Journal of Accounting, Business and Finance Research
ISSN: 2521-3830
Vol. 5, No. 1, pp. 1-6, 2019
DOI: 10.20448/2002.51.1.6

Structural Embeddedness and Firms' Impact on the Technology Standard Setting Process

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Abstract

The extant literatures often focus on the efficiency of standard committees to coordinate conflicts between members and how regulatory capture occurs, thus neglecting the impact of cooperation behaviour on the technology standard setting process. This paper aims to explore how structural embeddedness affects firms' impact on the technology standard setting process. We construct a network with the national standard data in China's communications industry in 2000-2017. With 326 firms participating in the standard formulation as the research sample, we use the negative binomial regression method to explore the relationship between structural embeddedness of technology sponsors and the impacts on the technology standard setting process. We find that while there is an inverted U-shaped relationship between the number of direct collaborators and firms' impacts on the technology standard setting process, the structural holes positively affect firms' impacts on the technology standard setting process. The conclusions obtained from this paper have important managerial implications for firms participating the technology standard setting processes.

Keywords:
Technology standard
Cooperative network
Structural embeddedness
Social network
Communication industry
Technology sponsors
China.

JEL Classification:
D22.

Publisher:
Scientific Publishing Institute

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing financial interests.

1. Introduction

Standardization can be critical in determining a technology's success and often plays a vital role in supporting major technological and societal trends. Many important ongoing developments, such as the transformation towards a platform economy, making things 'smart' and innovating large, complex systems rely on standardization. Technology standard emerges primarily through two mechanisms: market-based mechanism and committee-based mechanism (Farrell & Saloner, 1988; Funk & Methe, 2011). Although most literature has focused on the technology standard derived through market competition (Sheremata, 2004) more and more standards are created by standards development organizations (SDO), such as IEEE, ISO and ITU. For example, in the field of information technology, there are more than 550 organizations committed to the development of information technology standards.

In extant literature, some scholars have focused on the relationship between inter-firm cooperation and standard development ability. For example, Leiponen (2008) examined the relationship between informal alliances, the tie strength of between members of the standards development organizations (SDO) and their standardization capabilities based on the 3GPP standard. They found that the more the number of partners, and the closer the relationship with SDO members, the greater their influence on formal standard setting process. Other scholars have investigated the impact of the network location on firms' standard development ability.

Since the "unanimous consent" or "absolute majority" rules are usually adopted by the standard committees during the technology standard setting process, the extant literatures often focus on the efficiency of standard committees to coordinate conflicts between members (Blind, 2011) and how regulatory capture occurs (Blind, Petersen, & Riillo, 2017) thus neglecting the impact of cooperation behaviour on the technology standard setting process. Further, since firms are not atomic actors, but are embedded in networks composed of diverse relationships, previous literature have examined how network location affects the behaviour and performance of individuals (individuals, teams, firms, etc.)(Geerten, 2017) the network structure and network relationships may be leveraged by technology sponsors to influence the decisions of potential technology supporters and to acquire the technical and marketing resources which are needed to diffuse the technology standard. Along this line of thought, this paper uses the social network theory to the context of committee-based standard setting process, then examines the relationship between the structural embeddedness and their influence on technology standard setting process.

2. Theory and Hypotheses

Social network theory shows that the positions of actors in the network not only affect the frequency of contact and interaction with other members, but also affect the attractiveness of actors to other network members. Actors in the core position of the network can take advantage of the network location to gain better information and resources and thereby influence other actors. In addition, actors at the core position of the network have a larger "intelligence network" compared to actors at the periphery of the network, thereby gaining more information about potential partners and opportunities for collaboration. Such actor may not only access other members with the shortest possible paths, but also have more opportunities to connect with actors who are also at the core of the network. Network centrality may be used measure the extent to which actors act as network "hubs" and the extent to which resources are acquired and controlled. It can also be used to measure the extent of actors' popularity and attractiveness in the network.

In this article, structural embeddedness describes the overall relationships between actors, providing information on the interrelated actors' location in the network and how these actors get connected. This paper focuses on two characteristics of structural embeddedness: degree centrality and structural holes.

In social networks, degree centrality is a widely used measurement on structural embeddedness, which describes the power and superiority of actors. Similarly, in a standards network, firms in the core position will have direct ties with most other firms in the network, and thus have a strategic importance in the network. The existence of these ties may promote the sharing and combination of knowledge or resources between firms, thus providing firms with new knowledge and increasing their resource endowments. Lee and Song (2017) have found that technology sponsors with higher network centrality can attract more potential supporters, thus helping them to expand the scale and diversity of standard alliances. Thus, we can assume that the more centrally located in a standards network, the greater the number of direct ties, and the more easily to access to new knowledge, ideas and resources, thereby increasing firms' impacts on the technology standard setting process.

