Research Policy 52 (2023) 104656

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

This article forms part of the Special Issue on Standards and Innovation

Acceptance of Chinese latecomers' technological contributions in international ICT standardization — The role of origin, experience and collaboration

Lennart Schott [a], Kerstin J. Schaefer [b,*]

[a] Leibniz University Hannover, Institute of Economic and Cultural Geography, Schneiderberg 50, 30167 Hannover, Germany
[b] London School of Economics and Political Science, Department of Geography and Environment, Houghton Street, London WC2A 2AE, United Kingdom

ARTICLE INFO

Keywords:
Standardization
Latecomers
China
Standardization capabilities
ICT
3GPP

ABSTRACT

As technical standards are an important part of China's industrial transformation towards an innovation-driven economy, Chinese organizations have started to deploy substantial resources in recent years to take on a leading role in international ICT standardization. However, many Chinese organizations experience, similar to other latecomers to standardization, limited success when contributing to standardization processes, a phenomenon also referred to as the standardization gap. The literature on standardization to date has paid little attention to how Chinese latecomers enter and influence international standardization processes that have traditionally been shaped by organizations from industrialized countries. We therefore analyze the country-of-origin effect as well as factors such as experience and collaboration for successful contributions of Chinese organizations to standards. Using data from the Third Generation Partnership Project (3GPP) and binary logistic regression analysis, we are able to show that, in our sample, contributions from Chinese latecomers are significantly less likely to be accepted than those from more established actors from industrialized economies. Moreover, our findings indicate that experience is closely associated with success in international ICT standardization, but not moderated by national origin. Therefore, Chinese latecomers might not be able to catch up if they move at the same pace as established competitors. They need to find a way to leapfrog extensive development steps, narrow the standardization capability gap, and thus strengthen their participation and influence. One way to do so might be through strategic collaboration, as our results suggest that Chinese organizations benefit more from collaborating with organizations from more established regions than vice versa, on which we call for further research to establish the causal mechanisms.

1. Introduction

Standards surround us in everyday life, mostly inconspicuously, but nevertheless have a tremendous impact on transaction costs, product quality, innovation and economic growth (Blind, 2016; Swann, 2000; Tassey, 2000). Particularly in the telecommunications industry, international standards play an important role as they can bind entire markets to specific technical solutions, often for years (Leiponen, 2006). Companies from different regions of the world have adopted different approaches to standardization due to their institutions and policy frameworks, causing global inequalities in terms of access and influence in international standard-setting (Leiponen, 2006) and leading to the so-called standardization gap (ITU, 2021; Ernst et al., 2014; Henson et al., 2001; Ratanawaraha, 2006; Weithmann, 2018). For many decades, players from Europe, Japan and the United States in particular have dominated the international standardization landscape while other players have only found their way into international standard-setting organizations (SSOs) at a later stage and in isolated cases.

However, China in particular has recently been eager to strengthen its influence in international standardization. Until the early 2000s, standards in China were largely either a means of protecting the domestic industry or imported from abroad in order to facilitate trade (Seaman, 2020). In the last decade, however, improving the quality and enhancing the competitiveness of domestic technical standards has become a key priority of public policy, and with enhanced economic power, China is striving to position itself as a major developer of

* Corresponding author.
E-mail addresses: schott@wigeo.uni-hannover.de (L. Schott), k.schaefer@lse.ac.uk (K.J. Schaefer).

https://doi.org/10.1016/j.respol.2022.104656
Received 31 March 2021; Received in revised form 7 October 2022; Accepted 8 October 2022
Available online 21 October 2022

technical standards (Ernst, 2011; Kim et al., 2020; Seaman, 2020). In particular, the information and communication technology (ICT) industry has been declared a strategic sector in this context, and the country has been driving the development of the new generation of a mobile communications standard through strategic investment and extensive government support (Kim et al., 2020).

However, even though the presence of Chinese actors in international SSOs has been growing recently (Seaman, 2020), Ernst et al. (2014) emphasize that latecomer economies such as China face specific challenges in their standardization and innovation policies that differ significantly from those in today's established economies. Latecomers are primarily standards takers, and according to Ernst et al. (2014), they still face substantial obstacles and challenges when it comes to shaping international standards. We therefore aim to fill the research gap on how the influence and participation of Chinese actors in ICT standardization might differ structurally from established actors from industrialized economies. In order to understand the relationship between the national origin and the acceptance of contributions in international standardization processes, we further consider the active standardization experience and cooperation with other organizations. Using a detailed data set from the *Third Generation Partnership Project* (3GPP), one of the most influential SSOs in the field of mobile telecommunications, our study contributes to the discussion on the role of Chinese latecomers in international ICT standardization.

The results of the statistical analysis suggest that technical contributions involving only Chinese organizations have a significantly lower probability of acceptance in our data compared to those involving only actors from industrialized economies. The data further indicates that experience might be an important factor for success in standardization, and that collaborations with other stakeholders might significantly increase the likelihood of acceptance of technical submissions compared to solo submissions. Our findings help to shed light on disparities in the international standard-setting process within the ICT industry and thus provide further research avenues on how to narrow the standardization gap for actors from China.

2. Literature review

China has been dynamically increasing its global economic influence through outward foreign direct investment (OFDI) in recent years (Kolstad and Wiig, 2012; Si and Liefner, 2014; Schaefer and Liefner, 2017; Buckley et al., 2018, 2007; Luo et al., 2010; Deng, 2013). A recent World Bank Report shows OFDI from China making up more than a third of all emerging markets' OFDI stock in 2015 (Perea and Stephenson, 2019). These efforts put Chinese companies on their way to upgrade their technological capabilities and become competitive on the global market (Child and Rodrigues, 2005; Di Minin et al., 2012). However, gaining a foothold on the global market, in particular regarding high tech products, involves in many cases following already established standards, which can be very costly for newcomers (Ernst et al., 2014). Therefore, becoming part of standardization is immensely important in order to establish and maintain global competitiveness and some Chinese companies go to great lengths to achieve this. For instance, research on the Chinese telecommunication firm Huawei has shown that one of the main drivers for the firm's internationalization efforts into established markets was the need to enter and shape global ICT standards such as 4G through hiring experienced experts in order to prevail on the global market (Schaefer, 2020). This emphasizes that a better understanding of the barriers Chinese companies have to overcome when participating in global standards is crucial in order to understand how they can achieve global competitiveness.

The Chinese approach to standardization differs in many ways from the standardization systems in Europe or the United States, for example. In Europe, private industry stakeholders coordinate under the supervision of national (e.g. DIN, AFNOR) or European SSOs (e.g. CEN, CENELEC), and in the US, a highly market-driven model dominates, in which the national standardization organization ANSI takes on a rather limited role. The Chinese government, by contrast, plays a crucial part in the national standardization strategy, taking on centralized coordination functions, subsidizing, and financing standardization projects of national interest. Chinese standardization projects are therefore often seen as the result of prevailing political priorities rather than technology-driven efforts (Seaman, 2020).

Nevertheless, the Chinese government has recognized the competitive importance of international standards and has taken initial steps to reform and liberalize the highly state-driven standardization system. China considers standards to be a major component in the national industrial transformation to an innovation-driven economy and has developed several national technology programs in recent years in which the development of standards is a key priority, such as *Made In China 2025* or *China Standards* 2035 (Fägersten and Rühlig, 2019; Seaman, 2020; Murphree and Breznitz, 2018; Ernst, 2011; Wang et al., 2014). The past has shown how China's inability to transform domestically developed ICT standards into international ones has led to either high costs from integrating external standards or to international isolation. As a result, China has recognized how international standard-setting allows first-mover advantages and to achieve market dominance (Seaman, 2020).

The literature discusses multiple aspects of China's growing role in international technical standardization. Rühlig (2022), for example, points out how Chinese participation in standard-developing committees of ISO and 3GPP as well as the number of technical contributions and leadership positions in international SSOs have been increasing for many years. A similar development can be observed with regard to the increasing number of Chinese patent declarations on standard essentiality, which is interpreted as an indication of strength for players in international standardization. This finding is consistent with the work of von Laer et al. (2022), who find that even if China was late to enter the market for standard-essential patents (SEPs) it has caught up rapidly in recent years. However, alongside the enhancements that can be seen, various persisting challenges for Chinese actors are discussed. For example, Rühlig (2022) quotes a standardization expert who notes with regard to the quality of Chinese standardization contributions that "*many Chinese proposals are rejected because their technological quality is inferior to the contributions of other experts*" (Rühlig, 2022, p.7).

