Drivers for Companies' Entry Into Standard-Setting Organizations

Knut Blind, Annika Lorenz, and Julius Rauber

***Abstract*—Globalization has been a main driver for firms' entry into standard-setting organizations (SSOs). These global multifirm settings have caught attention due to tensions arising from simultaneous collaboration and competition among firms as well as due to the increasing geographical complexity of the standardization process. SSOs present one form of a multifirm environment, where companies proactively and voluntarily collaborate to develop a new standard. Although a growing body of literature has tried to understand firms' underlying rationales for engaging in SSOs, we know little about firm-level characteristics influencing the propensity to enter a standard-setting organization. For this purpose, data of the Community Innovation Survey 2011 for Germany are merged with data of companies' participation at technical committees of the German Institute for Standardization (DIN) between 2010 and 2013. Using these unique data, we can observe the moment when firms enter a technical committee of a formal SSO and, hence, tackle the problem of simultaneity. Our results show that the likelihood to enter a technical committee of an SSO increases for firms that introduce new products or services into the market, while absorptive capacity does not have a significant positive influence. Finally, the protection of innovations by patents further enhances the likelihood to enter a technical committee of an SSO.**

***Index Terms*—Complexity of standards, hazard model, multifirm settings, standardization, standard-setting organizations.**

I. Introduction

A MULTIFIRM setting describes a collective, voluntary collaboration between different organizational partners that interactively engages its multiple members in multilateral interaction among partners and thus generates unique dynamics. On one hand, partners engage in multifirm environments to achieve common objectives; on the other hand, there might be underlying tensions with respect to their individual interests and value capture strategies to get the largest share from that collaboration [64]. As a result, multifirm interactions shape coordination, competitive, and cooperative activities of firms.

Firms increasingly engage in multifirm settings due to accelerated product and technology life cycles, shortened time-to-market and higher costs for R&D [70]. Additionally, the growing complexity of technologies and products driven by a fragmentation of intellectual property rights and a further differentiation of value chains has increased the importance of multifirm environments such as described by multifirm alliances, R&D consortia, platforms, and standard-setting organizations (SSOs) [42], [61].

A particular form of a multifirm setting is elucidated in formal SSOs, which has evoked interest by several researchers because of their importance to shape technological trajectories and dominant designs and the resulting tensions arising from simultaneous collaboration and competition firms engaging in SSOs encounter ([9], [22], [81]). However, despite these competitive concerns, the growing membership numbers and a continued proliferation of standards bodies suggests an organizational form that enables the participating firms to manage such competitive tensions to attain a cooperative technology agreement. Wiegmann [104] show that companies often simultaneously engage in markets, SSOs and lobbying. Moreover, Leiponen [65] and Bar and Leiponen [8] and recently Vasudeva *et al*. [98] have begun to investigate companies' contributions to activities within SSOs. At the same time, SSOs are growing in importance due to the globalization of innovation [27]. The BRICs countries heavily promote technology standardization to further encourage and facilitate innovation activities and to become more dominant in global markets. Particularly, in environments of high market uncertainty formal standards lead to higher innovation efficiency [24]. Moreover, the complexity of the standardization process increases due to globalization as the number of actors, which may have different agendas multiplies. Hence, in an ever more globalized world, it is important to understand the drivers of firms' entry into SSOs.

Voluntary standard-setting committees offer the institutional framework environment for such coordination activity leading to so called de jure standards.[1] SSOs provide the arena for multifirm collaborative interaction by encompassing the entire ecosystem to coordinate the technical interoperability between various system components eventually reducing uncertainty and spurring

Manuscript received October 30, 2018; revised September 29, 2019, December 13, 2019, and January 31, 2020; accepted February 8, 2020. Date of publication June 29, 2020; date of current version November 13, 2020. The work of Knut Blind was supported by the European Union's Horizon TS.3 2020 research and innovation programme under Grant 778420—EURITO. The work of Julius Rauber was supported in part by the HARTING Technology Group and in part by the German Standardisation Institute DIN. Review of this manuscript was arranged by Department Editor E. Vairdot. *(Corresponding author: Annika Lorenz.)*

Knut Blind is with the Technische Universität Berlin, 10587 Berlin, Germany, and also with the Fraunhofer ISI, 76139 Karlsruhe, Germany (e-mail: knut.blind@tu-berlin.de).

Annika Lorenz is with the Copernicus Institute for Sustainable Development, Innovation Studies, Utrecht University, 3584 Utrecht, The Netherlands, and also with Technische Universität Berlin, 10587 Berlin, Germany (e-mail: annika.lorenz@tu-berlin.de).

Julius Rauber is with the Technische Universität Berlin, 10587 Berlin, Germany, ConPolicy GmbH-Institut für Verbraucherschutz, Berlin 10969, Germany (e-mail: j.rauber@conpolicy.de).

Digital Object Identifier 10.1109/TEM.2020.2975427

[1]De facto standards emerge from market-based competition as consumers gravitate toward one technical alternative (e.g., VHS vs. Betamax).

industry growth [65], [82], [84]. Despite SSOs being influential organizational settings that drive technological change and evolution, research is yet to investigate the firm-level antecedents of firms' engagement in SSOs. Only Axelrod *et al*. [7] theorized how firms form alliances by joining SSOs based on analyzing the choices of nine computer companies in a qualitative manner. Although we know why firms contribute to standardization, their underlying strategic motives and the formation processes associated with standardization committees, previous research tends to overlook why firms enter standardization in the first place and what firm-level characteristics influence that entry decision. For instance, Baron *et al*. [11] investigate R&D investments after the SSO entry, but this article studies the drivers for the SSO entry. Our research question thus is: Which firm-level factors explain firms' entry into SSOs?

Although, some prior studies [19], [21], [23], [52], [101] explored the characteristics of firms that participate in SSOs, they have some data-related shortcomings which we address in this article: First, the limited empirical work mentioned above is either only representative for a specific sector (e.g., Wakke *et al*. [101] for the service sector or Blind and Mangelsdorf [21] for the electrical engineering and machinery industry) or relied on limited samples for the analyzed population [19], [23], [52]. Second, and even more important, most existing papers explore correlations between firm characteristics and standardization engagement using cross-sectional data and may therefore be subject to endogeneity problems due to simultaneity. For example, the relationship between innovations and standards is in theory assumed to be reciprocal [4]. Innovative companies are supposed to be more likely to participate in standardization committees since "the standardization process is a continuation of the development phase of internal R&D" [19]. Conversely, Nambisan [72] shows that participation in technical committees that are central to the company's existing product technologies and offerings will contribute to its competence-enhancing innovation. Hence, engagement in standardization is supposed to help converting companies' R&D results into successful innovations. Thus, it is not clear, if innovative firms are more often active in SSOs or if the participation in SSOs helps firms to innovate more successfully. Since both directions of causality are reasonable, it is not possible to identify the isolated effects by solely observing one point in time. Specifically, the above-cited existing studies rely only on cross-sectional data and are not able to identify the driving factors for firms' decision to enter standardization. However, there are two exceptions in the current literature, Baron *et al*. [9] conduct a panel analysis based on a sample of the world's largest R&D performing firms to explain their membership in 180 standards organizations. In addition, they use changes in tax policies related to revenues generated from patent portfolios to construct an instrumental variable and to perform a two-stage regression analysis. Finally, Fischer and Henkel [40] apply a conjoint-based method based on discrete choice experiments with managers to study interactions between product-related patents and contributions to open standards. Our study aims to expand the analysis of entry decisions by applying a rigorous quantitative approach not limited to a specific sector or special types of companies. Consequently, this article reveals the drivers for a firm's decision to join technical committees at the main formal SSO for Germany, the German Institute for Standardization (German: Deutsches Institut für Normung, DIN e.V.).[2]

This article contributes to extant research on the drivers for entering SSOs, solving the problem of simultaneity by deploying different points in time. Using survival analysis, the effect of firm size, absorptive capacity, innovation activity, patent activity, and sector-affiliation on the propensity to enter formal standardization organizations in the following years is identified. The empirical analysis relies on data of the Community Innovation Survey for Germany 2011, which contains information about the firm characteristics for the years 2008–2010. This data is supplemented with information about the participation of firms at the German Institute for Standardization (DIN) in 2010 as well as the entry of firms between 2011 and 2013. Using different points in time for observing firm characteristics (2008–2010) and the time of entry at the DIN (2011–2013), respectively, it is assured that a firm's characteristics are observed before its entry at the SSO. Thus, it is possible to address endogeneity caused by the simultaneity between the explaining variables and the dependent variable, since the entry at the SSO cannot have an influence on the observed firm characteristics.

