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Knowledge Sources for Innovation and Formal Standardization

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Abstract

Tapping into heterogeneous knowledge sources for innovation through standardization

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This paper investigates the relation between a firm?s involvement in formal standardization and its external knowledge sourcing activities. Firms participate in formal standardization to understand and influence the technological development. With that, standardization has the potential to be a knowledge source for firms. We assume that firms strategically use standardization in combination with the sourcing of external knowledge. Firm-level data from the Dutch Community Innovation Survey combined with involvement in the Netherlands Standardization Institute provide an empirical test for the theoretical framework. We find that firms utilizing knowledge from their competitors and scientific organizations as more likely to be active in formal standardization committees. Utilizing suppliers? information, in contrast, reduces the likelihood of standardization involvement. From this we postulate that the access to external knowledge of the stakeholders in the formal standardization can be can be a further source for innovation.

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This paper investigates whether companies involved in formal standardization differently utilize external knowledge sources for their innovation activities. Firms active in standardization are intending in understanding and influencing the technological development. We therefore assume a link between the utilization of external knowledge sources for innovation and the involvement in formal standardization. Firm-level data from the Dutch Community Innovation Survey combined with involvement in the Netherlands Standardization Institute provide an empirical test for the theoretical framework. We find that firms using spillovers from their competitors and scientific organizations as more likely involved in formal standardization. Such companies seem to be more orientated towards the marketability of their innovations. Utilizing suppliers' information, in contrast, reduces the likelihood of standardization involvement. We postulate that involvement in standardization can be an alternative mean to access knowledge form suppliers for innovation activities. Our analysis hints at the importance of external knowledge sources for firms involved in formal standardization.

INTRODUCTION

The formal standardization process brings together firms in creating new products (Chiao et al., 2007) and shaping the technological development (Tassey, 2000) in setting new standards. An important effect, which merely has been touched upon, are potential knowledge spillovers from other organizations within the standardization process (Chiao et al., 2007; Gupta et al., 2008; Blind and Mangelsdorf, 2010; 2012). This paper investigates whether companies active in standardization committees use knowledge from external sources for innovation activities more than those not involved in formal standardization. We develop a theory based on the incentives of firms to participate in formal standardization committees – which is not only to influence but also to understand the technological development.

Despite a significant involvement of firms in formal standardization institutions[1], little theoretical and empirical attention has been paid to the motivations for participation in standard-setting committees related to potential knowledge sourcing activities (Leiponen, 2008). Such institutions, which are seen as strategic alliances, are built to develop formal standards: participating individuals and organizations gather in technical committees to develop consensually agreed standards on a topic within their

[1] The German standardization institute DIN, for example, saw around 1,800 full members in October 2013 (www.din.de). The British standardization institute BSI had about 10,000 committee members in October 2013 (http://www.bsigroup.com/en-GB/about-bsi/media-centre/Facts-and-figures/).

interest. Hence participants have to disclose at least some part of their knowledge to contribute to the development of the standard (Blind et al., 2011; Leiponen, 2008).

We consider potential external sources of information as suppliers, customers, scientific organizations and competitors. These external information sources provide different complementary resources for the firm (Miotti and Sachwald, 2003) and each gives access to a different breadth of knowledge (Un et al., 2010). We relate the utilization of these external sources for innovation to the involvement of firms in formal standardization. As the firms involved are interested in the development of the fundamental technological development, they are assumed to source information less likely from suppliers and more likely from customers, scientific institutions and competitors for innovation. If firms want to be successful within the technological development, they are assumed to orientate themselves towards their customers as well as monitor potentially competing technologies from their competitors. Firms in formal standardization are generally more open towards publicly available knowledge, and hence assumed more likely to use knowledge from research institutions.

To test the framework, we analyse data from the Dutch Version of the Fourth Community Innovation survey (CIS) that is matched with data from the Netherlands Standardization Institute (NEN). This empirical analysis supports that companies using suppliers' information for innovation are less likely involved in standardization. Companies sourcing information for innovation from customers or scientific organizations, however, are more prone towards standardization.

We discuss implications of our analysis for management and standardization policies. It provides the external information that firms in standardization committees utilize for their innovation activities. Firstly, companies active in standardization are more open towards using knowledge from customers and scientific organizations in their innovation activities, so managers should consider the potential revelation of knowledge inside and outside of standardization committees to their (potential) suppliers. Secondly, sourcing knowledge from suppliers has the potential to be an alternative to the involvement in formal standardization. This may be as suppliers alone may provide sufficient information for innovation or firms unable to participate in standardization might use their suppliers as an alternative source of information. The fact that there is no evidence that those firms utilize knowledge from their competitors may reduce the fear of firms to participate in standardization committees where competitors are present.

In the following section, the theoretical framework as the basis for the empirical analysis is presented. The emphasis of this section lies on the specific aspects of formal standardization participation and a company's perspective on external knowledge sourcing. The third section presents the empirical analysis based on the data available from the CIS and NEN. The last section summarizes and discusses the results, highlighting the differences in external knowledge sourcing of firms active in formal standardization.