Moreover, many Western stakeholders see the rapidly growing influence of Chinese companies, particularly Huawei, as a cause of increasing concern and Baron and Kanevskaia Whitaker (2021) argue that such tensions underscore the importance of impartiality in the leadership of international SSOs for the trustworthiness of standards. In their study, the authors show that while Chinese organizations are playing an increasingly important role in international ICT standardization, Western stakeholders still hold a disproportionately high share of SSO leadership positions.

Research suggests that long-term players in international standardization have a general interest in keeping new entrants at bay. For example, key intellectual property owners have used early standard-setting maneuvers in order to exclude latecomers from the market for wireless telecommunication. Bekkers et al. (2002) show the extensive and long-term impact this can have on competition, company performance and market development. In this context, it needs to be stressed that standards can lock markets into explicit, often proprietary, technical solutions for long periods of time. Companies that have been able to incorporate their patents into these standards benefit from long-term licensing revenues (Leiponen, 2008). These vested interests create incentives to shape standardization outcomes (Farrell and Simcoe, 2012) and the findings underscore both the technological and corporate strategic importance of standards. Shaping the standardization process within SSOs according to individual interests can be accomplished in a variety of ways. For example, stakeholders can exert influence by participating in SSO working group meetings, where technical specifications are discussed and decided by consensus, by taking on administrative leadership roles in the organization, or by contributing technical inputs and change requests (Leiponen, 2008).

In particular, the market and technology leaders from industrialized countries benefit from their influence in international standardization. They mainly achieve the positive economic effects of technological standardization in international competition, and SSOs such as the ISO are often referred to as an exclusive "*club for powerful economic actors*" (Wood, 2012, p.86) due to these prevailing inequalities. It is considered little disputed in the literature that actors from emerging economies have played a passive, marginal role in international standardization for many decades (e.g., Contreras, 2014; Jansen, 2010; Henson et al., 2001; Ratanawaraha, 2006; Seaman, 2020; Weithmann, 2018). Ernst et al. (2014) also highlight these geographical disparities and they emphasize that established players, in contrast to latecomers, hold extensive intellectual property rights and accumulated knowledge, which is essential for the emergence of innovations and enables them to influence the international standardization landscape. The debate around the access and participation of emerging countries in the international standardization landscape is also very prominently reflected in the literature on Indian standardization efforts, among others. In this context, the role of patents as a barrier is addressed in particular, and the question of how to strengthen the participation and influence of Indian actors in international standardization is discussed. Contreras (2017) emphasizes that both financial and institutional support from local governments, NGOs, and SSOs themselves is needed in order to enable greater Indian participation. In this way, positive impacts on domestic innovation, technical capabilities, and the labor market can be initiated. Ernst et al. (2014) accentuate that latecomers often still need to learn how to work successfully in standardization bodies and that it is a strategic challenge to break loose from their role as 'standard takers'. The International Telecommunication Union (ITU), an international standardization body for telecommunications, for example, is well aware of this issue and describes the standardization gap more specifically as "*the disparities in the ability of developing countries, relative to developed ones, to access, implement and influence […] international standards*" (ITU, 2021). Table 1 provides a broad overview of the various obstacles and constraints that disproportionately limit the ability of organizations from outside the established regions to actively participate in international SSOs.

In addition to technical skills, the specific role of particular social, communicative and also experience-based competences is emphasized in the context of the international standard-setting and coordination process (Jakobs, 2013). Technological capabilities need to be seen as a necessary but not a sufficient condition to be successful in international standardization bodies (Dokko and Rosenkopf, 2010; Leiponen, 2006; Gao, 2014). Choung et al. (2011) outline how acquiring standardization capabilities can be seen as a strategic path to catching up in international standardization. Furthermore, Ponte and Cheyns (2013) stress the importance for less established companies from emerging economies to gain cumulative, experience-based knowledge of international institution-building processes in order to influence international standardization processes successfully.

The preceding discussion has shown that the national origin of an organization considerably influences its resources, strategies and approaches to standardization and that the international standardization landscape is characterized by a wide variety of disparities in terms of integration and centrality. As a latecomer, China in particular has recently sought to strengthen its influence in international standardization by improving the quality and increasing the competitiveness of its technical standards. However, Chinese latecomers face specific obstacles and challenges when it comes to shaping international standards, and from an empirical point of view, it remains largely open how these structural differences are expressed in terms of their influence in international standardization processes. Particularly against the backdrop of the current dispute between some Western governments such as the US, UK or Australia and China over the development of 5G standards, the question of individual countries' ability to influence and shape international ICT standardization is once again gaining attention and importance (Kim et al., 2020). Therefore, we hypothesize that national origin of an organization is significantly associated with the acceptance of its technological contributions in the formal standardization committees of 3GPP and propose:

I. *Technological contributions of Chinese latecomers are less likely to be accepted than those of established players from industrialized countries.*

The importance of specific knowledge of standardization processes, familiarity with the working language and general standardization capabilities is emphasized time and again when it comes to how to successfully engage in international standardization and influence standard-setting processes (e.g., Choung et al., 2011; Henson et al., 2001; Choung et al., 2012). In the process of reaching consensus in the working groups of international SSOs, organizations with a variety of backgrounds enter into exchange, discuss with each other and lead negotiations on optimal configurations of technical specifications. In order to be able to assert oneself and one's interests strategically in this international context and to be able to incorporate one's own technical solutions into a new standard, comprehensive knowledge of this specific organizational setting is required. Such knowledge and familiarity with the specific practices, workflows and procedures can only be achieved through participative experience. We therefore hypothesize that the more experience the participating organizations have accumulated in this specific organizational setting, the more likely it is that their technical contributions will be accepted. Based on the above, we hypothesize the following:

II. (a) *An organization's accumulated experience in an SSO is positively related to the acceptance of its contributions. The longer an organization has been active in the working group of an SSO, the more likely its technical proposals will be accepted.*

Due to the multi-layered nature of the barriers in the international standardization landscape for latecomers, we assume that the acceptance probability of technical contributions with Chinese participation will be lower than for those that are developed solely by established

Table 1
Constraints to emerging country participation in international standard-setting (based on Henson et al., 2001).

Costs of participation	Resource-based constraints	Human capital resources	Attitudinal factors	Administrative structures
▪ membership fees, ▪ travel expenses or ▪ opportunity costs	▪ the lack of basic technical and scientific infrastructure	The limited availability of employees with the necessary ▪ technical expertise, ▪ knowledge and experience of the standardization processes ▪ skills in the working languages	▪ incumbent players tend to be skeptical of the technical capabilities of players from emerging countries ▪ the lack of confidence in the ability to provide the technical knowledge and experience to play a leading role in standard-setting	▪ established structures and procedures have a tendency to favor incumbent players ▪ national systems of standards-setting tend to be less developed

organizations from industrialized countries – even if the accumulated experience is the same. Given Wood's (2012) analysis regarding the importance of power relations within SSOs, it can be assumed that Chinese actors need to accumulate substantially more experience to overcome disadvantages and to prevail in negotiations and discussions. We therefore hypothesize the following:

II. (b) *The organizational origin moderates the relationship between experience and the acceptance probability of its technological contributions. The positive association between experience and the acceptance of technological contributions is lower for Chinese latecomers.*

Technological decisions made by an SSO committee are influenced by a variety of factors, including political capital and the market power of the supporting firms (Weiss and Sirbu, 1990; Bekkers et al., 2002; Kang and Bekkers, 2015). This means that the more organizations participate in the development of a technical specification, the greater the underlying expertise and market power that can enforce it in the discussions at the working group level. In her research on the standardization processes within the Third Generation Partnership Project (3GPP), Leiponen (2008) focused on the role of private alliances and industry consortia and she found that the likelihood of an organization's technical contributions being included in a standard depends significantly on the firm's involvement and embeddedness in such consortia. The work by Wen et al. (2020) also links the interconnectedness and cooperation of individual companies to their standard-setting influence. Joining forces, cooperation, and networking among individual actors and organizations thus seems to have a positive effect on the likelihood of accepting technical contributions. Based on this, we hypothesize that technological contributions are more likely to be accepted the more cooperating organizations have contributed to and supported them:

III. (a) *The more organizations are involved in a submitted technical contribution and the more diverse the background of these organizations, the more likely it is to be accepted.*

However, in line with our previous arguments, we also hypothesize that for contributions from Chinese participants the origin of the cooperation partner plays an important role in such alliances. Collaborating with organizations that are more embedded may be more promising than with companies that have the same origin and thus similar perspectives. Thus, cooperation with established players from industrialized countries could potentially be used as a mechanism to compensate for certain disadvantages in terms of human capital, reputation, and standardization capabilities.