The remainder of the article is structured as follows. First, we outline literature studying the most important drivers for standardization engagement and derive our hypotheses. Second, the sample is introduced, and the empirical methodology is explained. Afterward, results of the survival analysis are presented. Finally, the results are discussed, limitations and implications for further research are presented.

II. Entry Into Standard-Setting Organizations

Previous literature has described several multifirm environments where entities come together and collaborate rather than compete to be able to achieve common objectives.

Firms' entry into SSOs or their technical committees can be considered as another form of a multifirm environment. SSOs have been described as "industry-wide multifirm collaborative arrangements that bring together representatives from several firms to derive the technical rules of compatibility between various system components [81, p. 3194]".[3] Standard organizations operate in working groups and committees. By promoting divergent viewpoints, they bring together heterogeneous firms with unique resources and path-dependent investments. Firms participating in the same committees at SSOs are also often competing with one other in current technological developments and product markets [33], [82]. "Standards" are the technical specifications that define the rules

[2]This article focuses exclusively on the participation in specific open SSOs and does not cover participation in closed consortia, since there are probably other factors influencing the likelihood to enter.

[3]In recent times of dominant standards such as WiFi, 3G, and HDMI, SSOs have burgeoned as technology coordination forums in the information and communications technology sector (ICT) [81].

of interaction between the different complementary technologies that comprise a system [81, p. 3196]. Hence, firms participate in SSOs in order to favorably influence the direction of the standard by either submitting technical proposals within the working groups or by successfully contesting competing proposals put forth by other firms [81]. Despite the administrative effort, standardization has become an increasingly important strategic tool for companies over the last decades. Besen and Farrell [18] emphasize the growing importance of the subject by stating that "standard-setting has been transformed from an internal matter for individual firms to a subject of cooperation and competition among individual players" [18], which can be regarded as a special form of coopetition [26]. Moreover, [18] highlight that "a firm that controls a technology that becomes established as a standard can have an extremely profitable market position." Hence, while firms engage in SSOs to monitor and shape current industry trends, and reduce uncertainty, the ultimate choice for a specific technical solution may create a tension between competition and collaboration [81]. Each participant has the goal to dominate and steer the collective discussion toward maximizing own benefits [39], [60]. As SSOs require the open disclosure of technologies to be able to incorporate them into a standard, competitive concerns may rise [77], [97]. These competitive tensions can cause delays or even failures in the standard-setting process if firms cannot arrive at a compromise [39].

The standardization process in formal SSOs is (in contrast to most consortia) open to all interested parties, thus no one can be excluded. There are several reasons for firms to join formal standardization in SSOs (e.g. [22]) and, thereby, to help developing standards. In particular, companies contribute to the standardization process even if formal standards are seen as public goods in the literature (see, e.g., [62], [94], [94]) for which it is not possible to appropriate the outcome of the standardization process to the firm exclusively. However, the involvement in the development process facilitates the implementation of the standard and creates a competitive advantage compared to firms not active in the standardization process [102]. Likewise, companies can influence the upcoming standards in the standardization process and hence raise cost for their rivals [90], fight for the best position to diffuse their technologies [20], and, thereby, raise their own market shares [65], [102]. For some technologies engaging in SSOs can be detrimental for getting access to the technology and for subsequent commercialization and diffusion of the technology, e.g., in standard-essential patents [12], [13], [92]. Hence, the participation in SSOs is not arbitrary, but a strategic decision and contingent on firm characteristics. The following paragraph discusses the main characteristics according to the literature and their possible influence on the decision to enter an SSO. Furthermore, hypotheses are derived which provide the basis for the empirical part of this article.

III. Hypotheses

A. Firm Size and Standardization

In general, companies decide to enter an SSO or a technical committee within an SSO if the expected benefits outweigh the expected costs. In contrast to SMEs, larger firms can employ economies of scale and scope when it comes to standardization and thus create transaction cost benefits. Incumbent firms do not only have the financial capacity to send representatives to SSOs, they often also have established routines and processes when it comes to standardization. They simply know "the rules of the game" which smaller firms might not be aware of. Consequently, firm size plays a crucial role because the larger companies are the higher might be the benefits of standardization, e.g., by influencing the specifications of standards, whereas the fixed cost of participation is a relative high burden for smaller companies [19]. Based on their empirical analysis, Blind and Thumm [23] consequently conclude "the most decisive factor for participation in the standardization process is the company size." Nonetheless, strong hierarchies and greater bureaucracy can also make larger firms less efficient than smaller firms. Waguespack and Fleming [100] argue and empirically confirm that start-ups also benefit from participating in standardization by increasing their chances of a liquidity event. Additionally, according to the resource-based view, smaller firms possess fewer resources to invest in innovation projects ([66]; Wernerfelt and Karnani, 1987) but also into standardizing these efforts.

Besides the static explanation for a general positive correlation between firm size and participation in formal standardization, there is also a dynamic dimension to be considered. Firms that participate in standardization committees might grow stronger than their competitors due to the positive effects of the standardization process such as knowledge spillovers or the possibility to influence a standard, which might lead to facilitated market access and a larger market share.

Thus, the explanation that larger firms have more resources and are therefore more likely to enter an SSO is central in the line of argument here. Since the engagement in formal standardization is a long-term strategy, some powerful players with a strong market position do not need the support of formal standards anymore (see, e.g., [23]), because they might have already promoted their technologies to proprietary dominant designs (e.g., Suarez, 2004) within their markets. Following Haans *et al.*'s [48] advice on U-shaped relationships in strategic management, we expect an inverted U-shaped-relationship between firm size and the propensity to enter formal SSOs, which leads to the first hypothesis

> *H1:* The relationship between firm size and the likelihood to enter formal standardization is curvilinear (inverted U-shaped), with the highest likelihood occurring at an intermediate firm size.

B. Absorptive Capacity and Standardization

The standardization literature (e.g., [19]), describes standardization as the extended arm of internal R&D. Moreover, firms with high levels of internal R&D also tend to have a higher absorptive capacity defined as "a firm's ability to recognize the value of new information, assimilate it, and apply it to commercial ends" [31]. Absorptive capacity of a company to absorb and implement or apply the knowledge is discussed in standardization committees. In addition, own R&D activity (which is a driver for firms' AC) enables the continuous expansion of

the knowledge base and therefore allows a company to actively participate in standardization and to provide input or knowledge. High absorptive capacity in turn indicates that the ability to profit from knowledge spillovers generated in standardization processes is more distinct for these firms [21]. Since external knowledge sourcing is one of the main reasons for joining SSOs [22], firms with high levels of absorptive capacity will be more likely to enter SSOs. However, knowledge spillovers can negatively influence or deter very R&D-intensive firms from entering standardization due to the risk of losing valuable information and knowhow to competitors (see [21]). Consequently, the study by Blind [19] reveals an inverse U-shaped relationship between R&D-intensity and the likelihood of firms to be active in SSOs. Therefore, we leverage these insights to companies' entry decision and derive the following second hypothesis:

H2: The relationship between absorptive capacity and the likelihood to enter formal standardization is curvilinear (inverted U-shaped), with the highest likelihood occurring at an intermediate level of absorptive capacity.

