ***
Self Citations to Specific Patents/Specific Announ.			0.109	-0.545 *
External Citations to Specific Patents/Specific Announ.			-0.048 *	0.166 **
d_ANSI	0.098	0.009	0.095	0.029
d_ATIS	-0.413	-0.289	-0.421	-0.277
d_ETSI	0.055	0.083	0.061	0.066
d_IEEE	-0.160	-0.140	-0.143	-0.202
d_IETF	-0.024	-0.020	-0.014	-0.044
d_ISO	-0.302 ***	-0.245 **	-0.303 ***	-0.245 **
d_ITU	-0.013	0.014	0.000	0.023
d_TIA	0.304	0.326	0.299	0.342
Industry- and Timedummies included				
Observations	7103			

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

Table 8 Base estimations including pre-sample means (PSM)

Dependent: *ln* (TobinQ)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
R&D/assets	0.022 ***	0.026 ***	0.024 ***	0.024 ***	0.024 ***	0.023 ***	0.024 ***	0.023 ***
Patents/R&D		0.059 ***	0.064 ***	0.064 ***	0.064 ***	0.065 ***	0.064 ***	0.065 ***
Citations/Patents			0.003 ***	0.003 ***	0.003 ***	0.003 ***	0.003 ***	0.002 ***
Announ./Patents				0.001	0.001	0.000	0.001	0.000
Free Announ./Announ.					-0.144			-0.437 ***
RAND Announ./Announ.						0.196 ***		0.219 ***
Specific Announ./Announ.							0.151	0.332 ***
d_ANSI	-0.013	-0.006	-0.007	-0.006	0.004	-0.042	-0.016	-0.038
d_ATIS	0.058	0.068	0.064	0.063	0.060	0.018	0.067	0.014
d_ETSI	0.157	0.158	0.159	0.158	0.155	0.103	0.160	0.093
d_IEEE	-0.056	-0.052	-0.054	-0.054	-0.055	-0.074	-0.058	-0.086
d_IETF	0.049	0.048	0.051	0.052	0.055	0.025	0.051	0.030
d_ISO	-0.104	-0.102	-0.103	-0.104	-0.103	-0.137 *	-0.103	-0.135
d_ITU	0.089	0.094	0.095	0.095	0.099	0.012	0.097	0.018
d_TIA	0.264	0.271	0.275	0.275	0.276	0.212	0.277	0.214
Pre-sample *ln* (Tobin Q)	0.410 ***	0.407 ***	0.403 ***	0.403 ***	0.403 ***	0.405 ***	0.403 ***	0.404 ***
Industry- and Timedummies included								
Observations	7103							

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

Table 9 Estimation of patent selection effects (PSM)

Dependent: *ln* (TobinQ)	(1)	(2)
R&D/assets	0.023 ***	0.023 ***
Patents/R&D	0.065 ***	0.065 ***
Citations/Patents	0.002 ***	0.002 ***
Announ./Patents	-0.001	0.000
Free Announ./Announ.	-0.431 ***	-0.439 ***
RAND Announ./Announ.	0.201 ***	0.236 ***
Specific Announ./Announ.	0.335 ***	0.353 ***
Pre-Disclosure Citations/Patents	0.028	
Pre-Free Disclosure Citations/Free Announ.		-0.002 **
Pre-RAND Disclosure Citations/RAND Announ.		0.000
Pre-Specific Disclosure Citations/Specific Announ.		-0.006
d_ANSI	-0.030	0.004
d_ATIS	-0.097	-0.002
d_ETSI	0.090	0.079
d_IEEE	-0.087	-0.095
d_IETF	0.035	0.026
d_ISO	-0.130	-0.140 *
d_ITU	0.027	0.039
d_TIA	0.237	0.223
Pre-sample *ln* (Tobin Q)	0.403 ***	0.405 ***
Industry- and Timedummies included		
Observations	7103	

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

Table 10 Self and external citations to disclosed patents (PSM)

Dependent: *ln* (TobinQ)	(1)	(2)	(3)	(4)
R&D/assets	0.020 ***	0.020 ***	0.020 ***	0.021 ***
Patents/R&D	0.071 ***	0.070 ***	0.070 ***	0.070 ***
Announ./Patents	-0.001	-0.002	-0.001	-0.002
Self Citations/Patents	7.027 ***	6.191 ***	6.870 ***	6.301 **
External Citations/Patents	0.037	0.029	0.038	0.029
Free Announ./Announ.	-0.181			-0.423 ***
RAND Announ./Announ.		0.155 **		0.168 **
Specific Announ./Announ.			0.153	0.339 ***
Self Citations to Free Patents/Free Announ.	0.024 ***			0.039
External Citations to Free Patents/Free Announ.	-0.005 ***			-0.008
Self Citations to RAND Patents/RAND Announ.		0.016 ***		0.017 ***
External Citations to RAND Patents/RAND Announ.		-0.005 ***		-0.005 ***
Self Citations to Specific Patents/Specific Announ.			0.034	-0.325
External Citations to Specific Patents/Specific Announ.			-0.037 **	0.080
d_ANSI	0.005	-0.112	0.013	-0.055
d_ATIS	-0.270	-0.144	-0.278	-0.164
d_ETSI	0.078	0.057	0.084	0.038
d_IEEE	-0.132	-0.120	-0.109	-0.153
d_IETF	0.019	-0.005	0.030	-0.013
d_ISO	-0.117	-0.101	-0.117	-0.102
d_ITU	0.092	0.031	0.102	0.052
d_TIA	0.235	0.236	0.230	0.232
Pre-sample *ln* (Tobin Q)	0.409 ***	0.408 ***	0.409 ***	0.408 ***
Industry- and Timedummies included				
Observations	7103			

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

Table 11 Semielasticities

Dependent: *ln* (TobinQ)	(1)	(2)	(3)	(4)
R&D/assets	0.020 ***	0.020 ***	0.019 ***	0.020 ***
Patents/R&D	0.068 ***	0.067 ***	0.068 ***	0.067 ***
Self Citations/Patents	6.779 ***	5.975 **	6.630 ***	6.081 **
External Citations/Patents	0.036	0.028	0.036	0.028
Announ./Patents	-0.001	-0.002	-0.001	-0.002
Free Announ./Announ.	-0.174			-0.408 ***
RAND Announ./Announ.		0.149 **		0.163 **
Specific Announ./Announ.			0.148	0.327 ***
Self Citations to Free Patents/Free Announ.	0.023 **			0.037
External Citations to Free Patents/Free Announ.	-0.005 ***			-0.008
Self Citations to RAND Patents/RAND Announ.		0.016 ***		0.016 ***
External Citations to RAND Patents/RAND Announ.		-0.005 ***		-0.005 ***
Self Citations to Specific Patents/Specific Announ.			0.033	-0.314
External Citations to Specific Patents/Specific Announ.			-0.035 **	0.077

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

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