III. (b) *The acceptance probability of technical contributions with Chinese participation increases more when additional organizations from traditionally standard-setting countries are involved rather than when the additional cooperation partner is also from China.*

3. The empirical context: the Third Generation Partnership Project

The following chapter introduces the empirical context of our quantitative study: 3GPP, one of the most relevant SSOs in the field of mobile telecommunications. 3GPP emerged from the European Telecommunications Standards Institute (ETSI) and started its work in 2000 with the aim of developing a specification for a mobile telecommunications standard based on the 2G-GSM system. In order to create a globally recognized and applicable mobile phone standard, telecommunication SSOs from Europe, Asia and North America formed a consortium. The seven SSOs that make up this consortium today are referred to as *Organizational Partners*, and through them 689 companies and other entities (so called *Individual Members*) from 45 countries currently participate in the work of 3GPP (3GPP, 2021a). The *Organizational Partners* are responsible for setting the overall policy and strategy of 3GPP, as well as for approving and maintaining the 3GPP scope. They make decisions on the creation or cessation of *Technical Specification Groups* (TSGs), approve their scope and terms of reference, and allocate the human and financial resources provided to the *Project Coordination Group*. In addition, they act as a body of appeal on procedural matters referred to them.

3GPP develops technical specifications in a consensus-based process that relies on the voluntary participation of its *Individual Members*. The process of developing the technical specifications takes place in the TSGs and, more importantly, in their affiliated *Working Groups* (WG). Any member of these groups can propose a new technical feature, but to avoid holding up the work program with proposals that have little chance of progress and success, a commitment of support and active participation in the realization of the project is required from four other member organizations. The entities supporting the *Work Item* are tasked with designing the feature until it is sufficiently stable or near completion. Then the *Work Item* is reviewed by the TSG and either incorporated into the standard or referred back (3GPP, 2021b).

Once a *Work Item* is incorporated into a standard, change control goes into effect and following modifications to the specification can only be made through a formal process of *Change Requests* (CR). These can be submitted by individual companies or groups of organizations. Subsequently, a decision is made in the WGs through a consensus process as to whether the particular CR is accepted. However, there is also the possibility that it will be rejected, revised or even withdrawn by the submitting entity (3GPP, 2021c).

Each WG usually meets four to six times a year and once a CR is accepted at WG level, the results are presented to the TSG for information, discussion and for final approval. These meetings result in the final specifications, which are made available by 3GPP to the seven *Organizational Partners*, who then formally publish them as technology standards and make them available to the entire mobile industry (see Fig. 1).

While every 3GPP member has the right to submit technical contributions and actively participate in the WG discussions, Baron and Gupta (2018) were able to show that the different 3GPP members participate to a remarkably different extent. Thus, only a small proportion of the hundreds of members make the vast majority of technical contributions. Against this background, China in particular is trying to gain influence within the SSO. As one of the *Organizational Partners*, the China Communications Standards Association (CCSA) coordinates the Chinese standardization activities within 3GPP in close alignment with the national government and pursues the goal of Chinese companies becoming the main driving force in ICT standardization (CCSA, 2022; Zhao, 2017). To achieve this goal, the Chinese government supports the work of Chinese organizations within the SSO through substantial subsidies, and the CCSA frequently urges Chinese companies to vote in unison in order not to compromise China's national interests (Hart and Link, 2020).

Although the selection of 3GPP as the object of study is justified not only by the global significance of the consortium in the ICT context but also by the broad availability of data, it needs to be acknowledged that the study framework also offers some limitations. In particular, the limited representativeness of the SSO in the international standardization landscape needs to be stressed. The organizational structure of 3GPP is unique in many respects and differs from other major international standardization organizations such as ISO or ITU, for example, in that representation does not take place via a national delegation, but directly via company representatives. Furthermore, Jones et al. (2021) highlight that the companies involved invest large financial and human resources in the standardization work at 3GPP and that legal conflicts frequently arise as a result of the ownership of SEPs and the associated licensing negotiations. Such legal conflicts arise, for example, when SEP owners suspect that other companies have failed to acquire the necessary licenses or when licensees believe that the licensing agreements violate the 3GPP norm that licensing terms must be fair, reasonable and non-discriminatory (FRAND). This litigiousness illustrates how much is

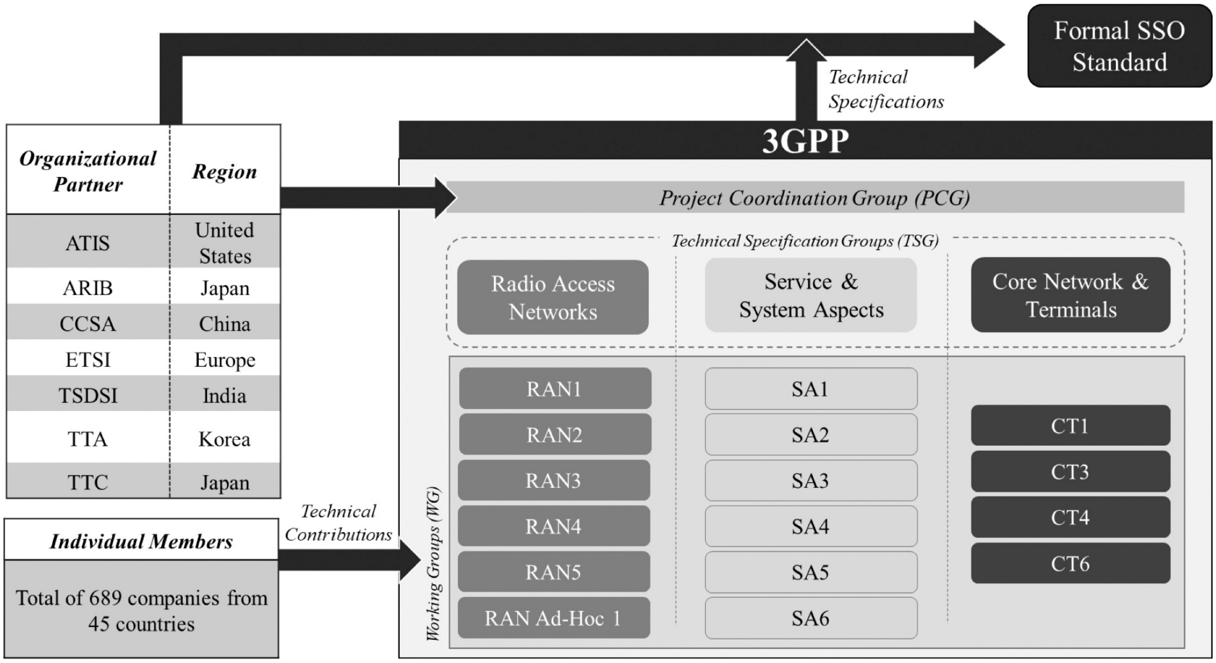


Fig. 1. 3GPP – organization, structure and processes.

at stake in the standardization work at 3GPP from a strategic point of view for the companies involved and why the focus on this consortium in the context of the study also reveals certain limitations. For example, Contreras (2017) describes that the majority of relevant standard essential patents are owned by large organizations based in industrialized economies and as a result, firms from outside these regions "*with sparse patent holdings are disadvantaged in both domestic and foreign markets*" (p.16). Nevertheless, we are convinced that the selection of 3GPP as the object of study provides a promising insight into international ICT standardization efforts and the research questions at hand.

4. Data sources, variables and descriptive statistics

4.1. Data sampling

In order to test the hypotheses and to better understand the role of China as a latecomer in international SSOs, this paper makes use of the *Change Request Database* made publicly available by 3GPP (3GPP, 2021d). This database contains information on all CRs that have been contributed to the various SSO working groups since 3GPP's formation. The original data set provides information on which technical specifications the CRs refer to, in which WG they were introduced and in which meeting their acceptance was discussed. The data set also contains information on which organizations originally submitted the CR, what type of CR it was and whether the CR was ultimately accepted at WG level or not.

The literature to date on 3GPP, and specifically on technical contributions within the SSO, considers CRs to be a valid measure of corporate influence in international telecommunications standard-setting (Leiponen, 2008; Johansson et al., 2019). However, in order to make this initial data set usable for our empirical work, it was necessary to perform comprehensive data cleaning. We aggregated the CR information contained in the original data in order to set each individual CR as the unit of observation. To this, we added the date of the final meeting discussing the CR using both the meeting identification number assigned by 3GPP and information available online from historical meeting records. In order to avoid an end-of-sample effect in the subsequent analysis, all CRs that were submitted after 2019 are removed from the data set. In the following subchapters, the individual variables and the restructuring of the data set are discussed in more detail. Following the aggregation and addition of individual variables, we obtain a data set with complete information on **116,977** CRs for the period 2000 to 2019.