THEORETICAL BACKGROUND

Standardization can foremost be seen as a tool to facilitate coordination among economic players (Farrell and Simcoe, 2012; Farrell J. and Saloner, 1988). Standards can be defined as constructs resulting from reasoned, collective choice that enable agreement on solutions of recurrent problems (Tassey, 2000). The ultimate goal of the technical committees in formal standardization is to find consensus on a technology or a process. Within that procedure, standards influence and shape new technologies (Axelrod et al., 1995; Tassey, 2000; Keil, 2002). During the stages of finding consensus, the knowledge about the technological development will therefore be revealed to the participants of the standardization process. Participation in standardization can henceforth be an organizational resource which enables firms to improve and extend their own pool of resources for new products during this process (Groetnes, 2009). Instead of focussing on the ex-post dissemination of knowledge after publication, this paper focusses on these knowledge flows intrinsic in the participation in formal standardization committees.

The aim of the standardization process to shape the direction of technological development implies that knowledge specific to this purpose becomes available. We proceed to explain the nature of the formal standardization process, where firms enter into a strategic alliance and collaborate to set a standard. This allows us to identify the specific knowledge on the technological development inherent in these settings. By looking at the motivations of firms to be active in the committees, we finally derive hypotheses relating the external knowledge sourcing activities to the involvement in formal standardization committees.

The process of Formal Standardization

This analysis rests on the understanding of the formal standardization process. Standardization promotes the interchangeability of complementary products; it eases communication and it saves costs (Farrell and Saloner, 1986, Farrell and Saloner, 1988). It features the coordination on the early shaping of the technological trajectory, where the firms involved in the process try to implement their own technology in the standard. The members of these formal standardization committees comprise suppliers, customers, competitors and scientific institutions[2]. The formal standardization process therefore unites multiple stakeholders of a particular topic with the objective to reach consensus on a proposed standard. Most literature focuses on the coordination effects of standardization (Farrell and Saloner, 1988; Tassey, 2000; Chiao et al., 2007) or the way that standards disseminate in the market (Axelrod et al., 1995). Standardization therefore serves as a way to bring together various stakeholders that coordinate their communication to agree upon setting the direction of technological development.

The first goal of a standardization committee, before introducing the standard to the market, is to develop a standard candidate (Keil, 2002). The technological solution in this candidate is created

[2] An example of the composition of the ISO Technical Committee 213 Working group surfaces in 2011, where 41% scientific research institutions, 36% measurement instrument suppliers, 14% consultants and 9% technical industry were members.

within the committee. This process of arriving at an agreed upon formal standard involves substantial uncertainty ex ante, however. If the result of the standardization process would be clear from the start, there would be little need to unite all stakeholders to agree on consensus. This enables participants to influence the activities and involve their own technological expertise in the standard (Leiponen, 2008). The representatives of firms can influence the standardization process by attending these committee meetings with voting and consensus building. Contribution to the technical specification development requires technical expertise, and so active participants in the process of setting formal standards are generally engineers or technical experts (Farrell and Saloner, 1988; Leiponen, 2008). Groetnes (2009) has even indicated that the process of standardization can be seen as open innovation, as it provides a neutral arena for knowledge sharing. Throughout the standardization process, the participating representatives of firm therefore either reveal technological expertise that they want to bring into the standard or they reveal in what technological direction they want to move by voting on their preferred new standard.

Collaboration in Formal Standardization

Standardization committees are forms of strategic alliances (Axelrod et al., 1995; Gupta et al., 2008; Blind and Mangelsdorf, 2012). In these committees, firms are executing explicit collaboration (Farrell and Saloner, 1988). In the absence of a dominant firm or a single obvious technology in the market, the efforts to develop and sponsor standards require implicit or explicit alliances among rivals or potential rivals (Saloner, 1990). Even further, we assume that formal standardization committees match elements of research collaborations or partnerships. As Hertzfeld et al. (2006) state, research partnerships include the infrastructure to support the informal sharing of information among partners as well as the creation of entirely new research entities. The former includes large numbers of firms joining together to set industry standards. As this definition matches the process of standardization, we can apply the theoretical background of such collaborations for this analysis.