C. Innovation Activities and Standardization

A firm's innovation success often critically depends on its expenditures for R&D and new product development. Expenditures for R&D can be regarded as input of the innovation process, while products or services new to the market ("successful innovations") represent the output of R&D [47]. However, companies can be successful in innovation without spending resources on R&D [80].[4] Regarding the relationship between successful innovations and standardization, Tassey [95] states that "Standards affect the R&D, production, and market penetration stages of economic activity and therefore have a significant collective effect on innovation, productivity, and market structure." Conversely, firms may strategically decide whether to enter SSOs at all and which efforts to take in shaping standards, especially, if they are very innovative and want to penetrate the market with new products. Moreover, Hussinger and Schwiebacher [56] find that disclosure of standard-relevant IP ownership is positively related with company valuation if associated patent rights are referred to explicitly which has recently been confirmed by Pohlmann *et al*. [78]. Following this line of argument, firms that conduct successful product or service innovations have higher incentives to join formal SSOs and to shape the relevant standards in order to gain product market advantages rather than enforcing their IP exclusively. The next hypothesis is hence formulated as follows:

H3: The likelihood to enter formal standardization processes is higher for firms that successfully introduce product or service innovations to the market.

D. Patent Activities and Standardization

As stated above, firms may abstain from enforcing exclusive rights such as patents in order to create standards, which facilitate access to the market. Innovation economics literature also describes patents as a proprietary instrument and standards as public or club goods [62], which are frequently discussed as opposing instruments. While patents are an instrument to appropriate the revenues of R&D expenditures, formal standards are open to all firms. Empirically, Blind and Thumm [23] discover that a higher patent intensity lowers the likelihood to participate in standardization. This indicates that very patent-intensive firms are reluctant to join standardization. Moreover, seeing standardization as multifirm collaboration, Olander *et al*. [76] state: "Firms with IPR protection may feel more inclined to collaborate because of the smaller perceived risk." Thus, a high degree of patent protection might be necessary in order to safeguard against potential knowledge spillovers [54]. Hence, patenting can be a prerequisite for entering into an SSO. Another important reason for patenting companies to join standardization is to introduce standard essential patents in the standard to gain licensing revenues according to FRAND[5] terms from all standard users [67] which may outweigh the loss of exclusivity [56]. This is not necessarily true for companies joining technical committees at DIN, but mainly for the information and communication technologies (ICT) sectors [15], [85], which are in general active in international SSOs or even consortia (e.g., [9] and [65]). However, mere patent activity is expected to raise the likelihood to join formal standardization.

H4: The likelihood to enter formal standardization processes is higher for patenting firms.

IV. Data and Methodology

In this section, we present the data for analysis, the choice and construction of the dependent and independent variables, and the estimation methods, which we apply to test our hypotheses.

A. Data

For this article, we merge data of the Community Innovation Survey (CIS) 2011 for Germany with data of firms' engagement in technical committees at the Deutsches Institut für Normung (DIN)[6] between 2010 and 2013. Information on firms active in standardization committees before 2011 and firms joining the German SSO between 2011 and 2013 were provided by DIN. Community Innovation Surveys are conducted in all European Union member states (sometimes even at a regional level) and are based on the Oslo Manual recommendations [73]–[75]. Innovation surveys exist under different acronyms in many other OECD countries and also in emerging, transition, and developing countries. Largely the surveys have the same structure and the same questions regarding innovation, but there are some differences between countries—even within the CIS—regarding content, formulation, and the ordering of the questions [69]. As a result, CIS data is frequently used (but mainly includes information from one survey in each country) and CIS data is therefore cross sectional in nature. As discussed above, CIS data have been extensively exploited in numerous ways and

[4] As a result, we distinguish between R&D activities and innovation success as drivers for companies entering SSOs.

[5] FRAND is short for "fair, reasonable and non-discriminatory" licensing terms.

[6] German Institute for Standardization.

TABLE I
DESCRIPTIVE STATISTICS: MEANS AND SHARES OF THE SAMPLE (STANDARD DEVIATION)

Variables	Total (N=4,071)	Non-standardizers (N=3,755)	Entering firms (N=78)	Established standardizers (N=238)
Firm size (average sales in millions €)	50.94 (490.80)	38.23 (448.32)	228.35 (1057.93)	193.41 (745.79)
Average absorptive capacity (R&D-expenditures/sales)	0.03 (0.08)	0.02 (0.08)	0.06 (0.13)	0.05 (0.13)
Share of patenting firms (Patent application 2008-10)	0.31 (0.46)	0.28 (0.45)	0.68 (0.46)	0.75 (0.43)
Share of innovative firms (Market introduction 2008-10)	0.47 (0.50)	0.44 (0.49)	0.77 (0.42)	0.79 (0.41)
Share of firms from lower-technology manufacturing industries (LTMI)	0.34 (0.47)	0.34 (0.47)	0.21 (0.41)	0.34 (0.47)
Share of firms from higher-technology manufacturing industries (HTMI)	0.19 (0.39)	0.17 (0.37)	0.40 (0.49)	0.45 (0.50)
Share of firms from knowledge-intensive services (KIS)	0.36 (0.48)	0.38 (0.48)	0.35 (0.48)	0.18 (0.38)
Share of firms from low knowledge-intensive services (LKIS)	0.11 (0.31)	0.12 (0.32)	0.05 (0.22)	0.04 (0.20)

researchers now recommend using CIS data to combine different countries or in longitudinal studies [69]. Although this data enables a comparison of national systems of innovation [38] only a few studies have started to merge these data with additional information and other datasets.

B. Sample

For our study, we use the German Community Innovation Survey 2011 (CIS 2011) which includes the core Eurostat CIS and additional topics for firms in Germany. The study is conducted every year and contains a random sample that is stratified by region, size, and sector.[7] We use CIS data because it includes information on firm size, absorptive capacity, innovation performance, and firms' patenting activity. Here a multitude of indicators for SSO entry can be considered to search for the most parsimonious model that fits the data.

Data for CIS 2011 were gathered by means of a voluntary postal survey for the period 2008–2010. In total, 7388 responses were received in Germany. We merge both datasets to a total of 4071 observations.

[7]The Oslo Manual opted for the subject approach: that is, data is collected at the firm level—including all innovation outputs and activities. This implies that we do not have data about specific innovation projects [69].

Table I shows that firms that have been active at technical committees of the German SSO, DIN, before 2011 ("Established standardizers") and firms that entered between 2011 and 2013 ("Entering firms") are quite similar, while both groups differ very much from firms that do not enter the DIN in the observed time period ("Non-standardizers"). This is true for the variables firm size, absorptive capacity and firms' sales as well as innovation- and patenting activities. When comparing the sector distribution, there are some interesting differences between firms entering technical committees for the first time and established standardizers at DIN. Whereas about 35% of the companies that entered technical committees at DIN between 2011 and 2013 stem from knowledge-intensive services (KIS), only 18% of the "Established standardizers" active at the DIN are from this sector. However, while 34% of the "Established standardizers" belong to the lower technology manufacturing industries (LTMI), this is only true for 21% of the entering firms. For firms operating in high-technology manufacturing industries (HTMI) and the low knowledge-intensive services (LKIS), respectively, there are only small differences between established standardizers and entering firms. In sum, firms that enter SSOs as well as "Established standardizers" are on average larger, have higher absorptive capacity, are more likely to be patent-active and innovative than firms that did not enter SSOs in the observed period. Moreover, standardization seems to be

considered relevant in KIS since a high share of entering firms belongs to that sector. The opposite seems to be true for companies of LTMI. Multivariate estimations are conducted in the following in order to carve out which of these firm characteristics have significant influences on the likelihood of companies to enter SSOs.

1) Dependent Variable: We use "Entry SSO," i.e., entering a technical committee at DIN, as the dependent variable in this study. Specifically, we construct "Entry SSO" applying a hazard ratio for the likelihood that a firm enters the German SSO each year between 2011 and 2013.

2) Independent Variables:

a) Firm size: Larger companies have more resources, can start more innovation projects, and have more opportunities to enter into an SSO. In our models, we use the firm's sales in 2010.

b) Absorptive capacity: The extent of R&D activities is shown as a very important measure of the likelihood to enter an SSO as absorptive capacity shows that the firm can benefit from knowledge spillovers generated in standardization processes [21]. The variable *absorptive capacity* measures the ratio of a firm's R&D expenditures and sales in 2010.

c) Innovation outcome: The CIS 2011 contains questions on whether a firm successfully developed and introduced an innovation to the market. Hence, we measure the variable *innovation outcome* by a dummy variable that equals one if the firm introduced a product or service innovation, respectively zero if the firm did not introduce an innovation in the three years prior to the survey (2008–2010).

d) Patenting activities: Additionally, the CIS surveys whether a firm applied for a patent. Hence, we measure the variable *patenting activity* by a dummy variable that equals one if the firm applied for a patent, respectively zero if the firm did not apply for a patent in the three years prior to the survey (2008–2010).