4.2. Variables

4.2.1. CR acceptance

The dependent variable for the models is the second-level status of a CR, the status after it has been submitted to the WGs. When aggregating the data, only the status corresponding to the final revision of a CR in the data set was used. Since there is a large number of distinct statuses, mainly due to inconsistent spellings, it was necessary to harmonize the data and assign each to one of the official statuses mentioned below.

Table 2 lists the status values assigned by 3GPP at the WG level and provides information on both their meaning and the frequency of their occurrence in the final data set used in the remainder of the analysis, with complete information on 116,977 CRs.

In order to make this information usable for the purpose of the analysis, a dichotomous variable is created that indicates whether a CR was agreed to (1) or rejected (0) at the level of the WG. In the course of this, all CRs that cannot be placed in this dichotomous decision space were removed from the data set: this concerns those with the status

Table 2
Meanings of the status values used for CRs (3GPP, 2021b).

CR status value	Usage	Number of observations	
Agreed	No sustained objection to its being forwarded to the TSG for approval	111,109	*Agreement*
Endorsed	Consensus at WG level that CR is technically correct, but there may be other solutions or another WG is responsible	653	
Rejected	Sustained objection to progressing the CR further	2716	*Rejection*
Not pursued	An alternative wording used in individual working groups for the status 'rejected'	2499	

withdrawn, noted, not treated, postponed, revised, merged and *other* (22.5 % of all observations in the raw data set). As can be seen in the Appendix in Table A.1, these statuses are voting results that are based on a wide variety of reasons and do not clearly position themselves in favor of or against a motion, and can often even be classified as rather neutral. Thus, only CRs with a final status of *agreed*, *endorsed,*[1] *rejected* or *not pursued* remain in the data set. The first two were coded with a '1' for agreement and the latter two were coded with a '0' for rejection (Table 2).

4.2.2. Number of contributing organizations

The data set contains information about which companies or organizations are involved in the contribution of a CR, from which we derive additional variables. First of all, a comprehensive cleaning of the given company names was necessary. This allowed us in a next step to determine the absolute number of organizations involved in a CR over time (*n_contributors*). This number varied from one to 24 between individual CRs. As Fig. 2 shows, the vast majority of the 116,977 CRs are submitted by a single organization and only few are submitted by groups of more than five organizations.

4.2.3. Origin

The next step was to locate the participating companies and organizations based on their headquarters location. The decision to use corporate headquarters data to identify the organization's location follows an approach commonly used in the literature (e.g., Coval and Moskowitz, 1999; Cooper and Ovtchinnikov, 2017; Ivković and Weisbenner, 2005; Pirinsky and Wang, 2006; Becker et al., 2011) and is based on the premise that the headquarters are in close proximity to the organization's core business activities (Pirinsky and Wang, 2006). The headquarters not only ensures corporate governance but also covers central corporate functions such as strategic planning, innovation and R&D coordination, legal affairs and finance, thus spatially bundling the central departments that are key in the context of international standardization efforts. The primary source for determining this location is the information on the respective company website as of March 2021. In unclear individual cases, this information was supplemented by an extensive web search. The data set also contains joint ventures with shared ownership. In these special cases, the organization was located in the country where the joint venture was established, not where the initiating parent company is located: for example, the Shanghai Bell joint venture, co-initiated by Nokia, was located in China, not in Finland, as part of the data preparation.

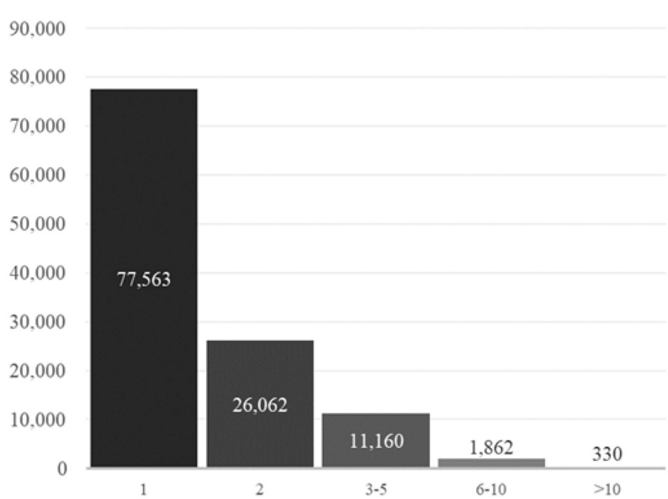


Fig. 2. Frequency of the number of contributing organizations per CR.

By extracting the company names from a list of contributing organizations for each CR, we were able to obtain 407 unique organization names to which we manually matched geographic information and, if available, R&D intensity data (see the robustness check in Chapter 5.1). In order to compare Chinese organizations with those from established industrialized countries, only contributions from countries with active long-term involvement in ICT standardization are included in the following analysis. Countries are considered actively involved if they have participated in an average of at least 10 CRs per year during the observation period from 2000 to 2019.[2] Following this approach, the data set contains CRs from 17 different countries, and Fig. 3 illustrates how many CRs organizations from each country have participated in.

In this context, it becomes apparent that, alongside the multitude of players from industrialized economies, China occupies a particularly prominent position: with >36,000 CR participations, Chinese organizations are taking on a leading role – at least in quantitative terms.

In recent years in particular, the involvement of Chinese players has increased considerably (see Fig. 4), especially in the context of technical specifications around 5G. To shed more light on the role and influence of Chinese actors in the following analysis, two dummy variables are added to the data set based on geographical information. The variable *China Only* indicates that all actors participating in a CR are from China and the variable *China & IC* is coded with '1' in cases where at least one Chinese actor has participated in a CR together with at least one organization from one of the other industrialized countries[3] displayed in Fig. 3. As a reference group, these two dummies are contrasted with all those CRs in which only organizations from industrialized countries were involved (*IC Only*) – these three groups do not overlap.

4.2.4. Experience

Another variable is the active working group experience (*experience*) of the participating organizations at the time of the initial submission of the CR. This experience variable is calculated as the difference in years between the date (*first_sub*) on which the contributing organization (j) first appears as a participant in a CR and the date (*CR_sub*) of the meeting at which the particular CR (i) is submitted for the first time. Where multiple organizations are named as contributors to a CR, we refer only to the experience level of the organization that has been an active part of 3GPP working groups the longest ($\max_{\forall j \in i}$). This is based on the assumption that all participating companies, and thus the CR, benefit most from the experience of the most experienced partner.

In the further course of the analysis, the natural logarithm of the variable *experience* is used. This approach reflects the assumption that the greatest gains from additional experience occur in the first years of active participation in a standard-setting organization.

$$experience_i = \max_{\forall j \in i}\left(CR\_sub_i - first\_sub_j\right)$$

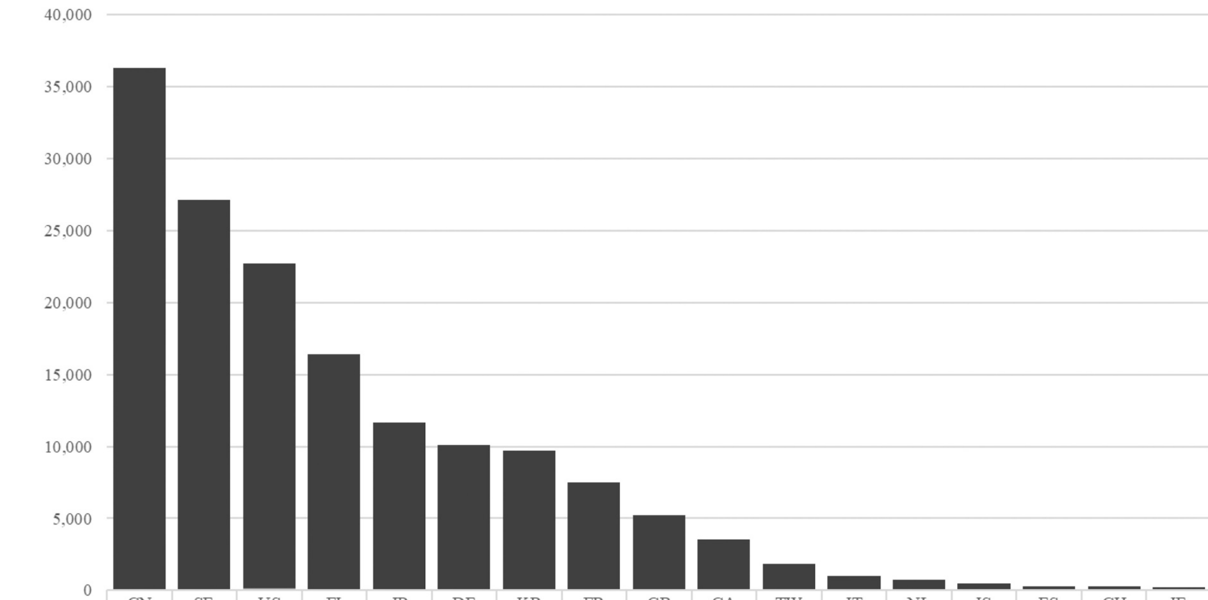
4.2.5. Diversity

Furthermore, we added a variable describing the degree of diversity (*diversity*) of national organizational origin on a CR (i). It is calculated as

[1] Based on 3GPP's status explanations (Table 2), we consider a technical endorsement to be a general agreement on the technical nature of the change request in the empirical framework of the paper.