The ability of firms to jointly pursue the collaborative development of a technology or product within an alliance requires some level of technological overlap (Mowery et al., 1998). This is important to facilitate the exchange and development of knowledge that are often the aim of such collaborations. The standardization process fulfils this requirement, as it includes technological experts and members from organizations that have a stake in the matter open for standardization. The ability to access knowledge from other firms is important for firms interested in technological development. Grant and Baden-Fuller (1995) suggest that firms use interfirm collaboration to gain access to other firms' capabilities such as knowledge, supporting more focused, intensive exploitation of existing capabilities within each firm. Therefore firms in strategic alliances and collaborations also aim at transferring and absorbing knowledge to and from their partners. Mowery et al. (1996) propose that

absorptive capacity[3] is important in the acquisition of capabilities through alliances, and support the argument that experience in related technological areas is a central determinant of absorptive capacity. Therefore the strategic alliances of formal standardization committees are by virtue of similar backgrounds able to absorb knowledge from other sources of the committee. Collaborations can even increase the efficiency in knowledge application by improving the efficiency of the integration of knowledge in the production process and by increasing the efficiency with which knowledge is utilized (Grant and Baden-Fuller, 2004). Accessing knowledge is therefore an important aspect of strategic alliances and collaborations.

Knowledge access as motivation for participation

The participation in formal standardization is voluntary and hence firms will only participate if they expect a nonnegative net benefit. This can arise if firms manage to push their own technology into a formal standard that is agreed upon in the standardization committees, for example by having a first mover advantage. Including own technology in a standard or influencing the technological development set in the standard is widely accepted as the primary motivation for participation (Farrell and Saloner, 1988; Tassey, 2000; Chiao et al., 2007; Leiponen, 2008; Bousquet et al., 2009). For example, Axelrod et al. (1995) state that firms do not favour partaking in the strategic standardization alliance with rivals, as this opens up effective price or product competition in the post adoption market for the standardized good. In practice, however, we observe participation of horizontal competitors within standardization committees. Also are small and medium sized companies, without the ability to push their own technology into the standard, participating in the formal standardization committees (Blind and Mangelsdorf, 2012).

A limited amount of studies confirm that companies are motivated by the knowledge available within standardization committees, and hence that standardization provides a channel for knowledge transfer. (Blind and Mangelsdorf, 2010; 2012) show that small and medium-sized firms and firms in the electrical engineering and machinery industries confirm the access to knowledge[4] of other participants as a motivation for joining standardization committees. They find that especially small firms aim to enhance their knowledge base through participation in standardization. We can therefore assume that firms use the participation in formal standardization committees as ways to access the knowledge of other participants.

Access to external knowledge sources for collaborations

We approach the access to external knowledge sources that are relevant for firms in strategic alliances and collaborations from the knowledge based view of a company. This knowledge-based view is an

[3] Absorptive capacity is the ability of a firm to recognize external information for its innovative capabilities(Cohen and Levinthal, 1990).

[4] In a questionnaire the motives of "acquiring competitive advantagte through head start in knowledge", "acquiring knowledge in undocumented discussion in committees" and "keeping track of other firms' technical knowledge" were confirmed.

extension of the resource-based view of the firm (Grant, 1991; Teece et al., 1997). This states that a company's competitive advantage is determined by the resources it holds and whether these are rare and inimitable. By learning information from outside sources of information, firms can build up their knowledge base and ultimately enhance the innovation activities of the firm (Lazaric and Marengo, 2000). This emphasizes that the resources a firm holds and how efficiently they are used are important drivers for its long-term performance. Such resources and the dynamic capabilities a firm possesses develop over time. Therefore firms can be conceived as a collection of their resources and capabilities. Organizations can learn, share, diffuse and create knowledge through interaction with other sources (Caloghirou et al., 2004), for example external organizations. This is especially important in today's world where individual firms can no longer rely on their own resources to compete (Sobrero and Roberts, 2002). Learning from outside sources of information from an organizational perspective has to be understood as knowledge building (Lazaric and Marengo, 2000). In order to learn from external sources, these need to be heterogeneous enough to have potentially new knowledge available. Some element of homogeneity, however, must exist so that mutual understanding is still possible (Mowery et al., 1996). Hence there are potentially different learning opportunities for innovation activities, depending on the partner involved (Un et al., 2010). Therefore firms can enhance their resources and ultimately their knowledge base by accessing information from outside sources. Caloghirou et al. (2004) show how this ability of firms to create linkages with other entities and establish channels of knowledge flows between them positively impacts the level of innovativeness of firms.

The cooperating with other organizations is motivated by the varying objectives that a firm is pursuing. Fritsch and Lukas (2001) find that a different source is used as a research partner, depending on the type of innovation. It is henceforth important to consider each of the available external sources of knowledge individually.

There is, however, a potential threat in sharing firm-specific knowledge within collaborations (Cassiman and Veugelers, 2002). Hertzfeld et al. (2006) highlight the importance of intellectual property protection for all members of research collaborations. Their analysis suggests that if firms find it beneficial to engage in research together[5], intellectual property might be a negotiation problem but is generally not the "showstopper". Cassiman and Veugelers (2002) find that especially spillovers to vertical partners matter and that in these cases the importance of strategic protection of their intellectual property is very high. If firms have a higher appropriability and higher incoming spillovers, they are more likely to cooperate with external sources. In these cases, protection mechanisms such as patents are used to appropriate own valuable information. In the case of formal standardization, patents have a special value if they are included in the standards (Farrell et al., 2007). If patents are covering a standard, they may confer market power ex post that was much weaker ex ante. It might therefore even be desirable to bring very valuable knowledge into the formal standardization process, as firms have the possibility to protect this knowledge; they can license it to

[5] In the broad sense of the definition of research collaborations this also applies to the organizations involved in the formal standardization process.

other participants under fair and reasonable conditions (Chiao et al., 2007). This is supported by Dokko and Rosenkopf (2010), who provide evidence that companies owning patents have a greater influence in standardization committee's decisions.