3) Control Variables:

a) Industry dummy variables: To check for the industry influence for each company we used the Eurostat indicators on high-tech industry and KIS (Eurostat, 2016). We created four groups of industries: LTMI, HTMI, LKIS, and KIS.[8]

b) Proportion R&D and proportion size: We include the control variables *Proportion R&D* and *Proportion size* to account for any dependencies of firms' entry decisions based on the characteristics of "Established standardizers." First, the firms' own R&D-intensity divided by the average R&D-intensity of the established standardizing companies in the sector (variable called proportion R&D) as well as the own firm size divided by the average firm size of the established standardizing companies in the sector (variable called *proportion size*) are included in the estimations separately.

C. Estimation Method

The main aim of this article is to identify the relevant firm characteristics that influence the likelihood to enter a technical committee of an SSO. Since it is possible to observe the firm characteristics in 2010 (taken from the CIS 2011) and the entries of firms in the years 2011, 2012, and 2013 into technical committees of DIN, the German SSO, survival analysis is an adequate estimation method. The whole sample is representative for Germany's economy in contrast to Baron *et al*.'s (2019). However, the companies involved in standardization are also characterized by an above average size and R&D expenditure intensity, which comes closer to the sample of the world's largest R&D performing firms analyzed by Baron *et al*. [2019]. However, Baron *et al.* [2019] rely on companies' membership at the standardization organization, whereas the companies, we investigate, are entering specific technical committees of DIN. Paying the fee of around 1000€ per year, which is in general independent from company size, allows companies to actively participate in one specific technical committee or just to get informed about the ongoing standardization processes before a first draft is published (see [22] on various motivations to get involved in standardization). In contrast to Baron *et al*. [2019] and our article, which focus both on companies' activities, Fischer and Henkel [40] survey individual managers of one German company in their choice experiment.

In the survival analysis, the dependent variable is determined by the duration of an observation in the sample until the event happens (failure) or it is not observed anymore. Thus, it is a combination of the length of the observed time without event or censoring and the event variable which is *1* if the event happens and *0* otherwise. For this study, observations are tracked until they enter DIN, the German SSO, or they are not observable anymore.

The two main concepts of this approach are the survival rate and the hazard rate. The survival rate *S(t)* is defined as the probability that the duration of an observation in the sample is at least *t* and thus is equal to $1 - F(t)$, which represents the converse probability that the duration will be less than *t*:

$$F(t) = \text{Prob}(T \leq t) = \int_0^t f(s)\, ds$$

$$S(t) = 1 - F(t) = \text{Prob}(T \geq t).$$

Thus, it indicates how long it takes until an event happens (i.e., how long does it take until a firm enters standardization SSO). The hazard rate captures the likelihood for a company to fail (i.e., to enter an SSO), i.e. it is defined as the probability that the event will happen given that the company is still alive:[9]

$$h(t) = \frac{f(t)}{S(t)}.$$

The cumulative hazard function is the accumulation of all hazard rates over time, i.e., the probability that the event has occurred at a certain point in time. The survivor function is usually pictured as Kaplan–Meier-survival curve [58] and depicts the

[8]The KIS variable in our dataset comprises high-tech knowledge intensive-services such as telecommunications, broadcasting and media as well as ICT and software sectors but also air transport, publishing, and financial services.

[9]The hazard rate can change over time, i.e., it can rise and fall. In the case of the "risk" to enter standardization SSO, the hazard rate might change according to firm age. However, since the age of a firm is not known and therefore the point in time the characteristics are observed is arbitrary, the Cox proportional model is applied and a constant hazard rate is assumed in order to facilitate the analysis and the interpretation of the results.

TABLE II
DISTRIBUTION OF THE SURVIVOR FUNCTION

Year (t)	Observations at beginning of the period without event	Events in year t	Net Lost	Survivor Function	Std. Error	[95% confidence intervall.]	
0	4,071	238	238	-	-	-	-
1	3,833	22	0	0.9943	0.0012	0.9913	0.9962
2	3,811	37	0	0.9846	0.0020	0.9802	0.9881
3	3,774	19	3755	0.9797	0.0023	0.9747	0.9837

share of observations that have not experienced the event (i.e., entering an SSO) over time. Since there are only four points in time and a constant hazard ratio in the Cox proportional model (which is applied in this article) is assumed, graphical presentations of these non-parametric estimations are not very meaningful and, thus, not presented here. Rather, the distribution of the events over time and the survival function are shown in Table II.

The 238 observations which are failures from the beginning represent firms that are already active in SSOs in period 0. Consequently, it is not possible to include them into further analyses. Furthermore, between 19 and 37 firms enter standardization after period 0. Since it is not possible to observe them after 2013, all observations leave the sample after three periods and the net loss is 3755.

As stated above, the group of the 238 "Established standardizers" cannot be included in the survival estimation since their entry is left censored. However, the characteristics of already standardizing companies within a sector might influence the likelihood of other firms to join an SSO. For example, firms might join standardization committees because there are already some very large organizations active in standardization in this field (see [7]). Additionally, companies that exhibit lower absorptive capacity compared to the average standardizing company in their sector might be more likely to enter standardization due to expected knowledge spillovers of the R&D-intensive established standardizers.

Thus, two additional estimations as robustness checks are conducted since it is not possible to include the group of established standardizers in the upcoming estimations due to the features of survival analysis. Hence, we include the control variables "Proportion R&D" and "Proportion size" to account for any dependencies of firms' entry decisions based on the characteristics of "Established standardizers." Significant negative influences would direct to the conclusion that companies with lower R&D-intensities respectively firm size compared to the average standardizing company in their sector are more likely to enter standardization and, accordingly, that the group of established standardizers has an significant impact on the decision to join an SSO. As a second robustness check, it is simulated that all left-censored observations (i.e. the established standardizers) enter in the first observation period and the following entries are moved back by one period. Thereby, the influence of the characteristics of the established standardizers on the outcome variable is included in the estimation. Significant changes in the sign and size of coefficients would indicate that there are substantial differences between firms entering SSOs and established standardizers.

For the multivariate estimations, the Cox proportional model [32] is applied where the hazard ratios or coefficients can be reported. The hazard ratios are connected to the hazard rate and can be interpreted in the following way: A hazard ratio of, e.g., 1.5 means that a one unit increase of the explaining variable equals a rise of the hazard rate by 50%. On the contrary, a hazard ratio of 0.7 means that a one unit increase of the explaining variable leads to a decline in the hazard rate of 30%. Thus, a hazard ratio of greater than one means that the event is more likely to happen and therefore a lower duration in the sample is expected while a ratio less than one indicates that the event is less likely to happen and the duration is higher. Since the influence of the variables on the likelihood to enter an SSO is of main interest here, the hazard ratios will be reported in the result table due to their meaningful interpretation.

V. RESULTS

In the following Cox proportional estimations, all variables of Table I as well as quadratic terms for firm size and absorptive capacity are included in order to identify the drivers of firms' SSO entry. The results are depicted in column (1) of Table III. Moreover, columns (2) and (3) present the results of the robustness checks mentioned in chapter 3.

First, all estimations fit the Cox proportional model quite well according to the Likelihood-Ratio-Test and that there seems to be no multicollinearity issues since the variance inflation factors (VIF) of all variables are low.[10]

Estimation (1) shows the results of the main regression. At first glance, the results display that there is a nonlinear relationship between the firm size and the likelihood to join a technical committee at DIN. Particularly, the influence of the linear firm-size term is significantly positive (i.e., Hazard Ratio greater than one), while its squared term is negative (i.e., Hazard Ratio less than one), but a lower level of significance. Since both coefficients are only slightly different from one and the limited number of observations, in particular of very large companies,

[10]According to Myers [71], multicollinearity is expected if the VIF of an explaining variable is greater than 10. This is not the case in all three estimations. The VIFs for the explanatory variables of all estimations are presented in Table IV in the Appendix of the article.

