

Technical Standard Competition in the Mobile Communication Industry: A Literature Review

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Abstract: This study mainly adopts the bibliometric method to draw the knowledge map and sort out the literature related to the technical standard competition in the mobile communication industry. First of all, this paper analyzes the publishing trend, publishing journals, publishing authors, and co-authors' networks of technical standard competition literature in the mobile communication industry through descriptive statistics, so as to understand the research panorama in this field. Secondly, the relationship between the contents of literature retrieval is discussed by keyword co-word analysis, then the keyword cluster map is formed. Finally, by reading 342 pieces of literature in detail and combining with the results of keyword clustering, the theoretical perspectives of the existing literature on technical standards of the communication industry are systematically sorted out, which are divided into four main theoretical perspectives: regulation theory, technology management, industrial organization, and strategic management.

Keywords: TechnicalStandards;MobileCommunicationIndustry;BibliometricAnalysis

I. Introduction

Technical standard competition is the competition between different technical tracks for dominance [1]. Previous studies have found that the formulation of standards is not entirely influenced by technology or other economic factors. Political and social benefits as well as the pressure of technological standardization on firms play a crucial role in determining the development path of technology and industry. Under certain conditions, the decision of the main actors in the industry determines the general path and result of the development of technology and standards [2], and dominates the entire technology system and industry chain through the control of technical standards [3].

The mobile communication network is a complex social technology system composed of many subsystems, and its interoperability is realized by standards. Therefore, the establishment and competition of technical standards in the field of mobile communication have been the focus of scholars' research. Through the bibliometric method, this study draws the knowledge map and combs the literature related to the technical standard competition in the mobile communication industry, then finds that the research perspectives of the existing literature mainly focus on four research perspectives: regulation theory, technology management, industrial organization, and strategic management.

II. Literature search strategy and analysis

This paper takes the Web of Science core collection as the source of literature. The search strategy is as follows: (TS=

(Standard OR Telecommunication);SO= (Research Policy OR Telecommunications Policy OR Telecommunications Systems OR Journal of High Technology Management Research OR Technological Forecasting and Social Change OR Technovation OR Technology Analysis and Strategic Management OR R&D Management OR Journal of Product Innovation Management OR IEEE Transactions on Engineering Management OR Journal of Engineering and Technology Management OR International Journal of Technology Management);Language: English; Index: SCI-EXPANDED, SSCI, CPCI-S, CPCI-SSH, CCR-EXPANDED, IC; Time span: 1986-2019. Retrieved 13 March 2020. Among the 1642 papers retrieved, Book Review (78), Note (12), Proceeding paper (157), Letter (2), and Reprint (3) were excluded. A total of 1,484 articles with the document types of "Article (1464 articles)" and "Review (20 articles)" have been retained.

In this study, the English abstract of each of the 1484 articles was further read, and the literature was cleaned according to the following principles:

(1) Editorial articles from some journals were excluded;

(2) Although there is some literature related to the communication industry, such literature obviously deviates from the research topic of technical standard competition. For example, the relationship between infrastructure and economic growth in the communication industry, smart cities, efficiency of communication operators, consumer protection in the communication industry, the impact of communication industry reform on operator performance, the relationship between the transportation industry and communication in developing countries, communication service pricing, consumers' willingness to pay for communication services, human resource management in the telecommunications industry, etc.

(3) There are also some pieces of literature related to technical standards of non-communication industries, such as the ventilation equipment industry, aviation industry, photovoltaic industry, data exchange, automobile industry, Internet, construction industry, banking industry, intelligent instrument, the global coffee industry, etc.

Finally, 342 pieces of literature were obtained after literature cleaning, involving 590 authors. In this study, all authors, titles, source publications, year of publication, keywords, abstracts, and cited references were exported into plain text format and visualized with VOSviewer software.