[2] Occasionally participating countries (India, Austria, Australia, United Arab Emirates, Turkey, Belgium, Luxembourg, Norway, Russia and Brazil) account for <0.0031 % of the contributions.

[3] Sweden (SE), United States (US), Finland (FI), Japan (JP), Germany (DE), South Korea (KR), France (FR), United Kingdom (GB), Canada (CA), Taiwan (TW), Italy (IT), the Netherlands (NL), Israel (IS), Spain (ES), Switzerland (CH) and Ireland (IE).



	CN	SE	US	FI	JP	DE	KR	FR	GB	CA	TW	IT	NL	IS	ES	CH	IE
CRs	36,287	27,109	22,736	16,399	11,676	10,121	9,684	7,524	5,201	3,527	1,825	979	748	479	306	260	246
organizations	47	8	121	6	21	40	18	29	27	11	13	2	10	6	9	5	3

Fig. 3. CR contributions and number of participating organizations per actively involved country, 2000–2019.

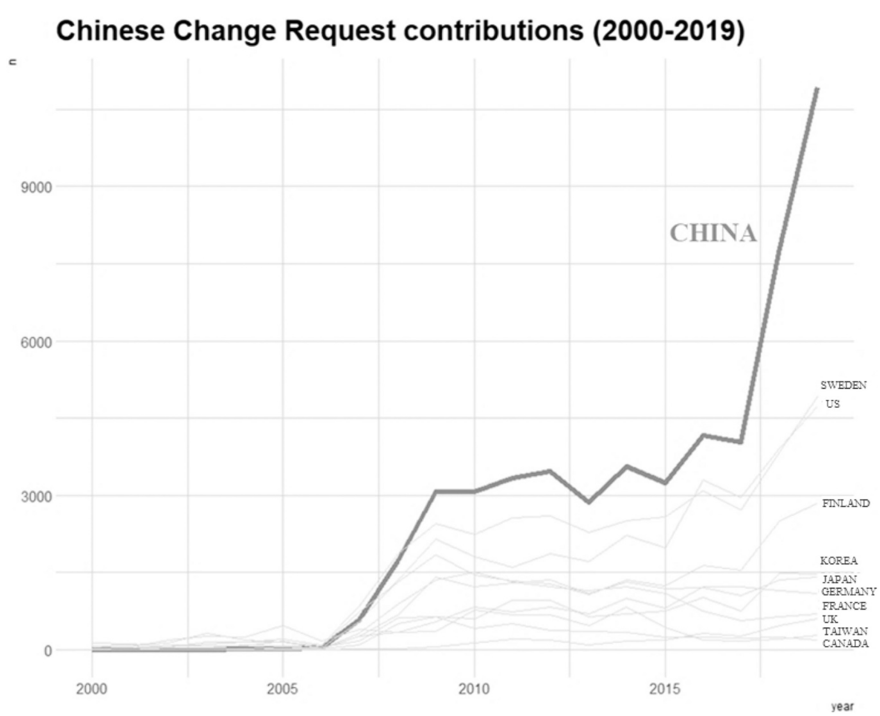


Fig. 4. CRs with Chinese contribution (2000–2019).

an inverted form of the Herfindahl–Hirschman Index (HHI), where s_{io} describes the share that organizations of a particular country of origin (o) have in all organizations participating in the CR, and N describes the number of different countries involved. In the case of a CR with only one participating organization, the HHI equals $1.0^2 = 1$. In the case of a CR with five participating organizations (from five different countries), on the other hand, the HHI would equal $0.2^2 + 0.2^2 + 0.2^2 + 0.2^2 + 0.22 = 0.20$. In order to make the value interpretable as a measure of diversity and not as a measure of concentration, the HHI value is then multiplied by -1. The higher the diversity index value, the more diversified a CR with regard to the national backgrounds of the participating organizations.

$$diversity_i = -\sum_{o=1}^{N} s_{io}^2$$

s_{io} is calculated as the quotient of the number of organizations (J) from country o on the CR i divided by the total number of organizations across all countries (N) participating in the CR. If, for example, three German and two Chinese organizations are involved in the development of a CR, the value of $s_{i_{china}}$ is calculated as follows: $\frac{2}{2+3} = 0.4$. Conversely, this example yields a value of $\frac{3}{2+3} = 0.6$ for the share of German organizations ($s_{i_{Germany}}$).

$$s_{io} = \frac{J_{io}}{\sum_{o=1}^{N} J_{io}}$$

4.2.6. CR category

In principle, there is a variety of reasons why a CR to an existing technical specification might be necessary. 3GPP has officially grouped these into five main categories (see Table 3).

Extensive data cleaning was also necessary for this variable, and we assigned the categories that appeared in the raw data set to one of these official CR categories. Since it can be assumed that the acceptance probability of CRs differs depending on the level of modification of the functionality of the technical specification, the assigned CR category will be included in the econometric analysis as a categorical control variable.

4.2.7. Number of revisions

As previously described, it is possible that a revision of the CR will be requested by the respective WG. As a result, a CR that needs to be revised is brought up several times in the discussion of the WGs and thus appears more than once in the data set. Due to the aggregation performed, they now no longer appear multiple times, and this new variable indicates the total number of revisions the CR has gone through (*n_revisions*). The decision to have a CR revised - and not rejected - is interpreted as recognition of a certain technical potential of the proposal. Based on this, it is assumed that a CR that has gone through many revision cycles and thus tied up a lot of time, financial and personnel resources is rejected less frequently. For this reason, the number of revisions performed is included as a control variable in the models.

4.2.8. Subject similarity

For CRs that were submitted more than once to the WG due to revisions, the optimal string alignment method (restricted Damerau-Levenshtein distance) was used to calculate pairwise string similarity (van der Loo, 2014) based on the titles of the first and last CRs. The newly calculated variable thus provides a proxy for how much a CR has changed over time (*similarity*). If the variable has a value of 1, the two titles of the initial and final CR are identical. The closer the value is to 0, the more the title and thus the character of the CR has changed. This variable is included in the models as a control variable, since it is assumed that in the case of CRs that have had to be changed considerably over time, there are major content-related issues that may prevent or delay their acceptance.

4.3. Descriptive statistics

As described above, the unit of analysis is a single CR, i.e. a technical contribution to one of the working groups of 3GPP. The data used goes back to 2000 and thus covers 20 years of standardization work completed in the organization's working groups. The raw data was retrieved from the SSO's publicly accessible FTP server (3GPP, 2021d) and Table 4 provides the descriptive statistics for the variables outlined.

The table confirms the observation that a large number of CRs are submitted by organizations acting alone. On average, 1.6 organizations were involved in each CR. The table further reveals that the number of accepted CRs far exceeds the number of rejected ones. A total of 20 % of the CRs were submitted exclusively by Chinese organizations and 11 % were developed in cooperation between Chinese actors and those from more established industrialized countries (*China & IC*).

Table 3
CR categories and counts (3GPP, 2021d).

CR category	Meaning	Observations
A	Corresponds to a correction to an earlier Release	17,842
B	Addition of feature	18,628
C	Functional modification of feature	2189
D	Editorial modification	1068
F	Essential correction	77,250

Fig. 5 shows the CR acceptance rate between the years 2000 and 2019 as a moving three-year-average for the origin countries with the most contributions.[4] First of all, we are able to identify two dips in the data around the years 2008 and 2017, which show that the acceptance rate of CRs at that time was considerably lower compared to previous and subsequent years. This development can be traced back to the initial introduction of technical specifications on LTE (Release 8, late 2008) and the initial introduction of 5G specifications (Release 15, late 2017). Shortly after the introduction of such fundamental development milestones, a particularly large number of CR submissions are recorded, as this is the phase when active development of devices begins and many improvements and corrections are identified with the implementation of real systems and the development of the actual protocols (3GPP, 2021b).