The sharing of knowledge creates direct network externalities for participants in synergistic activities: sharing intellectual property, joint development of complementary products, and agreeing to specifications for components (Farrell J. and Saloner, 1988). If the firms can anticipate the reactions of the different stakeholders and have foresight into future markets, this also allows for a better sense of the timing for technological development (Bousquet et al., 2009). In formal standardization, firms have the opportunities to learn about such new technologies, business processes and know-how developed by the other members (Gupta et al., 2008). Understanding the direction of the technological development is crucial for companies to steer own research and development (R&D) efforts this way.

Hypotheses on formal standardiza*tion companies'* utilization of external spillovers

So far we established that the motivation for invovlvement in standardization committees can be to access knowledge from other participatns. Formal standardization committees provide an extensive pool of knowledge for firms. We further recognized that companies participating in formal standardization are interested in technological development, actively by influencing and passively by observing its direction. We also highlighted that an important aim of collaborations and strategic alliances is to access external information. If companies active in standardization committees are therefore in external sources of information and the technological development, we can develop our theory on the type of knowledge sources such firms apply in their innovation activities.

Generally, external knowledge sources can be utilized for the internal innovation activities of a firm (Miotti and Sachwald, 2003; Un et al., 2010). Potentially relevant sources[6] are customers, suppliers, competitors and scientific institutions (Fritsch and Lukas, 2001). The complementary resources from each source individually available determine which one is utilized in research collaborations (Miotti and Sachwald, 2003). Important determinants for this are the breadth of knowledge available from the source, the ease of access to that information (Un et al., 2010) and the firm-specific characteristics (Fritsch and Lukas, 2001). We are interested in understanding how firms active in formal standardization utilize these external sources for their innovation activities, compared to firms that are not active in the committees. We will therefore review the potential of each external source to be beneficial as information sources for innovation and thereby derive hypotheses which ones are used more by companies involved in formal standardization.

We first consider suppliers as potential innovation sources for companies in formal standardization. Suppliers provide valuable information on the inputs of products to be innovated, such as possible ways to improve a component of a new product or the process of production. In a study of German firms, Fritsch and Lukas (2001) find that cooperation with suppliers works for many firms as

[6] As mentioned previously, these sopurces are generally present in formal standardization committees.

substitute for own innovation efforts. This effect is not shown for cooperation with other sources. Cooperation is a much stronger form of receiving knowledge from an external source. However, if information received from a supplier is already sufficient for the observation of future technological development, this can dampen the need to receive such information from collaborations in larger knowledge pools, such as standardization.

Firms using their supplier's knowledge base for innovations are less dependent on other knowledge sources, as suppliers can accumulate information from multiple buyers. This knowledge is encoded in products and thereby passed on to the buyers (Appleyard, 2003). Therefore companies have the potential to acquire knowledge about their competitors via common suppliers (Cassiman and Veugelers, 2002). Formal standardization provides a broad pool of knowledge which can include these competitors, thus decreasing the need to acquire such knowledge from suppliers.

Lau et al. (2010) show that utilizing information from a supplier directly improves product performance, which is supported by Cousins et al. (2011) who find that a firm's supply base is a major source for ideas and innovations. If knowledge on the technological development is available from suppliers, there is little incentive to acquire such knowledge from the process of standardization. Cooperation with suppliers is however generally aimed at rationalization or process innovations and also done by less innovative firms (Fritsch and Lukas, 2001). We hence assume that firms involved in formal standardization are using knowledge from their suppliers less for innovation compared to firms not involved in formal standardization, because they are interested in more fundamental innovations and can potentially see direct knowledge sourcing from suppliers as substitutes to formal standardization participation.

> **Hypothesis 1:** Companies sourcing information from their suppliers for innovation activities are less likely to be involved in standardization.

Secondly we turn to customers as an additional source of vertical information. Information from customers for innovation processes can provide indication where future market needs are located and steer the innovation activities of the company into the right direction. Fritsch and Lukas (2001) find more innovative firms to aim at cooperation with customers. They further find that collaborations with customers produce knowledge that is utilized for product innovations rather than further development of already existing products. Understanding the wants of customers is crucial for marketing new technological developments and therefore arriving at effective innovations.

As companies active in formal standardization are aiming at understanding and influencing the technological development and market their innovations, they want to utilize information from their customers for their innovation processes. We therefore arrive at our second hypothesis:

Hypothesis 2: Companies sourcing knowledge from their customers for innovation activities are more likely to be involved in standardization.