2.1 Analysis of the Number of Publications and issuing institutions

Figure 1 describes the trend of publication of literature related to the competition of technical standards in the mobile communication industry. From 1990 to 2012, the technical standard competition literature of the mobile communication industry basically showed an increasing trend year by year, reaching a peak of 36 in 2012. After a brief decline in 2013, it gradually increased, reaching a second peak of 33 articles in 2017. In the early days of a piece of literature, Besen and Farrell [4] discussed earlier that the historic role of the International Telecommunication Union (ITU) in setting international telecommunication standards may be increasingly threatened by Regional Standards Organizations (RSOs) and the threat of formal or informal coordination of these regional standardization organizations; Moreover, these regional standardization organizations are able to set standards more effectively than ITU in terms of size, structure, and procedures.

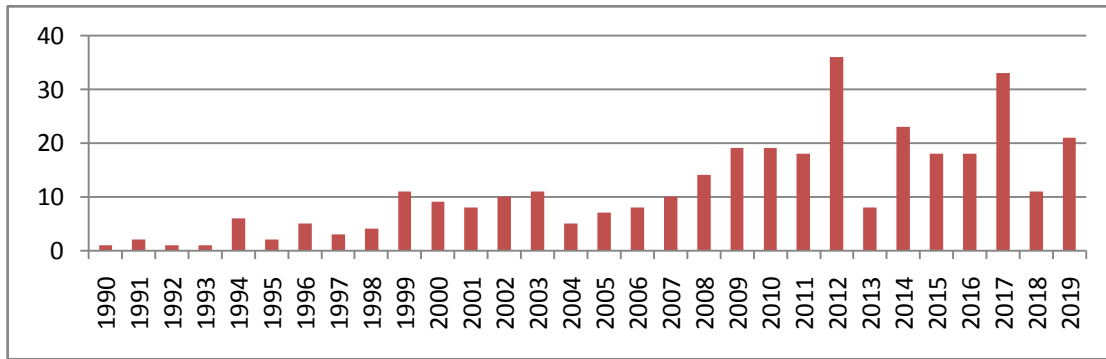


Figure 1 Trend of technical standard competition literature in the mobile communication industry

In the literature on the formulation of technical standards for the mobile communication industry, Yonsei University, Beijing University of Posts and Telecommunications, Erasmus University, Carnegie Mellon University, Technical University of Berlin, Penn State University, Seoul National University, Delft University of Technology, and The Ohio State University ranked in the top 10. These institutions are mainly from South Korea, China, the Netherlands, the United States and Germany (see Figure 2).

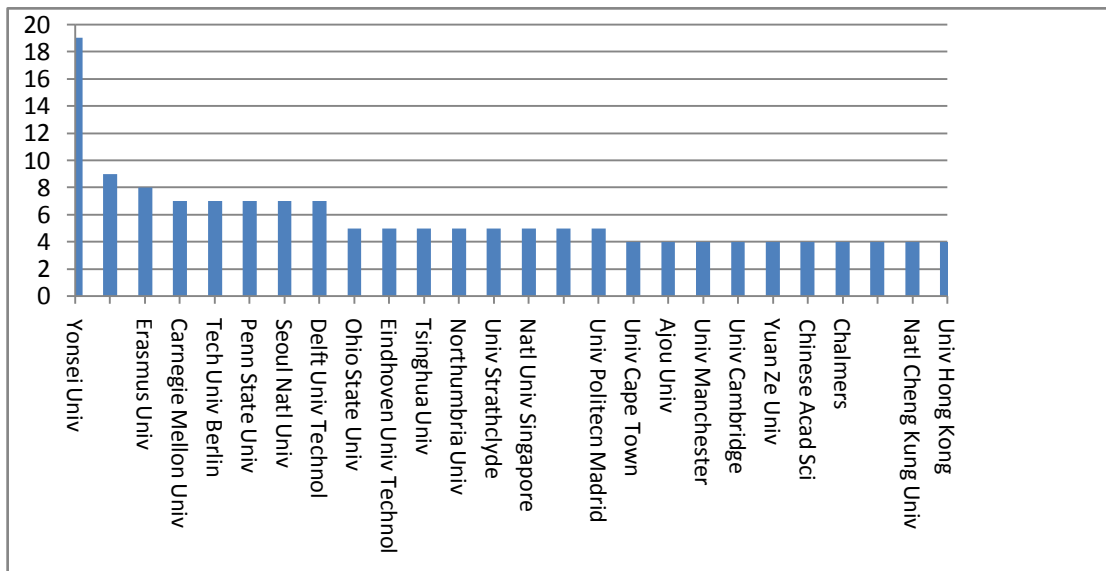


Figure 2. Distribution of publishing institutions in the field of technical standard competition literature in the mobile communication industry