TABLE III
RESULTS OF THE COX PROPORTIONAL ESTIMATION WITH DIFFERENT SETS OF EXPLAINING VARIABLES

Variables	(1) hazard ratio	(2) hazard ratio	(3) hazard ratio
Sales (in million €)	1.001**		1.001***
	(0.0004)		(0.0002)
Sales squared (in million €)	0.999*		0.999***
	(5.39e-08)		(2.65e-08)
Absorptive capacity	2.204	3.693	1.977
	(5.052)	(11.75)	(2.308)
Absorptive capacity squared	0.852	0.764	1.445
	(2.742)	(2.569)	(2.200)
Patenting activity (Application 2008-10) (Y/N)	3.493***	3.486***	3.798***
	(0.929)	(0.922)	(0.529)
Innovation outcome (Market introduction 2008-10) (Y/N)	2.157***	2.274***	2.025***
	(0.634)	(0.665)	(0.303)
Proportion size		1.021	
		(0.0155)	
Proportion R&D		0.950	
		(0.124)	
HTMI	2.276***	2.308***	1.492***
	(0.723)	(0.739)	(0.208)
KIS	1.337	1.368	0.596***
	(0.437)	(0.471)	(0.0982)
LKIS	0.918	0.946	0.560**
	(0.517)	(0.531)	(0.161)
Likelihood –Ratio	77.33	84.00	362.47
Prob > chi2	0.00	0.00	0.00
Observations	3,833	3,833	4,071

Hazard ratios with standard errors in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. LTMI is the reference category.

the empirical evidence does not contradict, but also does not robustly confirm the inverted U-shape relationship between firm size and the likelihood to enter an SSO (Hypothesis 1).[11] Moreover, the significant positive coefficient of the variable "patenting" is very interesting as firms active in patenting seem to be more likely to join a formal SSO (Hypothesis 4). Conversely, absorptive capacity does not enhance the likelihood to enter a technical committee at DIN (Hypothesis 2), but the introduction of successful innovations exerts an influence (Hypothesis 3).[12] Apparently, firms that are successful in R&D increasing innovation outcome are entering DIN. Regarding the differences between sectors, companies from HTMI are more likely to enter standardization compared to companies from LTMI, which is the reference category in the estimations. Moreover, changing the reference category reveals that companies from HTMI are also more likely to enter a technical committee at DIN compared to KIS as well as LKIS. Finally, there are no significant differences between companies from LTMI, KIS) or LKIS.[13]

The variables controlling for possible influences of the group of established standardizing companies in estimation (2) have no significant effect on the likelihood to enter a technical committee at DIN for firms that were not active in standardization before[14]

[11] An estimation without the squared term for firm size was conducted. However, the coefficient was insignificant. Thus, the squared term was included.

[12] We also conducted an estimation without the squared term for absorptive capacity. Like in the estimation including the squared term, the coefficient was insignificant. Thus, a significant influence of absorptive capacity can be ruled out.

[13] Results with changed base categories are available upon request.

[14] Firm size was excluded in this estimation due to multicollinearity issues with the variable prop_size_normer.

and the influences of the explaining variables remain significant. Including the established standardizers in estimation (3) does not change the results either, except for the sector dummies. Firms from the service sector are significantly less likely to enter a technical committee at DIN compared to firms from the LTMI, since there are many companies from LTMI among the established standardizers. Altogether, the results of estimation (1) can be regarded as robust.

VI. Conclusion, Limitations, and Further Research

In an ever more globalized world, where the standardization process becomes increasingly complex, it is of utmost importance to understand the drivers of firms' entry into SSOs. The BRICs countries promote technology standardization leading to new global innovation champions, which at the same time further increases the complexity of the standardization process at SSOs. The main contribution of this article is the identification of the most important firm characteristics that influence the likelihood to enter a technical committee at DIN. In contrast to previous research approaches, which rely mostly on cross-sectional analyses, we use different points in time for the explanatory and the dependent variables. Therefore, possible endogeneity problems related to reverse causality, between innovation and standardization or firm size and standardization, can be at least partially addressed. An appropriate tool to analyze this kind of data is the Cox proportional model, a semi-parametric survival analysis estimation method. However, we still face the challenge that companies' entry decisions are based on pre-existing trends, anticipatory behavior, and other relevant, but omitted or confounding factors. These limitations cannot be addressed by the existing data, e.g., the rather limited panel, and methodology.

Nonetheless, this article's empirical contribution is a first attempt to emphasize and analyze the relevance of companies' characteristics for entering a technical committee exemplified at the case of the German standardization body DIN based on a representative sample of German companies surveyed in the context of the German edition of the Community Innovation Survey. This allows us to address the issue of reverse causality.

In contrast to our expectations, the results of this analysis reveal that a higher absorptive capacity does not lead to an increased likelihood to enter an SSO in the observed period. Hence, we do not find support for Hypothesis 2 that predicted an inverted U-shaped relationship between a firm's AC and its entry into an SSO. However, firms that successfully innovated are more likely to join SSOs (Hypothesis 3). Moreover, patent protection seems to be an important prerequisite when it comes to the decision to enter an SSO confirming the choice experiments by Fischer and Henkel [40] since knowledge spillovers are seen as main issues of standardization (Hypothesis 4) [21]. Therefore, firms strategically decide whether to enter an SSO or not. Finally, it can be stated that with increasing firm size also the benefits from participating in standardization processes rise (Hypothesis 1), but very large players will engage less in SSOs since they already possess enough market power to push their products to the market [23].

The results provide interesting evidence for the specific multifirm environment of an SSO and confirm previous research on multifirm settings, such as R&D consortia, and platforms. Firms are very strategic about whether to join formal standardization. An SSO creates a unique dynamic environment—like other multifirm settings—where tensions arise from simultaneous collaboration and competition among firms [17], [43], [63], [68]. Formal standardization may lead to an unintended and undesirable knowledge drain [51]. At worst, a firm loses critical resources to a committee member without receiving equal reimbursement, which eventually dilutes a firm's competitive advantage [28]. Therefore, firms need to be prepared for possible knowledge spillovers and apply, e.g., "selective revealing" strategies to protect their intangible assets [3], [53] since there is an intensive and implicit knowledge exchange in the standardization process. As a result, there is a potential tradeoff between the advantages of entering an SSO and the costs of misappropriation, and firms internally measure benefits against risks of entering such a setting beforehand. Veer *et al*. [99] show that firms' R&D collaboration is associated with infringement and further argue that intellectual property rights are better mitigating mechanisms than contracts. Applying this insight to formal standardization bodies, patenting seems to be an important prerequisite for entering into an SSO to avoid misappropriation by others.

From a managerial perspective, it seems to be beneficial for firms with successful innovations to enter standardization which has been previously confirmed by the performance analysis by Wakke *et al*. [102]. Thus, firms should consider the option of standardizing a new product or service, as this might accelerate the route-to-market of these innovations since standardization can also lead to a dominant design. Furthermore, SSOs might be an interesting alternative for firms operating at the technological frontier. This is because particularly innovators want to push their technology to the mass market. As explained by Arthur [5] increasing returns to adoption (which happens in case the utility of a technology goes up with the number of producers or users) generally cause one design to win as both producers and users greatly benefit from standardization. This leads to the rise of a dominant design [1], which standardizes some key components of a design as well as the way in which components are assembled into a product architecture. Standardization makes mass production easier, and allows firms to outsource components to supplier firms in case they can make such components cheaper.

This article also has implications for policy. Despite some efforts of the German government to support small firms, this group of firms seems still to abstain from entering formal SSOs. Particularly, they often lack resources and capabilities which are needed to participate in SSOs. Furthermore, small firms are also not always aware of the opportunities that participation in formal standardization can offer. Finally, Ranganathan and Rosenkopf [82] prove that larger and hence established standardizers tend to vote against the proposals made by newcomers in standardization processes. Thus, politics within SSOs can pose severe problems for new entrants and participating firms have to think about new ways to help newcomers to overcome

possible obstacles so that their know-how can be integrated in the standardization process and hence in the development of new standards.