We now turn to the potential knowledge spillovers from outside the supply chain. A study of Blind and Mangelsdorf (2012) discovers that small and medium-sized enterprises relying on incoming spillovers from competitors and research organizations are more likely to participate in standardization activities. In the following, we separate the potential sources of customers and scientific organizations for firms active in formal standardization.

The third sources of interest for a company are scientific organizations, for example universities. Scientific organizations provide a broad knowledge base for companies (Un et al., 2010). Firms that consider publicly available information as more important for their innovation processes are more likely to cooperate with research institutions (Cassiman and Veugelers, 2002). Also do firms that are more open in their search strategies and higher investors in R&D more likely to use universities as a source for innovation (Laursen and Salter, 2006). Firms active in formal standardization are interested in large pools of knowledge available, and are hence assumed to utilized knowledge from scientific organizations more for their innovation activities.

Hypothesis 3: Companies utilizing knowledge from scientific organizations are more likely to be involved in standardization.

The last external sources we consider are competitors. Joining strategic alliances, where close rivals are present, increases the competitive pressure on firms (Axelrod et al., 1995). This lowers the incentive of firms to participate in formal standardization committees. However, firms interested in the technological development must consider their competitors' strategies and closely observe their actions. Although the breadth of knowledge available from competitors is small (Un et al., 2010), it is crucial to be aware of the competing technologies when trying to develop a new industry standard. We hence assume that firms active in formal standardization will consider the information available from their competitors for their own innovation activities.

Hypothesis 4: Companies utilizing knowledge from competitors are more likely to be involved in standardization.

After introducing the hypotheses resulting from the theoretical framework, we will now present the methodology and the results of our analysis.

RESULTS

This section describes the construction of our sample followed by the empirical test of the framework developed above.

The data stems from the Dutch version of the Fourth European Community Innovation Survey (CIS) that compiles firm's innovation activities[7]. This survey directly questions individual firms about their product and process innovations, the sources of information for their innovation activities, cooperation activities and expenditures on R&D. The survey was conducted in 2007 and relates to innovation activities undertaken in the three-year period from 2004 to 2006. The CISs are executed within multiple European countries and were used in over 60 recent articles as a basis for innovation research (Laursen and Salter, 2006). We therefore believe it to be a sound database for our investigation. The sample comprises over 3450 companies that provided all necessary information.

To relate the knowledge acquisition activities of firms for innovation to the participation in standardization, these two datasets are matched by the participating organization with the individual companies' involvement in the national standards development organization: The Netherlands Standardization Institute (NEN). A complete list of all 1400 companies actively involved in standardization at the NEN at the end of 2008 was provided. More than 480 of these companies provided full information in the CIS; therefore 14% of the surveyed companies were actively participating in standardization at NEN[8]. Tables A1 and A2 in the appendix provide a summary of the constructed variables and their means and distributions, respectively. We will provide a brief introduction to the variables along with the specification of the model.

This cross-sectional dataset allows us to investigate the characteristics of firms that are involved in formal standardization. The focus lies on the attitudes of firms towards their knowledge pool and therefore on the usage of external sources of information for innovation. The binary variable NEN indicates whether the firm has been participating in standardization.

The explanatory variables of interest are the external information sources a company utilized for innovation activities (is_i). This is measured on a three-level scale from low importance to high importance for the time period of 2004 to 2006. On average, information sourcing from suppliers (is_{su}) is rated highest, followed by sourcing from customers (is_{cu}) and competitors (is_{co}). Information used from scientific (is_{sc}) institutions is least important for the companies in the sample. We assume these variables to relate to the likelihood of participation in NEN in the way specified by our hypotheses.

[7]Because these surveys are used extensively in the literature, we will not introduce the procedure of the data collection here. The interested reader might consult Tether (2002) and Brouwer and Kleinknecht (1999) for further information.

[8] Blind (2006) found that half of the firms in a sample of German manufacturing companies were involved in formal standardization bodies. The difference in the share of involvement in standardization can be explained by the bias towards larger companies and those active in standardization. Because of the construction of the CIS survey such bias can be avoided.

We further include a series of control variables important for the likelihood to participate in standardization. To distinguish the general knowledge sourcing from external sources from directed cooperation with external sources, we also include information on cooperation activities as well as the utilization from spillovers of such cooperation activities. The cooperation with external organizations is measured with a binary variable indicating whether the firm has cooperated with the specific institution in the period between 2004 and 2006. The variables are cooperation with suppliers (co_{su}), cooperation with customers (co_{cu}), cooperation with competitors (co_{co}) and cooperation with scientific institutions (co_{sc}). 37% of the companies in the sample cooperate with suppliers, followed by customers and scientific organizations. 15% of the firms in the sample cooperate with their competitors. To relate the cooperation with external sources and the use of information for innovation activities we also include an interaction term of the two variables (x_i). This allows us to see where information from cooperation is used for innovation activities and helps to discriminate the effects of information sourcing from external knowledge sources in general and from specific cooperation activities.