However, Uzzi (1997) mentioned that excessively embedded network relationships may cause instability, thus reducing the flow of new information in the network. Furthermore, excessively embedded relationships in the network could produce negative emotions among the firms, thus negatively affect the collaborative relationships in the network. Christensen (1992) also argued that excessively embedded network relationships may create inertia, making their behaviour less proactive. Additional, densely network relationships may result in higher opportunity costs, organizations may have to maintain strong connections by invest significant resources or time, rather than linking them to non-redundant participants (Molina & Martínez, 2009). Based on the above, we hypothesize:

Hypothesis 1: In the standards network, there is an inverted U-shaped relationship between degree centrality and the impacts on the technology standard setting process.

In addition to being the core of the network, being the resource intermediary is also conducive to expanding the resource endowment of the actor. Burt (1992) argued that in the social network, ties between nodes can provide a certain amount of information, but if diverse ties in the network provide the same information, there will be information redundancy. Therefore, non-redundant ties should be promoted in the network because they can provide heterogeneous information (Burt, 1992; Ronald, 2004). A structural hole is understood as a gap between two individuals who have complementary sources to information. In an open network with many structural holes, actors who connect between organizations can leverage their "bridge" role to connect with new members in other groups to control heterogeneous information and resources more quickly. Zeng, Zou, and Zhang (2015) found that firms with rich structure holes may access more information in different fields, so as to have a better understanding about the knowledge or complementary technologies needed for diversifying activities that are different from the routine businesses. Therefore, we can assume that in the standards network, firms in the structural hole position will grasp more heterogeneous information and resources because of their "bridge" role, which will increase the opportunities for firms to participate in the formulation of standards, and thus increasing firms' impacts on the technology standard setting process. Therefore, we hypothesize:

Hypothesis 2: In the standards, the structural hole location is positively related with firms' impacts on the technology standard setting process.

3. Research Methodology

3.1. Sample and Data Collection

Communication technology is a cumulative evolution technology. The development of new technologies is supplemented and improved based on the original technology or combined with other existing technologies, so as to obtain better functions or better performances. Therefore, in the field of communication technology, there are many innovations that can be generated, patents' number is huge and the growth rate is significant. As the products and technologies update quickly, collaborations within the industry are frequent and network effects are obvious, thus the communication industry is suitable as the research context.

The data is obtained from CNKI's Standard Data Pool. It is the largest and most complete standard databases in China. It contains all Chinese national standards (GB), national construction standards (GBJ) and Chinese industry standards. We retrieve the technology standard for communication industry of China from 2000 to 2017 to construct a standards network.

The specific search tactics are as follows: we first select "communication, broadcasting class" under Chinese standard document classification directory, then select communication, broadcast general, communication network and communication equipment under sub-directories. Because the technology standard related to communication are mainly in the above three areas, the remaining sub-directories such as radar, navigation, remote control, telemetry, antennas, radio and television networks, radio and television equipment, postal and other communication technologies are omitted. We use the above search results of the three areas as the communication industry standard samples. There are 3,534 standards and all involved standards are divided into national standards and industry standards (mainly postal and telecommunications industry standards).

After searching the relevant standards documents, the documents titles are exported from CNKI and saved as Endnote format. With SATI, the sponsors are extracted by frequency statistics. Among them 57 standard literatures whose sponsors are personal are excluded, and keep the 3,477 standards only whose sponsors are firms, universities or scientific research institutions. With SATI, it is found that in the period of 2000-2017, there are 351 firms involved in technology standard setting in China's communication industry. Due to the large time span, some organizations have changing their names. By manually searching and verifying, organizations with changed name are classified as one name. For example, China Unicom Group Corporation is previously named as China United Communications Co., Ltd., China United Network Communications Co., Ltd., and the final name was China United Network Communications Group Co., Ltd. As another example, Shanghai Bell Alcatel Co., Ltd. was referred to as Shanghai Bell Co., Ltd. Name, so it was classified as Shanghai Bell Co., Ltd. After repeated verification, 327 firms are confirmed as our final sample. In order to examining the cooperative relationship between these firms, we generate an adjacency matrix by SATI, and then import it into UCINET 6.0 software, a network analysis tool, to obtain some network structure measurements.

3.2. Measures

3.2.1. Dependent Variables

Firms' impacts on the technology standard setting process. consistently with extant literature, this article takes the number of standards drafted by firms as the measurement of firms' impacts on the technology standard setting process.

3.2.2. Independent Variables

Degree centrality. Historically first and conceptually simplest is degree centrality, which is defined as the number of links incident upon a node (i.e., the number of ties that a node has). The degree can be interpreted in terms of the immediate risk of a node for catching whatever is flowing through the network (such as a virus, or some information). The degree centrality d_i of the node i is defined as follows:

$$d_i = \sum_j m_{ij}$$

where m_{ij} refers to links between i and the other nodes j that other than i in the network. Generally speaking, the greater the value of degree centrality, the more the actor is at the core of the network, and the more power it possesses. Therefore, the greater the degree centrality or the more the number of connected nodes, the greater the ability of an actor to influence others in the network.