The actors in the participating committees are thus moving in a field full of novelties and uncertainties, and this is presumably also reflected in the acceptance rate of the CRs.

Furthermore, the plot reveals that the acceptance rates differ, sometimes considerably, across countries over time. It becomes apparent that CRs with exclusively Chinese or South Korean participation have by far the lowest acceptance rates. These initial descriptive findings strengthen our primary research interest and raise the question of how the influence of Chinese actors in 3GPP differs structurally from that of more established organizations from industrialized economies. The following chapter answers this question by discussing the results of our statistical models.

5. Analysis and findings

Following our hypotheses described in Chapter 2, our model explains the acceptance or rejection of change requests based on the independent variables ***origin***, ***experience***, ***n_contributors,*** and ***diversity***. In order to control for the technical and functional level of the CR, the number of revisions it went through, and how much it was changed in the process, we include the variables *CR category*, *n_revisions* and *similarity* as described above. The basic econometric equation to be estimated can be written as follows:

$$\begin{aligned} CR\ acceptance_i = {} & \beta_1 origin_i + \beta_2 experience_i + \beta_3 n\_contributors_i \\ & + \beta_4 diversity_i + \beta_5 CRcategory_i + \beta_6 n\_revisions_i \\ & + \beta_7 similarity_i + \psi_w + \alpha_t + \varepsilon_{i,w,t} \end{aligned}$$

We estimate the effects by using a binomial generalized linear mixed-effects model (GLMM).[5] Because our observations of CRs are spread out over multiple periods of time, we need to control for time variations by using time-fixed effects (α_t). Additionally, in order to control for working-group-specific effects, we added fixed-effects for each of 3GPP's working groups (ψ_W) in the model.

The correlation matrix (Table 5) for the numeric independent variables shows no excessive correlations that could potentially disturb the output of our regression model. Most variables are uncorrelated except for the number of *contributing organizations* and the *diversity* of the contributors (0.717). However, further testing using the variance inflation factor (VIF) reveals that multicollinearity does not pose a

[4] Only those Change Requests were counted in which only organizations of the respective country participated.

[5] The fixed-effects binomial model is best fitted to model the binary dependent variable in our model. We attached the coefficients of the corresponding linear probability models in the Appendix (Table A.4) for reference.

Table 4
Variables and descriptive statistics.

Variable name		Type	Observations	Minimum	Maximum	Median	Mean
CR acceptance		Dummy	116,977	0.00	1.00	1.00	0.96
Experience (max)		Numeric	116,977	0.00	19.87	11.12	10.97
	China Only	Dummy	116,977	0.00	1.00	0.00	0.20
Origin	*China & IC*	Dummy	116,977	0.00	1.00	0.00	0.11
	IC Only	Dummy	116,977	0.00	1.00	1.00	0.69
n_contributors		Numeric	116,977	1.00	24.00	1.00	1.60
Diversity		Numeric	116,977	−1.00	−0.12	−1.00	−0.89
	A	Dummy	116,977	0.00	1.00	0.00	0.15
	B	Dummy	116,977	0.00	1.00	0.00	0.16
CR category	C	Dummy	116,977	0.00	1.00	0.00	0.02
	D	Dummy	116,977	0.00	1.00	0.00	0.01
	F	Dummy	116,977	0.00	1.00	1.00	0.66
n_revisions		Numeric	116,977	0.00	21.00	0.00	0.77
Similarity		Numeric	116,977	0.00	1.00	1.00	0.99
Experience (total)		Numeric	116,977	0.00	184.18	12.64	14.53
R&D intensity		Numeric	52,728	0.00	126.69	15.93	14.91

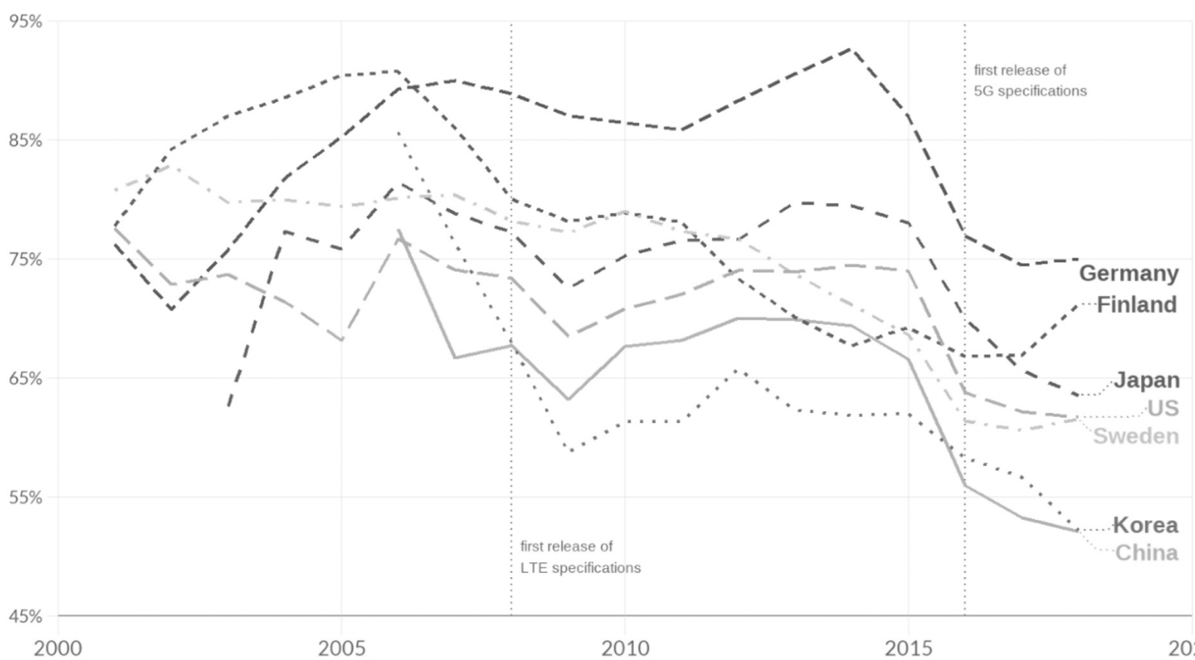


Fig. 5. Percentage of accepted CRs per country (the figure is limited to the leading countries in terms of their Change Request participation (>9000 CRs; see Fig. 3)), 2000–2019 (three-year moving averages).

Table 5
Correlation matrix.

	Experience	n_contributors	Diversity	n_revisions
n_contributors	0.140			
diversity	0.165	0.717		
n_revisions	0.043	0.221	−0.206	
similarity	−0.015	−0.044	0.069	−0.185

problem for the independent variables in our model (low correlation: VIF < 10, see Table A.2 in the Appendix).

Table 6 illustrates the initial results of the analysis in five logistic regression models with the binary dependent variable *CR acceptance*. The first model contains only the independent variables to be analyzed and no further control variables. Models (2), (3), and (4) add the control variables described in Chapter 4 and examine the different effects of the origin dummy variables *China Only*, *China & IC*, and *IC Only*. In addition, model (4) includes the interaction effects of the variables *China Only* and *China & IC* with the variable *experience*.

Table 6 further includes two logistic regression models, which examine the role of origin and the associated interaction effects in greater depth. For models (5) and (6), the original data set was split based on geographic origin to examine the relationship for each of the groups separately: model (5) includes only data on those CRs in which only Chinese organizations were involved (*China Only*), and model (6) utilizes all cases in which only organizations from industrialized countries participated in (*IC Only*).

The findings from the models are as follows. Concerning hypothesis I. on the effect of origin, we find that CRs developed exclusively by Chinese organizations display a significantly lower acceptance rate than CRs drafted solely by organizations from industrialized economies. Based on these results, we can confirm hypothesis I.

With regard to hypothesis II. (a), we can observe in all regression models that the coefficient of *experience* is positive and highly significant. Thus, we find a statistically significant indication that an organization's accumulated experience is generally associated with a higher CR acceptance probability.

However, if we turn to hypothesis II. (b), we find that the interaction

Table 6
Binary logit regression models (1) to (6).