We consider the relative spending on R&D to be important for the participation. The variable rd reports the firm's expenditure on R&D activities divided by total turnover in the year 2006. Average R&D spending in the sample is 3.2%. A higher level of R&D indicates a firm's higher level of absorptive capacity (Cohen and Levinthal, 1990), i.e. the ability of a firm to recognize external information for its innovative capabilities.

As mentioned before, the existence of patents can be a valuable resource in a standard. The existence of intellectual property rights is also important for the revelation of knowledge in collaborations (Cassiman and Veugelers, 2002). The variable pat therefore measures the importance of patent protection for intellectual property on a three level scale from low to high importance.

Further is the size of a company relevant, as it determines the resources available for standardization. Participation in national standardization is costly and firms need to cover travel expenses for technical committees meetings and membership fees. The $size$ of a company is measured by the logarithm of the number of employees in the year 2006. The export activities of a company further are suggested to have a positive relation with the likelihood of participation in standardization. Participation in national standardization is usually the precondition for the involvement in international standardization and often are national results simply transferred to the international level as input for an international standard (e.g. ISO). Being able to influence and comply with international standards can reduce transaction costs. The export activity exp is measured on a three-level scale from national over European to international activities. Finally, we include sector specific dummies (ind_i). We discriminate between manufacturing and services industries. Manufacturing industries are low-tech (lt), medium-low-tech (mlt) and medium-high-tech (mht). Service industries are knowledge intensive service (kis), less knowledge intensive services ($lkis$) and infrastructure related services ($infra$).

The model used to test the hypothesis relates the probability that a firm is participating in standardization to information sourcing from external sources for innovation activities. Two cross sectional probit models measure the effects of the independent variables on a company's likelihood of participating in NEN. In the first model, we focus only on the general information sourcing from external sources for innovation. The second model also includes the utilization of knowledge from specific cooperation activities. This checks whether the information available from specific cooperation alters the utilization of the knowledge sources available.

1. $\Pr obability\ (NEN = 1) = \beta_0 + \beta_1 is_{su} + \beta_2 is_{cu} + \beta_3 is_{sc} + \beta_4 is_{co} + \beta_5 rd + \beta_6 pat + \beta_7 size + \beta_i ind_i + \varepsilon$
2. $Probability\ (NEN = 1) = \beta_0 + \beta_1 is_{su} + \beta_2 is_{cu} + \beta_3 is_{sc} + \beta_4 is_{co} + \beta_5 co_{su} + \beta_6 co_{cu} + \beta_7 co_{co} + \beta_8 co_{sc} + \beta_9 x_{su} + \beta_{10} x_{cu} + \beta_{11} x_{co} + \beta_{12} x_{sc} + \beta_{13} rd + \beta_{14} pat + \beta_{15} size + \beta_i ind_i + \varepsilon$

In order to examine the proposed relationships with the involvement in national standardization, we estimated two simple Probit regression models. Table 1 provides the output of this analysis. The model has been estimated with sector dummies, which are not included in the regression output for brevity. The coefficients of the regression as well as the standard errors in parentheses are reported.

The model tests our hypotheses concerning the external knowledge sourcing activities of firms for innovation. The first hypothesis assumed that companies sourcing knowledge from their suppliers are less likely to be involved in standardization. We find that the coefficient of information sourcing from suppliers is highly significant in both models. The data therefore support hypothesis one. The second, third and fourth hypotheses are assuming that firms who are sourcing information from customers, scientific organizations and competitors, respectively, are more likely to be involved in standardization. The results from the regression analysis report a significant relationship of information sourcing from customers and scientific institutions in both models, lending support to hypotheses two and three. The last hypothesis, however, is not supported by our data. There exists no significant relationship with the information sourcing from competitors in either of the models.

The data from the Netherlands support three of the four hypotheses we postulated. There exist significant relationships with three of the four external knowledge sources for innovation and the participation in formal standardization. This remains if we control for potential spillovers that can be absorbed from directed cooperation. We will now turn to discuss the implications of the data analysis for research and management policy.

Table 1: Results of the Probit Estimation Models

Model	2	3
Explanatory Variables		
is_{su}	-0.027	-0.030
	(4.76)***	(4.21)***
is_{cu}	0.009	0.012
	(1.66)*	(2.03)**
is_{co}	-0.003	-0.001
	(0.50)	(0.12)
is_{sc}	0.044	0.020
	(5.83)***	(2.01)**
Control Variables		
co_{su}		-0.013
		(0.55)
co_{cu}		-0.005
		(0.16)
co_{co}		0.064
		(1.91)*
co_{sc}		0.011
		(0.57)
x_{su}		0.010
		(0.87)
x_{cu}		-0.008
		(0.62)
x_{co}		-0.011
		(0.72)
x_{sc}		0.027
		(1.68)*
RD	0.001	0.001
	(2.73)***	(2.57)**
Pat	0.042	0.036
	(3.18)***	(2.72)***
$Size$	0.061	0.058
	(15.31)***	(14.52)***
Exp	0.035	0.034
	(5.28)***	(5.12)***
Observations	3456	3456
Pseudo R^2	0.23	0.23

The table reports the coefficients of the Probit regression on the variable NEN. Standard errors are in parentheses. Asterisk ***,**,* denote statistically significant coefficients at the 1%, 5% and 10% level of significance.