Structural holes. Most social structures tend to be characterized by dense clusters of strong connections, also known as network closure. The theory relies on a fundamental idea that the homogeneity of information, new ideas, and behaviour is generally higher within any group of people as compared to that in between two groups of people. Four aspects are considered in Burt's structural hole index: effective size, efficiency, constraint, hierarchy (Burt, 1992). Among them, "constraint" refers to the ability of an actor to use structural holes in the network. Burt's formula for constraint is:

$$C_{ij} = (p_{ij} + \sum_{q} p_{iq} m_{qj})^2$$

where p_{iq} is the proportion of actor *i*'s energy invested in relationship with *q*, and m_{qj} is calculated as *q*'s interaction with *j* divided by *q*'s strongest relationship with anyone. In essence, the degree of restriction is the degree to which an actor is associated with other actors in the network, which may create a large amount of redundancy in the ego-network. Using the description of the structural hole index by Gonzalez, Veloso, and Krackhardt (2013) the structural hole is measured by "1-constraint".

3.2.3. Control Variables

The number of patents. Patents are the basis of technology standards, and patents filed and patents granted are factors that affecting the firms' impacts on the technology standard setting process. Therefore, the number of patent applications of firms during the participation in standards network is taken as a control variable.

The number of times that firms participate in standards draft. The number of times that firms participate in standards draft is used as a control variable. The larger number of times that firms participate in the standard setting process means that firms may play a greater role in the standards network.

4. Empirical Analyses

4.1. Descriptive Statistics and Correlation Matrix

The data is processed and analyzed using Stata12.0 software. The descriptive statistics and correlation matrix are presented in Table 1. The dependent variable "firms' impacts on the technology standard setting process (StandImpac)" in this paper is a discrete non-negative integer, thus the Poisson regression model or negative binomial regression model should be used. Since the Poisson regression model requires the condition that the mean and variance of the dependent variable are equal, and the dependent variable is excessively dispersed (Expected value is 14.4, Variance is 62.3), the negative binomial regression model is more suitable. It can be seen from Table 1 that the correlation coefficients of all independent variables are less than 0.76, and multicollinearity is not a problem.

Table-1. Descriptive Statistic and Correlations.

Variable	Means	SD.	Min.	Max.	1	2	3	4
1. StandImpac	14.3620	62.3277	1	655	1.000			
2. DegreCentr	2.9158	4.1329	0	34.945	0.8467	1.000		
3.Structure holes	0.6987	0.2528	-0.125	1	0.1990	0.4334	1.000	
4.Patents	373.3374	3177.316	0	42936	0.8179	0.6063	0.0897	1.000
5. NumbeStan	1.2607	5.9502	0	58	0.8659	0.7586	0.1598	0.6248

Source: Output by Stata112.0.

4.2. Empirical Results and Discussions

Table 2 shows the results of negative binomial regression. Model 1 and Model 2 respectively examine the relationship between degree centrality, the structural hole and firms' impacts on the technology standard setting process.

The firms' degree centrality has a significantly positive influence on their impacts on the technology standard setting process (β=0.5189, P<0.01), indicating that as the number of directly connected ties increases, firms' impacts on the technology standard setting process will increase. In the standards network, Huawei Technologies Co., Ltd., ZTE Corporation, China Mobile, China Unicom, etc. have more than 100 direct partners, and these firms have participated in drafting more than 200 standards. The number of standards set by ZTE and Huawei is as high as 600, indicating that these firms have strong impacts in the standard setting process.

The quadratic term of degree centrality is significantly and negatively correlated with firms' impacts on the technology standard setting process (β = -0.0172, P<0.01), and the while degree centrality is positively correlated with firms' impacts on the technology standard setting process (β = 0.5189, P<0.01), indicating that there is an inverted U-shaped relationship between degree centrality and firms' impacts on the technology standard setting process. In this paper, the degree centrality of China Mobile and China Unicom (128, 107 respectively) is much higher than that of Shanghai Bell (72), but the number of standards drafted by China Mobile and China Unicom is relatively small. In addition, the same phenomenon exists for firms such as Emerson Network Power Co., Ltd., and Beijing Power Source Technology Co., Ltd. This means that the number of partners cannot be pursued as the only aim in the standards network, and maintaining a moderate level of cooperation will help to increase firms' impacts on the technology standard setting process. Previous studies such as Leiponen (2008) and Zeng et al. (2015) only examined the relationship between the level of direct ties (degree centrality) and the influence on firms' impacts on the technology standard setting process. Based on Uzzi (1997) theory, we examine the relationship between degree centrality and firms' impacts on the technology standard setting process, and confirm that there is an inverted U-shaped relationship between them. Hypothesis 1 is thus verified.