2.2 Analysis of published journals

As the literature on the competition of technical standards in the mobile communication industry is mainly published in English journals where communication technology and innovation management intersect, more than 70% of the 342 pieces of literature retrieved are from Telecommunications policy (251). Given that the research object of this paper is highly consistent with the research topic of Telecommunications policy, this result seems very reasonable. In addition, 11% of the literature was from Technological forecasting and social change (38 papers), 9% was from Research policy (30 papers), and the number of publications in other journals accounted for less than 10% of the total literature (see Figure 3).

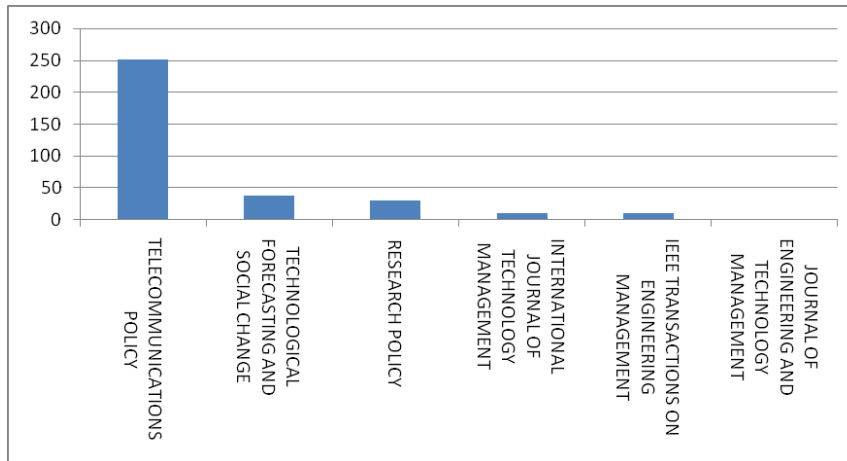


Figure 3. Distribution of published journals in the field of technical standard formulation literature in the mobilecommunication industry

2.3 Author and co-author network analysis

Table 1 shows the 14 scholars who published the most papers in the technical standard formulation literature of the mobile communication industry. Whalley Jason from Northumbria University has published 10 articles focusing on structural changes in telecommunications markets and their consequences. He has worked with various regulators and telecommunications companies on the development of regulatory regimes and how organizations can take advantage of technological change. Professor Xia Jun is currently the director of the Institute of Information and Communication Industry and Policy at Beijing University of Posts and Telecommunications. He is also an internationally renowned scholar in the field of information and communication economics and policy research and a guest editor and editorial board member of Telecommunications Policy (SCI, SSCI). Professor Gao XD (Gao Xudong), School of Economics and Management, Tsinghua University, his research interests include competitive strategy, technology strategy and technology innovation of Chinese firms. Professor Xia Jun and Professor Gao Xudong have conducted in-depth research on 3G and 4G competition and regulation in China's mobile communication industry and published a number of academic papers. Professor Gao Xudong published his Research policy paper "A latecomer's strategy to promote a technology standard: The case of Datang and TD-SCDMA" which discusses the key strategies of Datang Telecom in promoting TD-SCDMA, which provides new insights into the formulation and adoption of technical standards for latecomers in developing countries.