DISCUSSION

This paper highlighted that external knowledge sourcing can be an important aspect for firms active in formal standardization. We postulated that companies that are active in standardization use external knowledge sources differently than those not involved. We found that firms utilizing supplier's information for innovation activities are less likely to be involved in standardization. Firms that utilize customers and scientific institutions, on the other hand, are more likely to be involved in standardization. Finally, there is no evidence that firms involved in formal standardization committees use competitors differently for innovation activities.

The aim of this analysis was to identify how firms active in formal standardization use knowledge from external sources for innovation activities differently than those not involved. We assumed that

firms interested in influencing and understanding the technological development use formal standardization for this purpose. We will now discuss the implications and limitations of our analysis.

The fact that firms active in standardization use information for innovation less from their suppliers is the most noticeable result of this paper. The knowledge for innovation derived from suppliers should therefore be seen in contrast to the knowledge used by firms involved in standardization committees. We could postulate that suppliers provide an alternative source for innovation activities to the knowledge pool available from the strategic alliance of standardization. It also seems that the orientation towards process innovations rather than product innovations of the information sourcing from suppliers contrasts with the objectives in formal standardization. An alternative explanation is that some firms may experience barriers to participate in standardization, for example as the costs of membership are high. If they want to access complementary resources, they turn to the source most easily accessible: their suppliers. Firms that are not participating in standardization could hence be more inclined to use their suppliers as sources for innovation, if information from other sources is not available. As we cannot test this with our data, it is left to be an open question for future research.

An implication of our analysis is that firms active in standardization are more open towards knowledge from customers and scientific institutions in their innovation activities. This means that companies involved in formal standardization orientate themselves forward in their supply chain for innovation activities. For managers this highlights how these firms monitor their customers, and therefore how attention should be paid the kind of information that is released, for example in technical committees. Furthermore the sourcing of information from suppliers seems to be an alternative means for firms involved in formal standardization. Hence managers should consider whether the opening up in strategic collaboration for potential knowledge sources can be an alternative to sourcing information for innovation from suppliers. Finally, as we find no evidence that firms involved in standardization utilize spillovers from their competitors, this may reduce the fear of standardization managers that knowledge revealed in the technical committee benefits their rivals.

The study has several limitations. First of all we are not discriminating between knowledge available from the standardization process and other available knowledge, although we control for the knowledge available through directed cooperation activities. The availability of cross-sectional data only does not enable us to consider the longitudinal evolution of knowledge sourcing with respect to the involvement in standardization. Furthermore our data is constrained to a single national standardization institute, which may not be representative for the involvement in other kinds of formal standardization organizations.

Additional studies could complement the issue by looking at the specific knowledge generation resulting from the formal standardization processes. The introduction of panel data could shed light on possible causal relations. We see this paper as a first step in establishing the importance of formal standardization as a knowledge pool for innovation activities.

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Appendix

Table A.1: Construction of Variables

Model Variable	Indicator
	Dependent Variable
NEN	1 if a company actively participated in standardization in the year 2008, 0 otherwise
	Independent Variables
is_su, is_cu, is_co, is_sc	Importance of incoming knowledge spillovers from suppliers (is_su), customers (is_cu), competitors (is_co) or scientific organizations (is_sc) from 0 (not important) to 3 (very important).
co_su, co_cu, co_co, co_sc	1 if company cooperated with suppliers (co_su), customers (co_cu), competitors (co_co), private research organizations (co_pr) or scientific organizations (co_sc) in innovation activities between 2004 and 2006, 0 otherwise.
x_su, x_cu, x_co, x_sc	Interaction term between cooperation activities and importance of incoming knowledge spillovers from suppliers (x_su), customers (x_cu), competitors (x_co or scientific organizations (co_sc) from 0 to 3.
Rd	Expenditure on own R&D divided by total turnover in 2006
Size	Logarithm of employment 2006
Exp	Degree of export from national over European to international activities (0 to 2)
Pat	Relevance of patent protection from low to high (0 to 3)
Lt	Low-technology manufacturing industries: NACE 15, 17, 21, 22, 23
Mlt	Medium-low-technology manufacturing industries: NACE 25, 27, 28
Mht	Medium-high-technology manufacturing industries: NACE 29, 30, 34
Kis	Knowledge-intensive services industries: NACE 65, 72, 73, 74.1, 74.2, 74.4, 90, 93
Lkis	Less-knowledge-intensive services industries: NACE 51, 52, 55, 60
infra (basis)	Infrastructure related services: NACE 40, 45