	Dependent variable:					
	Status CR: agreed/endorsed					
	(1)	(2)	(3)	(4)	(5)	(6)
					China Only	*IC Only*
Independent variables						
China Only	−0.317***	−0.297***	−0.575***	−0.288***		
	(0.036)	(0.038)	(0.094)	(0.108)		
China & IC	0.312***	0.279***		0.527		
	(0.085)	(0.089)		(0.493)		
IC Only			−0.279***			
			(0.089)			
ln(experience)	0.094***	0.143***	0.143***	0.145***	0.188***	0.117***
	(0.022)	(0.023)	(0.023)	(0.025)	(0.038)	(0.023)
n_contributors	0.138***	0.049**	0.049**	0.048*	0.015	0.123***
	(0.025)	(0.025)	(0.025)	(0.025)	(0.035)	(0.025)
diversity	0.818***	0.900***	0.899***	0.906***		
	(0.145)	(0.151)	(0.151)	(0.152)		
China Only * ln(experience)				−0.004		
				(0.047)		
China & IC * ln(experience)				−0.093		
				(0.180)		
Control variables						
CR category		*Included*	*Included*	*Included*	*Included*	*Included*
n_revisions		*Included*	*Included*	*Included*	*Included*	*Included*
Similarity		*Included*	*Included*	*Included*	*Included*	*Included*
Constant	5.008***	4.591***	4.869***	4.594***	3.260***	4.270***
	(0.451)	(0.577)	(0.566)	(0.546)	(0.973)	(0.562)
Observations	116,977	116,977	116,977	116,977	22,923	80,690
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
WG fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Log Likelihood	−16,934.740	−15,145.840	−15,145.840	−15,145.700	−3979.046	−9806.098
Akaike Inf. Crit.	33,885.480	30,319.690	30,319.690	30,323.410	7980.093	19,634.200
Bayesian Inf. Crit.	33,962.840	30,455.060	30,455.060	30,478.130	8068.532	19,736.480

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

effect between the *China Only* and *experience* variables is insignificant in model (4) and thus does not allow for further interpretation. Thus, we find no conclusive evidence for hypothesis II. (b) that organizational origin from China moderates the effect of *experience* on CR acceptance. Although the standardized beta coefficients for *experience* presented in the models (5) and (6), split by country of origin, display different effect sizes, after performing a z-test and examining the 95 % confidence intervals, we can conclude that the two coefficients are not statistically different in magnitude. This result confirms the findings from the interaction terms that the effect of experience is not moderated by national origin.

With respect to hypothesis III. (a), we find in models (1) through (4) that a higher number of organizations submitting a CR generally appears to be linked to a higher likelihood of the particular CR being accepted. In model (5), which considers CRs developed exclusively by Chinese organizations, we observe that this positive effect of the number of contributing organizations turns insignificant. CRs developed exclusively by Chinese organizations do not seem to benefit from an additional Chinese collaboration partner in terms of acceptance probability. The advantage of an additional cooperation partner only seems to be apparent when the partner comes from an industrialized country. This is also supported by the positive and highly significant effect of the variable *China & IC* in models (1) and (2). Model (6) indicates that the generally observed positive effect of an additional contribution partner persists when only organizations from industrialized countries are involved.

The diversity of the origin of the participating organizations also seems to be positively associated with the acceptance of the CRs - the coefficient is positive and highly significant in all models in Table 6. The more organizations have contributed to a CR and the more diverse the national backgrounds are, the higher the likelihood of the request being accepted. With regard to the positive effect of an additional contribution partner, it becomes clear that this is considerably lower and statistically insignificant as soon as only Chinese organizations are involved in a CR. Thus, we find evidence for hypothesis III. (a) as well as for hypothesis III. (b) when examining the origin dummy variables in models (1) through (4). The coefficient of the *China Only* variable is consistently negative and significant, and the coefficient of *China & IC* is positive and mostly significant across all model specifications. This suggests that, on average across all IC partners, the collaboration has a significant positive effect for Chinese contributions and increases the probability of acceptance. Moreover, in model (3) we show that the previously omitted origin variable *IC Only* exhibits a significant negative effect in reference to the now omitted *China & IC* cooperation dummy. This indicates that beyond the general positive effect of collaboration and diversity, IC organizations might also benefit from partnering with Chinese actors. However, a test for difference in coefficients shows that the negative effect of the *China Only* variable in model (3) is significantly stronger compared to the *IC Only* variable. Thus, we can conclude that Chinese organizations might benefit considerably more from these collaborations than IC partners.

5.1. Robustness checks

We perform a number of robustness checks to verify the results above. First, we check whether the apparent lack of influence of Chinese organizations could be attributed to their low R&D intensity. In order to check whether lower R&D spending can explain the negative coefficient for Chinese origin, a robustness check of the results was carried out (Appendix Table A.3). Using *orbis* data from *Bureau van Dijk*, we are able to add information on R&D intensity (R&D expenditure as a percentage of company revenue in the year in which the CR was submitted) to a subsample of the CRs. In the case of group submissions, the CR is attributed the R&D value of the organization that spends the most in percentage terms. This data is only available for the period from 2012 to 2019 and only for about 129 companies. The results of this robustness check reveal that the negative and highly significant coefficient of the variable *China Only* persists even after controlling for this indicator and we, therefore, have reason to assume that the apparent lack of success of organizations from China cannot be attributed to their R&D spending.

As described in detail in Chapter 4, the experience variable refers to the group member who has the longest experience. In models (7) and (8) (Appendix Table A.3), a robustness check is performed in order to explore whether the observed effects of the number of contributing organizations (*n_contributors*) are driven by the size of the submitting group or by the collective experience of the contributing organizations. For these two models based on models (1) and (2), we exchange the variable *experience* for the variable *experience total*, which is defined as the sum of the years that the individual organizations have actively participated in the standardization work in 3GPP. The results show that the coefficient of this experience variable is also positive and highly significant, with only a slight change compared to the results in Table 6. However, the effect of the number of contributors becomes insignificant in model (8), because the new variable is highly correlated with the number of contributors.[6]

In a next step, we build multiple models based on model (2) to obtain a more nuanced picture of the effect of organizational origin from established regions. In analogy to the *China Only* dummy, we include a single-origin dummy in each model as well as a dummy variable for multi-origin collaborations including that respective origin[7] in order to isolate the effect of each origin. To compare the success of CRs submitted solely by organizations of the respective origin with CRs submitted by all other organizations from industrialized economies in the sample, we also control for CRs with Chinese participation. This shows us how CRs that exclusively involve organizations from the respective country fare in terms of acceptance (Fig. 6).

The results show that in particular CRs involving only organizations from China or South Korea have a significantly lower chance of acceptance compared to all CRs developed exclusively by organizations from established industrialized countries. This could be a remnant of South Korea's former latecomer status, which might still affect the acceptance of CRs. It does not seem to be a general effect for Asian organizations, as we can see that Japan, as an established player from Asia, has a positive country coefficient. We can also see that while requests from more established players are more likely to be accepted, the coefficient for Finland for example is significantly higher than the ones for the US or Sweden. Therefore, there seems to be a differentiation even among the more established contributors when it comes to the acceptance of CRs.

Finally, we want to shed more light on the observed positive coefficient for Chinese organizations cooperating with those from industrialized countries. For this purpose, we build another regression model based on model (2), which breaks down the more general collaboration variable *China & IC* and instead introduces dummy variables for the collaboration of Chinese actors with organizations from each major IC origin. The collaboration dummies visualized in Fig. 7 represent those cases in which only Chinese organizations and those of the respective country collaborated. We also include a dummy for group submissions involving only Chinese organizations and a dummy for Chinese CRs submitted by one single organization. This way, we are able to examine how the effects of collaboration differ depending on collaborator origins in reference to the omitted *IC Only* group. The results show that the acceptance probability of Chinese CRs does not seem to increase significantly when additional Chinese collaboration partners are involved in the creation. However, if the collaboration partners come from one of the major industrialized economies, the coefficient for acceptance probability is higher than for purely Chinese groups.

This supports the previously stated proposition that Chinese CRs created in the course of a partnership with an organization from an industrialized country have, on average, higher acceptance probabilities. Nevertheless, there is also a certain differentiation depending on the origin of the collaboration partner. Collaborations with German or South Korean organizations show a positive effect, but due to the comparatively small number of cases and the resulting higher effect variance, it cannot be conclusively determined whether these collaborations offer an advantage over purely Chinese contributions. On the other hand, the cooperation with Swedish organizations displays a particular positive and significant effect. Collaborations with Japanese or US organizations show a higher variance of effects, but are also both positive and significant, and therefore still seem to have certain advantages over purely Chinese collaborations in terms of acceptance probability. A deeper analytical consideration of the mechanisms underlying these differences certainly offers potential for future research.