Table 1The affiliations of the author and the number of published publications

Author Name	Affiliations ¹	Nationality	Number of publications
Whalley Jason	Northumbria University	Britain	10
Blind Knut	Technical University of Berlin	Germany	9
Lee Heejin	Yonsei University	South Korea	7
Xia Jun	Beijing University of Posts and	China	6

¹Most academics have experienced job changes, such as Whalley Jason, who worked at Strathclyde Business School before joining Northumbria University; Prior to his appointment at the National University of Singapore, Funk worked for Hughes Aircraft Company, Westinghouse Electric Company, Pennsylvania State University, Kobe University and Hitotsubashi University. The institution to which the author belongs refers to the institution to which the author currently works.

	Telecommunications		
Bekkers Rudi	Eindhoven University of Technology	Holland	5
Funk JL	National University of Singapore	Singapore	5
Gao Ping	University of Manchester	Britain	5
Cave Martin	London School of Economics	Britain	4
Gao Xudong	Tsinghua University	China	4
Gerpott Torsten J.	University of Duisburg-Essen	Germany	4
Kwak Jooyoung	Yonsei University	South Korea	4
Lyytinen Kalle	Case Western Reserve University	Britain	4
Majumdar Sumit K.	University of Michigan	United States	4
Yan Xu	Hong Kong University of Science and Technology	Hong Kong, China	4

III. Co-word analysis

In 342 pieces of literature, there were 1461 keywords, 71 of which appeared more than 7 times, and these keywords constituted 4 clusters. Table 2 describes the core keywords involved in the four clusters and their correlation strength. By further reading the original literature on core keyword clustering, the four clustering literature are divided into regulation theory perspective, technology management theory perspective, industrial organization theory perspective, and strategic management theory perspective.

3.1 Literature Review of technical standard Competition in the mobile communication Industry from different theoretical Perspectives

3.1.1 The perspective of regulation theory

From the 1980s to the end of the 1990s, developed and developing countries gradually began to introduce competition in the communication industry and restrain the behaviors of dominant operators through administrative coercive means. Thus, it can provide a relatively superior development environment and market conditions for emerging operators [5]. From the perspective of literature development, early literature was mainly based on regulation theory. The literature based on regulation theory mainly takes the government and industry as the analysis unit. The purpose of government regulation is to improve the efficiency of resource allocation to enhance social welfare by overcoming market failure.

According to the clustering results of co-word analysis, the high-frequency words Telecommunication, Policy, Regulation, Broadband, Entry, and Liberalization in cluster 1 are widely used literature keywords in this theoretical perspective. In the early theoretical literature, Besen and Johnson [6] showed that when users do not know others' preferences or have no obvious preference for competitive technologies, formal standards formulated by government or private organizations can lead to efficient results. In contrast to the above studies, Greenstein and Rysman [7] examined the role of the International Telecommunication Union in setting standards for 56K modems and argued that government regulation or market competition could not avoid the social costs of coordinating conflicts among members. Furthermore, due to the unique role of the government in the setting of technical standards in the communications industry, large firms may invest resources to influence the outcome of the setting of technical standards. Internal manipulation of standard-setting rules and lobbying of governments by standard-competing participants to advance their economic

interests make the standard-setting process potentially anti-competitive.

3.1.2 The perspective of technology management theory

Literature from the perspective of technology management theory mainly takes the technical standard itself as the analysis unit and emphasizes the important role of technological advantage in the competition of technical standards. According to the clustering results of co-word analysis, high-frequency words Industry, Standardization, Standard, Performance, Evolution, Patents, and IPR in clustering 3 are widely used literature keywords from this theoretical perspective.