Table A.2: Descriptive Statistics of Variables

Model Variable	Observations	Mean	Standard Deviation	Min	Max
Dependent variable					
NEN	3456	0.14	0.35	0	1
Independent variable					
Rd	3456	3.28	31.96	0	1265.79
Pat	3456	0.18	0.38	0	1
is_{su}	3456	1.76	0.91	0	3
is_{cu}	3456	1.68	1.08	0	3
is_{co}	3456	1.28	0.93	0	3
is_{sc}	3456	0.62	0.67	0	3
co_{su}	3456	0.37	0.48	0	1
co_{cu}	3456	0.25	0.43	0	1
co_{co}	3456	0.15	0.36	0	1
co_{sc}	3456	0.26	0.44	0	1
x_{su}	3456	0.74	1.09	0	3
x_{cu}	3456	0.57	1.07	0	3
x_{co}	3456	0.25	0.67	0	3
x_{sc}	3456	0.25	0.54	9	3
Control variables					
$Size$	3456	4.50	1.41	0	10.33
Exp	3456	0.98	0.86	0	2
Lt	3456	0.16	0.36	0	1
mlt	3456	0.09	0.29	0	1
Mht	3456	0.17	0.37	0	1
Kis	3456	0.26	0.44	0	1
$Lkis$	3456	0.25	0.43	0	1

Table A3: Correlation Matrix of Independent Variables

	is_{su}	is_{cu}	is_{co}	is_{sc}	co_{su}	co_{cu}	co_{co}	co_{sc}	x_{su}	x_{cu}	x_{co}	x_{sc}	rd	$size$	exp	pat
is_{su}	1.00															
is_{cu}	0.15	1.00														
is_{co}	0.21	0.50	1.00													
is_{sc}	0.15	0.28	0.35	1.00												
co_{su}	0.22	0.14	0.11	0.25	1.00											
co_{cu}	0.09	0.32	0.15	0.31	0.57	1.00										
co_{co}	0.05	0.09	0.16	0.28	0.41	0.46	1.00									
co_{sc}	0.08	0.17	0.13	0.50	0.53	0.53	0.45	1.00								
x_{su}	0.43	0.15	0.12	0.24	0.89	0.52	0.36	0.47	1.00							
x_{cu}	0.11	0.44	0.20	0.30	0.52	0.92	0.39	0.49	0.49	1.00						
x_{co}	0.07	0.13	0.29	0.29	0.37	0.42	0.89	0.40	0.35	0.40	1.00					
x_{sc}	0.07	0.16	0.16	0.65	0.44	0.49	0.49	0.79	0.40	0.46	0.47	1.00				
rd	-0.01	0.01	0.02	0.06	0.04	0.06	0.05	0.04	0.01	0.03	0.03	0.07	1.00			
$size$	0.06	0.12	0.12	0.25	0.20	0.20	0.19	0.26	0.18	0.19	0.18	0.29	-0.03	1.00		
exp	0.03	0.18	0.09	0.12	0.13	0.16	0.02	0.17	0.11	0.16	0.03	0.15	0.02	0.13	1.00	
pat	0.04	0.15	0.11	0.22	0.19	0.22	0.13	0.24	0.16	0.20	0.18	0.26	0.03	0.19	0.27	1.00
lt	0.07	0.04	0.02	0.01	0.02	-0.01	-0.03	-0.01	0.03	-0.01	0.03	0.01	-0.02	0.05	0.08	0.04
mlt	0.03	0.02	-0.01	-0.02	0.01	0.01	-0.02	0.01	0.01	0.01	0.12	-0.02	-0.01	-0.04	0.13	0.08
mht	0.03	0.13	0.08	0.08	0.08	0.14	0.01	0.11	0.08	0.14	-0.02	0.09	-0.01	-0.01	0.33	0.20
kis	-0.07	-0.03	-0.06	-0.02	-0.06	-0.01	0.01	-0.02	-0.07	-0.01	0.09	0.03	0.01	-0.02	-0.26	-0.14
$lkis$	-0.04	-0.08	-0.01	-0.07	-0.06	-0.10	-0.04	-0.09	-0.05	-0.10	-0.04	-0.07	-0.01	-0.01	-0.07	-0.12
inf	-0.01	-0.07	-0.02	0.05	0.03	-0.01	0.01	0.03	0.01	-0.02	0.04	0.06	0.03	0.09	-0.17	0.01

Table A3: Correlation Matrix of Independent Variables (Continued)

	lt	mlt	mht	kis	$lkis$	inf
lt	1.00					
mlt	-0.13	1.00				
mht	-0.18	-0.13	1.00			
kis	-0.24	-0.17	-0.25	1.00		
$lkis$	-0.23	-0.17	-0.24	-0.32	1.00	
inf	-0.12	-0.08	-0.12	-0.16	-0.16	1.00