While our study provides important contributions and shows that firm size, patenting and innovation activity, can be important drivers for SSO entry, some questions remain unanswered—providing exciting opportunities for further research. Although the results are representing the German standardization landscape, in line with the Special Issue that focuses on standardization in a global context, we want to emphasize that firms' entry into an SSO is a global phenomenon. It is even more important to understand under which conditions firms engage in SSOs in a globalized world, where firms no longer operate only in national markets but also internationally. Though we mainly analyze German firms and their specific entry behavior into a German SSO, which is the most influential both on the European and even the international level at the International Standardisation Organisation ISO, the results can also be transferred to the global context, because multinational enterprises are very prominent in the German SSO. A quarter of the companies in the German SSO are foreign, a quarter represents global and the remaining half domestic firms. Internationally active companies represented in the SSO include big players such as Bosch, Siemens, and IBM, which are multinational companies. Since Vasudeva *et al*. [98] find that firms' interorganizational learning within standardization is embedded in their macro-level country context, a replication of the study for other national SSOs, like DIN in Germany, would allow a further confirmation of the identified firm-level characteristics as drivers of firms' entry decisions. Furthermore, the firms' competitive environment is not included in the analysis, which certainly has a strong influence on entering coopetition-like setting firms find themselves in when entering formal standardization committees. More specifically, a firm's position within the relevant technology and industry networks will also influence a firm's likelihood to enter an SSO [82]. The data we use provide a unique source of information and allow us to trace back whether is part of an SSO or decides to enter an SSO each year. This information is hardly available and hence—even though—the data stem from 2011–2013, they are still representative for the main question we aim to analyze: "What drives firms' entry into an SSO?"

Due to the limited number of 78 firms entering the SSO during the observation period we cannot perform any subsample analyses resulting in robust results. For future research, we recommend following and including a larger number of entering firms to verify the results. Besides, a real panel analysis would be preferable in order to account for changes of firm characteristics in the observation period. In this context, it must be added that it is not possible to rule out the influence of possible unobserved shocks after 2010 on the observed entries at the DIN between 2011 and 2013. Also, including the established standardizers in the estimations is not possible using survival analysis. Even though these observations were included in some robustness checks, further research should address this issue in more detail. A closer look at the relationship between patenting, market introduction of innovations, and standardization engagement is also a potential task for further research, since the analysis revealed the significant importance of these factors for firms that enter SSOs.

Despite these limitations, this article constitutes a first approach to study the drivers for entering formal standardization and contributes to previous research by differentiating between firms that freshly enter standardization and established standardizers.

Appendix

TABLE IV
VARIATION INFLATION FACTORS FOR ALL ESTIMATIONS

Estimation	(1)	(2)	(3)
Variables	VIF	VIF	VIF
Sales (in million €)	4.23	-	3.91
Sales (squared)	4.22	-	3.89
Absorptive capacity (R&D-expenditures/sales)	5.78	8.47	5.95
Absorptive capacity (squared)	5.47	5.78	5.64
Patenting activity (Application 2008-10)	1.16	1.16	1.19
Innovation activity (Market introduction 2008-10)	1.21	1.21	1.23
Proportion size	-	1.00	-
Proportion R&D	-	2.40	-

ACKNOWLEDGMENT

The authors would like to thank the three anonymous reviewers for their comments, which helped us to improve the paper significantly. The authors would also like to thank Dr. C. Rammer at ZEW—Leibniz Centre for European Economic Research for providing access to the data of the German version of the Community Innovation Survey.

REFERENCES

[1] W. J. Abernathy and J. M. Utterback, "Patterns of industrial innovation," *Technol. Rev.*, vol. 80, no. 7, pp. 1–9, 1978.

[2] R. Adner and R. Kapoor, "Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations," *Strategic Manage. J.*, vol. 31, no. 3, pp. 306–333, 2010.

[3] O. Alexy, G. George, and A. J. Salter, "Cui bono? The selective revealing of knowledge and its implications for innovative activity," *Acad. Manage. Rev.*, vol. 38, no. 2, pp. 270–291, 2013.

[4] R. Allen and R. Sriram, "The role of standards in innovation," *Technol. Forecast. Soc. Change*, vol. 64, pp. 171–181, 2000.

[5] W. B. Arthur, "Competing technologies, increasing returns, and lock-in by historical events," *Econ. J.*, vol. 99, no. 394, pp. 116–131, 1989.

[6] C. d'Aspremont and A. Jacquemin, "Cooperative and noncooperative R&D in duopoly with spillovers," *Amer. Econ. Rev.*, vol. 78, pp. 1133–1137, 1988.

[7] R. Axelrod, W. Mitchell, R. E. Thomas, D. S. Bennett, and E. Bruderer, "Coalition formation in standard-setting alliances," *Manage. Sci.*, vol. 41, no. 9, pp. 1493–1508, 1995.

[8] T. Bar and A. Leiponen, "Committee composition and networking in standard setting: The case of wireless telecommunications," *J. Econ. Manage. Strategy*, vol. 23, no. 1, pp. 1–23, 2014.

[9] J. Baron, J. Contreras, M. Husovec, P. Larouche, and N. Thumm, Eds., Making the Rules. The Governance of Standard Development Organizations and Their Policies on Intellectual Property Rights, Office Eur. Union, Brussels, Belgium, 2019.

[10] J. Baron and T. Pohlmann, "Who cooperates in standards consortia – rivals or complementors?" *J. Competition Law Econ.*, vol. 9, no. 4, pp. 905–929, 2013.

[11] J. Baron, T. Pohlmann, and K. Blind, "Essential patents and standard dynamics," *Res. Policy*, vol. 45, no. 9, pp. 1762–1773, 2016.

[12] J. Baron and T. Pohlmann, "Mapping standards to patents using declarations of standard-essential patents," *J. Econ. Manage. Strategy*, vol. 27, no. 3, pp. 504–534, 2018.

[13] J. Baron and D. Spulber, "Technology standards and standard setting organizations – introduction to the searle center database," *J. Econ. Manage. Strategy*, vol. 27, no. 3, pp. 462–503, 2018.

[14] J. Baron, C. Li, and S. Nasirov, "Why do r&d-intensive firms participate in standards organizations? The role of patents and product-market position," working paper, 2019.

[15] R. Bekkers, B. Verspagen, and J. Smits, "Intellectual property rights and standardization: The case of GSM," *Telecommun. Policy*, vol. 26, nos. 3/4, pp. 171–188, 2002.

[16] R. Bekkers, R. Bongard, and A. Nuvolari, "An empirical study on the determinants of essential patent claims in compatibility standards," *Res. Policy*, vol. 40, no. 7, pp. 1001–1015, 2011.

[17] M. Bengtsson and S. Kock, "'Coopetition" in business networks—to cooperate and compete simultaneously," *Ind. Marketing Manage.*, vol. 29, no. 5, pp. 411–426, 2000.

[18] S. M. Besen and J. Farrell, "Choosing how to compete: Strategies and tactics in standardization," *J. Econ. Perspectives*, vol. 8, no. 2, pp. 117–131, 1994.

[19] K. Blind, "Explanatory factors for participation in formal standardisation processes: Empirical evidence at firm level," *Econ. Innov. New Technol.*, vol. 15, no. 2, pp. 157–170, 2006.

[20] K. Blind and S. Gauch, "Research and standardization in nanotechnology: Evidence from Germany," *J. Technol.Transfer*, vol. 34, no. 3, pp. 320–324, 2009.

[21] K. Blind and A. Mangelsdorf, "Alliance formation of SMEs: Empirical evidence from standardization committees," *IEEE Trans. Eng. Manage.*, vol. 60, no. 1, pp. 148–156, Feb. 2013.

[22] K. Blind and A. Mangelsdorf, "Motives to standardize: Evidence from Germany," *Technovation*, vol. 48–49, pp. 13–24, 2016.