Table-2. Negative Binomial Model Estimation.

Independent variables	Model 1			Model 2			Model 3		
	β	***z***	***P***	***β***	***z***	***P***	***β***	***z***	***P***
DegreCentr	0.5189***	15.27	0.000				0.4540***	10.82	0.000
DegreCentr DegreCentr	-0.0172***	-8.13	0.000				-0.0147***	-6.36	0.000
StrucHoles				3.39***	12.13	0.000	0.7667**	2.48	0.013
Patents	0.0001***	3.80	0.000	-0.0035	-1.11	0.267	0.001***	3.06	0.002
NumbeStan	0.0945***	3.82	0.000	0.132***	6.45	0.000	0.0862***	3.65	0.000
_cons	0.1753*	1.80	0.071	-0.967***	-4.36	0.000	-0.2369	-1.22	0.221
Log likelihood	-817.71			-887.69			-814.61		
LR chi2	533.04			393.06			539.24		
Prob>chi2	0.000			0.000			0.000		
Obs	326			326			326		

Note: ***p<0.01, ** p<0.05, * p<0.1.

Model 2 examines the relationship between structural holes and its impacts on the technology standard setting process. It can be seen from Model 2 that the structural hole has a significantly negative influence on firms' impacts on the technology standard setting process (β=3.39, P<0.01), indicating that the structural hole is conducive for firms to obtain a large number of heterogeneous resources, thereby increasing its own resources endowment so as to make a positive impact on standard setting process. In this paper, the structural hole indices of ZTE, Huawei, Shanghai Bell and other firms are all above 0.95, indicating that in addition to the large number of direct partners these firms are often in the "bridge" position in the network. By leveraging diverse ties, they get a lot of heterogeneous resources, which increases their impact on standard setting process. Zeng et al. (2015) also confirms that firms with rich structure holes can access heterogeneous information, build information-rich networks at lower cost, and obtain non-redundant heterogeneous resources from the network faster. Thus Hypothesis 2 is verified.

Model 3 combines Model 1 and Model 2. In this model, the degree centrality is positively correlated with firms' impacts on the technology standard setting process (β =0.4540, P<0.01), and the quadratic term of degree centrality is significantly and negatively correlated with the degree centrality (β= -0.0147, P<0.01), which means that controlling the factor of the structural hole, the degree centrality and firms' impacts on the technology standard setting process still demonstrate an inverted U-shaped relationship, indicating that the firms needs to maintain a moderate level of collaboration size, Hypothesis 1 is further supported. Secondly, the structural hole is positively correlated with firms' impacts on the technology standard setting process (β=0.7667, P<0.05), which means that while maintaining the moderate level of collaboration, occupying structural holes is more conducive for firms to obtain non-redundant information and resources and to expand its resource endowment, thereby increasing firms' impacts on the technology standard setting process. Hypothesis 3 is further supported.

4. Conclusion and Implications

Based on the social network theory, this paper aims to explore how structural embeddedness affects firms' impact on the technology standard setting process. We construct a network with the national standard data in China's communications industry in 2000-2017. With 326 firms participating in the standard formulation as the research sample, we use the negative binomial regression method to explore the relationship between structural embeddedness of technology sponsors and the impacts on the technology standard setting process. We find that while there is an inverted U-shaped relationship between the number of direct collaborators and firms' impacts on the technology standard setting process, the structural holes positively affect firms' impacts on the technology standard setting process.

The conclusions obtained from this paper have the following managerial implications: Firstly, in order to enhance their impacts on the technology standard setting process, it is necessary for firms to seek collaborations such as firms or scientific research organizations that dominant in industry to increase the collaboration size. In this study, the dominant firms are ZTE, Huawei, Shanghai Bell and the three major telecom operators. Firms should actively expand their cooperation channels and seek opportunities to get access to dominant players. Secondly, while actively access other partners, we may also pay attention to obtaining different industry resources and avoid resource redundancy. After accessing partners with high status, firms should leverage collaboration opportunities so as to increase the frequency of resource exchange, thus further establish a common resource pool to promote the diffuse of tacit knowledge and increase firms' impacts on the technology standard setting process. Thirdly, the number of partners accessed or resources received and exchanged should be moderate, firms are supposed to cooperate within a certain limit. Because heterogeneous resources beyond their capabilities may not only be harmful to firms' impacts on the technology standard setting process, but will cause excessively embeddedness in the network and increase cooperation costs.

As with other research, this article also suffers some limitations. First, this article takes the communication industry as the research context, and conclusions may not be generalizable to other industries. In addition, this article only considers two measures on structure dimension of embeddedness, the relational and cognitive dimensions of embeddedness are needed to be involved in future studies.

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