Table 2 Clustering results of co-word analysis

Cluster 1	Frequency	Correlation strength	Cluster 2	Frequency	Correlation strength	Cluster 3	Frequency	Correlation strength	Cluster 4	Frequency	Correlation strength
Access	11	43	3g	22	96	Compatibility	19	83	Adoption	12	66
Broadband	18	61	China	31	137	Determinants	10	36	Behavior	7	18
Digital divide	8	35	Competitive advantage	9	37	Dynamics	12	72	Competition	63	288
Efficiency	12	50	Convergence	8	26	Failure	11	61	Demand	7	36
Entry	15	69	Evolution	12	75	Firms	7	35	Developing countries	8	47
Europe	7	33	Governance	14	74	ICT	12	46	Diffusion	38	201
Government	12	71	Industry	30	156	Information	8	34	India	7	35
Growth	12	45	Institutions	15	86	Innovation	62	275	Markets	12	62
Impact	11	39	IPR	8	27	Market	29	149	Mobile communication	21	87
Infrastructure	11	45	Management	10	27	Mobile communication	10	49	Mobile telephony	8	37
Internet	23	93	Mobile	16	70	Model	22	100	Models	10	45
Investment	14	52	Networks	9	37	Network externalities	13	62	Network effects	7	42
Korea	15	65	Patents	7	11	Standardization	9	32	Phones	7	45
Liberalization	11	48	Performance	21	86	Systems	10	52	Technology	31	138
Mobile Telecommunication	7	23	Standardization	28	134	TD-SCDMA	13	77	Telecommunications services	8	45
Policy	34	154	Standard	28	126	Technology standard	7	41	Telephony	8	60
Privatization	11	47	Strategies	8	40						
Reform	8	41									
Regulation	27	98									
Services	12	62									
Spectrum	8	14									
Telecommunications	65	259									

Scholars in the field of technology management are the first to systematically study the formation of technical standard competition and dominant design. In 1978, Abernathy et al. created the term "dominant design" to describe the result of competition among different technical standards in the industry [8]. The dominant design establishes the future trajectory of technological evolution and marks a key turning point in the process of technological development. In essence, only technical standards accepted by the market can be called dominant design [9]. Subsequently, a series of studies confirmed the existence of dominant design in some industries.

The mobile communication network is a complex social technology system composed of many subsystems, and its interoperability is realized by standards. The technological transformation of such networks largely follows the intergenerational change of standards, which is driven by the demand for larger capacity, higher transmission speed, and smoother global roaming networks [10]. Therefore, technological advantage is crucial to achieve a competitive advantage in the industry. Firms in the mobile communication industry attach importance to the value of intellectual property rights, actively develop patented technologies, obtain technical advantages, and enhance their competitiveness. But technological advantage does not always play a key role in standards competition. A large number of patents do not necessarily guarantee the company's future industry dominance [11]. Bekkers et al. [12] verified the impact of the intrinsic value of patented technology, the degree of participation and enthusiasm of the patentee in the standard-setting process on promoting patents to become standards. Through W-CDMA case verification, the successful application of basic patents is the result of both the intrinsic technology value and the holder's participation in the standardization process. But participation in the process is a much stronger determinant than the technical merit of a patent. Kang et al. [13] analyzed and derived the two most successful global standards of mobile communication -- WCDMA and LTE, and observed the differences between the standard strategies and follow-up performance of China and South Korea in catch-up modes. Research has shown that technological capabilities gained through catch-up processes do not guarantee leadership: the selection of standards to be pursued must take into account the impact of standards on technological catch-up, and if the technological trajectory is different, new technological capabilities need to be added to this pass.

3.1.3 The perspective of industrial organization theory

The literature based on the industrial organization theory mainly takes the industry (market) as the analysis unit and emphasizes the role of compatibility, network externality and self-reinforcing mechanism on the competition of technical standards. According to the clustering results of co-word analysis, the high-frequency words Innovation, Market, Model, Compatibility, Network externalities and Dynamics in clustering 2 are widely used literature keywords in this theoretical perspective.

Literature based on industrial organization theory started from a series of studies by Katz and Shaprio [14], Farrell and Saloner [15], David [16], Arthur [17] and other scholars in the middle and late 1980s. Literature in this field mainly focused on game theory and mathematical model analysis. Firm technology standard competition decision. Most models assume that the market consists of two firms providing different products, and network externalities are added into the demand function as a factor affecting demand, that is, demand depends not only on product features, but also on the installed base scale of the product [14].