[23] K. Blind and N. Thumm, "Interrelation between patenting and standardisation strategies: Empirical evidence and policy implications," *Res. Policy*, vol. 33, no. 10, pp. 1583–1598, 2004.

[24] K. Blind, S. S. Petersen, and C. A. F. Rillio, "The impact of standards and regulation on innovation in uncertain markets," *Res. Policy*, vol. 46, pp. 249–264, 2017.

[25] K. J. Boudreau, "Open platform strategies and innovation: Granting access vs. devolving control," *Manage. Sci.*, vol. 56, no. 10, pp. 1849–1872, 2010.

[26] A. M. Brandenburger and B. J. Nalebuff, *Co-Opetition*. New York, NY, USA: Crown Publishing Group, 2011.

[27] M. Bruce, L. Dal, and K. B. Kahn, "Delineating design factors that influence the global product launch process," *J. Prod. Innov. Manage.*, vol. 24, no. 5, pp. 456–470, 2007.

[28] B. Cassiman and R. Veugelers, ""R&D cooperation and spillovers: Some empirical evidence from Belgium," *Amer. Econ. Rev.*, vol. 92, no. 4, pp. 1169–1184, 2002.

[29] H. W. Chesbrough, *Open Innovation: The New Imperative for Creating and Profiting From Technology*. Boston, MA, USA: Harvard Bus. School Press, 2003.

[30] H. W. Chesbrough, *Open Business Models: How To Thrive in the New Innovation Landscape*. Boston, MA, USA: Harvard Bus. School Press, 2006.

[31] W. M. Cohen and D. A. Levinthal, "Absorptive capacity: A new perspective on learning and innovation," *Administrative Sci. Quart.*, vol. 35, no. 1, pp. 128–152, 1990.

[32] D. Cox, "Regression models and life tables," *J. Roy. Statist. Soc.*, vol. 34, no. 2, pp. 187–220, 1972.

[33] G. Dokko, A. Nigam, and L. Rosenkopf, "Keeping steady as she goes: A negotiated order perspective on technological evolution," *Org. Stud.*, vol. 33, nos. 5/6, pp. 681–703, 2012.

[34] Y. L. Doz, P. M. Olk, and P. S. Ring, "Formation processes of R&D consortia: Which path to take? Where does it lead?" *Strategic Manage. J.*, vol. 21, no. 3, pp. 239–266, 2000.

[35] K. M. Eisenhardt and C. B. Schoonhoven, "Resource based view of strategic alliance formation: Strategic and social effects in entrepreneurial firms," *Org. Sci.*, vol. 7, pp. 136–150, 1996.

[36] T. R. Eisenmann, G. Parker, and M. W. van Alstyne, "Strategies for two-sided markets," *Harvard Bus. Rev.*, vol. 84, no. 10, pp. 92–101, 2006.

[37] T. R. Eisenmann, G. Parker, and M. W. van Alstyne, "Platform envelopment," *Strategic Manage. J.*, vol. 32, pp. 1270–1285, 2011.

[38] R. Evangelista, S. Iammarino, V. Mastrostefano, and A. Silvani, "Measuring the regional dimension of innovation. Lessons from the Italian innovation survey," *Technovation*, vol. 21, no. 11, pp. 733–745, 2001.

[39] J. Farrell and T. Simcoe, "Choosing the rules for consensus standardization," *RAND J. Econ.*, vol. 43, no. 2, pp. 235–252, 2012.

[40] T. Fischer and J. Henkel, "Complements and substitutes in profiting from innovation – A choice experimental approach," *Res. Policy*, vol. 42, no. 2, pp. 326–339, 2013.

[41] J. L. Furman and S. Stern, "Climbing atop the shoulders of giants: The impact of institutions on cumulative research," *Amer. Econ. Rev.*, vol. 101, pp. 1933–1963, 2011.

[42] A. Gawer and M. A. Cusumano, "Industry platforms and ecosystem innovation," *J. Prod. Innov. Manage.*, vol. 31, no. 3, pp. 417–433, 2014.

[43] M. S. Giarratana and M. Mariani, "The relationship between knowledge sourcing and fear of imitation," *Strategic Manage. J.*, vol. 35, no. 8, pp. 1144–1163, 2014.

[44] D. R. Gnyawali and B.-J. R. Park, "Co-opetition and technological innovation in small and medium-sized enterprises: A multilevel conceptual model," *J. Small Bus. Manage.*, vol. 47, no. 3, pp. 308–330, 2009.

[45] D. R. Gnyawali and B.-J. R., Park, "Co-opetition between giants: Collaboration with competitors for technological innovation," *Res. Policy*, vol. 40, no. 5, pp. 650–663, 2011.

[46] R. M. Grant and C. Baden-Fuller, "A knowledge accessing theory of strategic alliances," *J. Manage. Stud.*, vol. 41, no. 1, pp. 61–84, 2004.

[47] C. Greenhalgh and M. Rogers, *Innovation, Intellectual Property, and Economic Growth*. Princeton, NJ, USA: Princeton Univ. Press, 2010.

[48] R. Haans, C. Pieters, and Z. L. He, "Thinking about U: Theorizing and testing U - and inverted U-shaped relationships in strategy research," *Strategic Manag. J.*, vol. 37, no. 7, pp. 1177–1195, 2016.

[49] J. Hagedoorn, "Understanding the rationale of strategic technology partnering," *Strategic Manage. J.*, vol. 14, pp. 371–385, 1993.

[50] J. Hagedoorn, A. N. Link, and N. S. Vonortas, "Research partnerships," *Res. Policy*, vol. 29, pp. 567–586, 2000.

[51] G. Hamel, "Competition for competence and inter partner learning within international strategic alliances," *Strategic Manage. J.*, vol. 12, pp. 83–103, 1991.

[52] B. Haudeville and D. Wolff, "Enjeux & déterminants de l'implication des entreprises dans le processus de normalisation," *Revue d'économie Industrielle*, vol. 108, no. 4, pp. 21–40, 2004.

[53] J. Henkel, S. Schöberl, and O. Alexy, "The emergence of openness: How and why firms adopt selective revealing in open innovation," *Res. Policy*, vol. 43, no. 5, pp. 879–890, 2014.

[54] M. Holgersson, O. Grandstrand, and M. Bogers, "The evolution of intellectual property strategy in innovation ecosystems: Uncovering complementary and substitute appropriability regimes," *Long Range Planning*, vol. 51, vol. 2, pp. 303–319, 2018.

[55] P. Huang, M. Ceccagnoli, C. Forman, and D. J. Wu, "Appropriability mechanisms and the platform partnership decision: Evidence from enterprise software," *Manage. Sci.*, vol. 59, no. 1, pp. 102–121, 2013.

[56] K. Hussinger and F. Schwiebacher, "The value of disclosing IPR to open standard setting organizations," *Ind. Innov.*, vol. 22, no. 4, pp. 321–344, 2015.

[57] M. Iansiti and R. Levien, *The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability*. Boston, MA, USA: Harvard Bus. School Press, 2004.

[58] E. Kaplan and P. Meier, "Nonparametric estimation from incomplete observations," *J. Amer. Statist. Assoc.*, vol. 53, pp. 457–481, 1958.

[59] M. L. Katz, "An analysis of cooperative research and development," *RAND J. Econ.*, vol. 17, pp. 527–543, 1986.

[60] T. Khanna, R. Gulati, and N. Nohria, "The dynamics of learning alliances: Competition, cooperation, and relative scope," *Strategic Manage. J.*, vol. 19, pp. 193–210, 1998.

[61] D. J. Kim and B. Kogut, "Technological platforms and diversification," *Org. Sci.*, vol. 7, no. 3, pp. 283–301, 1996.

[62] C. P. Kindleberger, "Standards as public, collective and private goods," *Kyklos*, vol. 36, pp. 377–396, 1983.

[63] K. Laursen and A. J. Salter, "The paradox of openness: Appropriability, external search and collaboration," *Res. Policy*, vol. 43, no. 5, pp. 867–878, 2014.

[64] D. Lavie, C. Lechner, and H. Singh, "The performance implications of timing of entry and involvement in multipartner alliances," *Acad. Manage. J.*, vol. 50, no. 3, pp. 578–604, 2007.