Existing studies have found that network externalities increase with the diffusion of industry fields. The intergenerational iteration in the field of mobile communication is not only a simple technology upgrade, but also a rapidly increasing number of industry areas, which will bring more players to this already huge industry. Therefore, since the 2G era began, the change in mobile communication technology needs to be seen as a major economic

transformation, because it requires the reconfiguration of existing value networks. Tilson and Lyytinen [18] mainly studied the overall changes of the industry, changes in the field of standardization and changes in the relationship between industry participants in the transformation stage from 2G to 3G wireless technology standards in the United States. In this process, the number of standards has decreased while the number of standards bodies and standardized interfaces has increased substantially, and the manufacturing of mobile phones and other mobile communication equipment is transitioning to a more horizontal industrial structure.

3.1.4 The perspective of strategic management theory

The literature based on strategic management theory mainly takes the firm as the analysis unit and emphasizes the important role of the firm's entry time and competitive strategy on the competition of technological standards and technology diffusion. According to the clustering results of co-word analysis, Competition, Diffusion, Technology, Mobile communication, Adoption and other high frequency words in cluster 2 are widely used literature keywords in this theoretical perspective.

Different from the perspective of industrial organization theory, literatures based on strategic management theory attempt to predict the results of technological standard competition based on firm-level factors, and emphasize the importance of strategic decisions, resources and capabilities of technology sponsors to technological standard competition. The main strategic decisions of technology initiators include entry timing [19], pricing strategy [20], licensing strategy and strategic alliance [21-24]. Resources and capabilities include a firm's operational advantages, financial advantages, corporate reputation, core capabilities and absorptive capacity in production and distribution [19].

In the process of technical standard competition, the establishment of cooperative relations with supporting product manufacturers has a positive impact on expanding the foundation of technological development and improving the possibility of adopting technical standards. Through strategic alliance, firms can sign cooperation agreements with actual or potential competitors to jointly initiate a certain technical standard [22]. Tan Jinsong and Lin Runhui [3]. explored alliance forms, alliance members, alliance strategies and other factors at different stages in the industrialization process of TD-SCDMA standard, and analyzed the influence of alliance and government on the maturity of industrial chain. At the same time, the network structure of TD-SCDMA standard is compared with the other two 3G technical standards, and the strategic choice and implementation effect of telecom industry standard competition are analyzed. Kwak et al. [25] studied the evolution of China's 3G and 4G mobile technology standards (TD-SCDMA and TD-LTE) from the perspective of alliance formation, and believed that China's standardization methods had developed from technological nationalism to technological globalization. Over time, as links with foreign companies become more important than local ones in building, developing and maintaining alliances, Chinese companies are becoming more open to obtaining support and cooperation from foreign companies to help commercialize local standards and internationalize local standards.

IV. Conclusions

Mobile communication network is a complex social technology system composed of many subsystems, and its interoperability is realized by standards. Therefore, the establishment and competition of technical standards in the field of mobile communication has been the focus of scholars' research. Through bibliometric method, this study draws the knowledge map and combs the literature related to the technical standard competition in the mobile communication industry, and finds that the research perspectives of the existing literature mainly focus on four research perspectives: regulation theory, technology management, industrial organization and strategic management. Although the research on technical standard competition based on the above four theoretical perspectives has achieved fruitful results, there are

still some research limitations, which need to be further studied in the future.

Firstly, literatures from different theoretical perspectives have conducted in-depth studies on the technical standard competition of the mobile communication industry from multiple levels (such as government, technology, market and firm). However, due to the complexity of the formulation of technical standards of mobile communication, the process of the formulation of technical standards involves the interaction between different levels of subjects, and there are few literatures on the interaction between different subjects.

Secondly, as the liberalization degree of the mobile communication industry becomes higher and higher, the market competition becomes more and more fierce. Firms, as the main body of technical standard formulation, are playing an increasingly important role. However, most of the existing literature focuses on the influence of firms on the external environment such as the government, the market and the standardization committee in the technical standard competition. There are relatively few strategic researches on how to exert the subjective initiative and obtain the legitimacy of the technical standards in the competition process.

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