[65] A. E. Leiponen, "Competing through cooperation: The organization of standard setting in wireless telecommunications," *Manage. Sci.*, vol. 54, no. 11, pp. 1904–1919, 2008.

[66] A. E. Leiponen and J. Byma, "If you cannot block, you better run: Small firms, cooperative innovation, and appropriation strategies," *Res. Policy*, vol. 38, no. 9, pp. 1478–1488, 2009.

[67] M. A. Lemley, "Intellectual property rights and standard-setting organizations," *California Law Rev.*, vol. 90, no. 6, pp. 1889–1980, 2002.

[68] A. Lorenz and T. Veer, "Once bitten, less shy? The influence of prior misappropriation experience on R&D collaboration," *Ind. Innov.*, vol. 26, no. 1, pp. 31–56, 2019.

[69] J. Mairesse and P. Mohnen, "Using innovation surveys for econometric analysis," in *Handbook of the Economics of Innovation*, B. H. Hall and N. Rosenberg, Eds. Amsterdam, The Netherlands: Elsevier, 2010, pp. 1130–1155.

[70] L. Miotti and F. Sachwald, "Co-operative R&D: Why and with whom? An integrated framework of analysis," *Res. Policy*, vol. 32, pp. 1481–1499, 2003.

[71] R. H. Myers, *Classical and Modern Regression With Applications*, 2nd ed. Boston, MA, USA: PWS-Kent, 1990.

[72] S. Nambisan, "Industry technical committees, technological distance, and innovation performance," *Res. Policy*, vol. 42, no. 4, pp. 928–940, 2013.

[73] *Oslo Manual: Proposed Guidelines for Collecting and Interpreting Technology Innovation Data*. Paris, France: OECD, 1992.

[74] *Oslo Manual: Proposed Guidelines for Collecting and Interpreting Technology Innovation Data*, 2nd ed. Paris, France: OECD, 1996.

[75] *Oslo Manual: Proposed Guidelines for Collecting and Interpreting Technology Innovation Data*, 3rd ed. Paris, France: OECD, 2005.

[76] H. Olander, M. Vanhala, and P. Hurmelinna-Laukkanen, "Reasons for choosing mechanisms to protect knowledge and innovations," *Manage. Dec.*, vol. 52, no. 2, pp. 209–229, 2014.

[77] J. Oxley and R. Sampson, "The scope and governance of international R&D alliances," *Strategic Manage. J.*, vol. 25, nos. 8/9, pp. 723–749, 2004.

[78] T. Pohlmann, P. Neuhäusler, and K. Blind, "Standard essential patents to boost financial returns," *R&D Manage.*, vol. 46, no. S2, pp. 612–631, 2016.

[79] W. W. Powell, K. W. Koput, and L. Smith-Doerr, "Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology," *Administrative Sci. Quart.*, vol. 41, pp. 116–145, 1996.

[80] C. Rammer, D. Czarnitzki, and A. Spielkamp, "Innovation success of non-R&D-performers: Substituting technology by management in SMEs," *Small Bus. Econ.*, vol. 33, no. 1, pp. 35–58, 2009.

[81] R. Ranganathan, A. Ghosh, and L. Rosenkopf, "Competition–cooperation interplay during multiform technology coordination: The effect of firm heterogeneity on conflict and consensus in a technology standards organization," *Strategic Manage. J.*, vol. 39, pp. 3193–3221, 2018.

[82] R. Ranganathan and L. Rosenkopf, "Do ties really bind? the effect of knowledge and commercialization networks on opposition to standards," *Acad. Manage. J.*, vol. 57, no. 2, pp. 515–540, 2014.

[83] P. S. Ring, Y. L. Doz, and P. M. Olk, "Managing formation processes in R&D consortia," *California Manage. Rev.*, vol. 47, no. 4, pp. 137–156, 2005.

[84] L. Rosenkopf, A. Metiu, and V. P. George, "From the bottom up? Technical committee activity and alliance formation," *Administrative Sci. Quart.*, vol. 46, no. 4, pp. 748–772, 2001.

[85] M. Rysman and T. Simcoe, "Patents and the performance of voluntary standard-setting organizations," *Manage. Sci.*, vol. 54, no. 11, pp. 1920–1934, 2008.

[86] M. Sakakibara, "Heterogeneity of firm capabilities and cooperative research and development: An empirical examination of motives," *Strategic Manage. J.*, vol. 18, pp. 143–164, 1997.

[87] M. Sakakibara, "Formation of R&D consortia: Industry and company effects," *Strategic Manage. J.*, vol. 23, pp. 1033–1050, 2002.

[88] M. Sakakibara, "Knowledge sharing in cooperative research and development," *Managerial Dec. Econ.*, vol. 24, pp. 117–132, 2003.

[89] M. Sakakibara and L. Branstetter, "Measuring the impact of US research consortia," *Managerial. Dec. Econ.*, vol. 24, pp. 51–69, 2003.

[90] S. C. Salop and D. T. Scheffman, "Raising rivals' costs," *Amer. Econ. Rev.*, vol. 73, no. 2, pp. 267–271, 1983.

[91] D. Somaya, "Patent strategy and management: An integrative review and research agenda," *J. Manage.*, vol. 38, no. 4, pp. 1084–1114, 2012.

[92] D. Spulber, "Standard setting organizations and standard essential patents: Voting and market," *Econ. J.*, vol. 129, no. 619, pp. 1477–1509, 2019.

[93] F. F. Suarez, "Battles for technological dominance: an integrative framework," Research Policy, vol. 33, pp. 271–286.

[94] P. Swann, "The economics of standardization. final report for standards and technical regulations," Manchester, U.K.: Univ. Manchester, 2000.

[95] P. Swann, "The economics of standardization: An update," UK Dept. Bus., Innov. Skills, London, U.K., Rep., 2010.

[96] G. Tassey, "Standardization in technology-based markets," *Res. Policy*, vol. 29, nos. 4/5, pp. 587–602, 2000.

[97] P. K. Toh and C. D. Miller, "Pawn to save a chariot, or drawbridge into the fort? Firms' disclosure during standard setting and complementary technologies within ecosystems," *Strategic Manage. J.*, vol. 38, pp. 2213–2236, 2017.

[98] G. Vasudeva, E. A. Alexander, and S. L. Jones, "Institutional logics and interorganizational learning in technological arenas: Evidence from standard-setting organizations in the mobile handset industry," *Org. Sci.*, vol. 26, no. 3, pp. 830–846, 2015.

[99] T. Veer, A. Lorenz, and K. Blind, "How open is too open? the mitigating role of appropriation mechanisms in R&D cooperation settings," *R&D Manage.*, vol. 46, no. S3, pp. 1113–1128, 2016.

[100] D. M. Waguespack and L. Fleming, "Scanning the commons? Evidence on the benefits to startups participating in open standards development," *Manage. Sci.*, vol. 55, no. 2, pp. 210–223, 2009.

[101] P. Wakke, K. Blind, and H. de Vries, "Driving factors for service providers to participate in standardization: Insights from the Netherlands," *Ind. Innov.*, vol. 22, no. 4, pp. 299–320, 2015.

[102] P. Wakke, K. Blind, and F. Ramel, "The impact of participation within formal standardization on firm performance," *J. Productivity Anal.*, vol. 45, no. 3, pp. 317–330, 2016.

[103] B. Wernerfelt and A. Karnani, "Competitive strategy under uncertainty," *Strategic Manage. J.*, vol. 8, pp. 187–194, 1987.

[104] P. M. Wiegmann, H. De Vries, and K. Blind, "Multi-mode standardisation: A critical review and a research agenda," *Res. Policy*, vol. 46, no. 8, pp. 1370–1386, 2017.

[105] S. Yami and A. Nemeh, "Organizing coopetition for innovation: The case of wireless telecommunication sector in Europe," *Ind. Marketing Manage.*, vol. 43, no. 2, pp. 250–260, 2014.

[106] F. Zhu and M. Iansiti, "Entry into platform-based markets," *Strategic Manage. J.*, vol. 33, pp. 88–106, 2012.