Lastly, we perform an additional robustness check to test whether the observed effect of the variable *China & IC* can possibly be attributed to collaborations between the leading standard developers in the field of 5G: Nokia, Ericsson, and Huawei (Buggenhagen and Blind, 2022). For this purpose, we excluded all CRs in which at least one of the three companies participated and then re-run the regression in model (11) (Appendix Table A.3). Even though the effect size of the collaboration coefficient slightly decreases, the regression results show that the core findings of the analysis remain largely stable. The negative coefficient of the *China Only* variable even increases after Huawei's exclusion.

6. Discussion and conclusion

The main aim of this study is to examine how organizations from China enter and influence standardization processes that have traditionally been carried out by a few major players predominantly from Europe, Japan, and the United States. Since the mid-2000s, the absolute number of CRs involving Chinese organizations in 3GPP has increased by over 230 %. This demonstrates the growing importance of international ICT standardization from a Chinese perspective and underscores China's aspiration to develop into an innovation-driven economy that is emancipating from its role as a standard-taker. With regard to technical standardization, China seems to be following an avenue that is already frequently referred to as the *brute force* approach in the innovation literature with regard to its excessive patenting activities. This involves seeking to generate large numbers of ideas and innovations through the sheer deployment of large amounts of capital, low-cost labor, and extensive resources (e.g. Kao, 2009). However, although Chinese organizations invest substantial time and resources to contribute to international standardization in the ICT industry, the data from 2000 to 2019 also shows that the acceptance rates of technical proposals with Chinese participation are noticeably lower than those with European or US participation. The Chinese influence on standardization work in 3GPP thus seems to lag behind that of other players, at least in relative terms. These findings are in line with the results of Contreras (2014), who was able to show, with regard to the internet standardization organization IETF, that Chinese involvement in standardization has increased strongly since the mid-2000s, but that the acceptance of Chinese proposals still lags behind that of more established actors.

Our statistical analysis confirms a measurable difference for

[6] The number of contributing organizations and the total experience (i.e. the sum of the individual accumulated experience) exhibit a high correlation of 0.72.

[7] As before, the focus here is on the countries that are most involved in the development of CRs in absolute terms (> 9.000 CRs) and cover a large proportion of all CR participations (see Fig. 3).

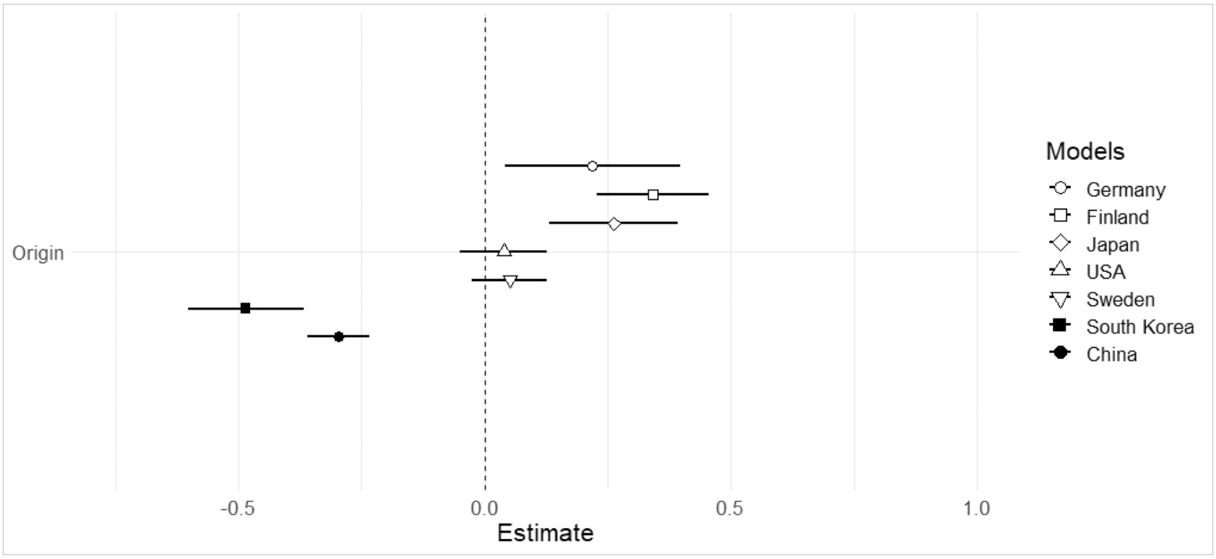


Fig. 6. Coefficients for origin dummies in separate models based on model (2).

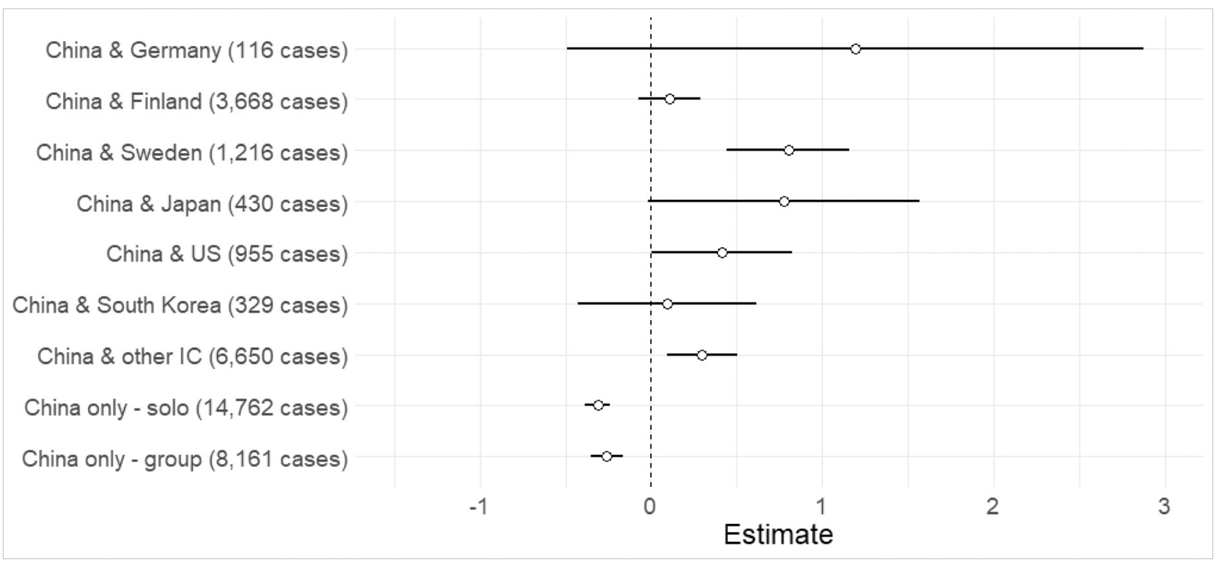


Fig. 7. Coefficients for the respective collaboration dummies in a model based on model (2).

latecomer companies from China with regard to the acceptance probability of their requests and their influence on the standardization work at 3GPP. CRs drafted exclusively by organizations from China are significantly less likely to be agreed upon than those in which only organizations from industrialized countries have participated. The ability of a Chinese organization to determine international standardization appears to be significantly associated with its national origin.

Turning to the relevance of accumulated experience in standardization processes, our results indicate that the involvement of experienced organizations in the drafting of CRs is positively related to the likelihood of their acceptance. Lack of experience therefore might present a tangible barrier to access, influence, and shape standardization processes. If this effect is confirmed, policy makers in regions seeking to enter standardization might foster training of domestic actors in order to strengthen their role in the international standardization landscape. However, the finding that the organizational origin seems not to moderate the relationship between experience and the acceptance probability of its technological contributions shows that latecomers and less established actors might not be able to catch-up if they move at the same speed as their established competitors from industrialized countries. Consequently, this can lead to the persistence of a standards capability gap. This reveals that following the exact path established organizations took is likely insufficient to catch-up with incumbents, and latecomers need to strategically find shortcuts such as strategic learning from incumbents or hiring experienced personnel that readily provides standards capabilities in order to join established players in international standardization in terms of influence and success.

Beyond our findings on the association of standardization experience and acceptance, our results also suggest that the more organizations contributed to a CR and the more diverse the national backgrounds, the higher might be the likelihood of the request being accepted. Furthermore, the results indicate that collaboration with more established actors from industrialized countries benefits Chinese actors more than vice versa. In particular, collaborating with actors from countries such as Sweden or the US, might increase the likelihood of acceptance of Chinese CRs most and thus strengthen their influence in the SSO's working groups. For less established actors such as China, such collaborations may offer the opportunity for strategic knowledge transfer in order to leapfrog a comprehensive development of expertise with regard to drafting successful CRs. Chinese latecomers using these avenues might be able to achieve mature status earlier comparable to the mechanisms described in the literature on latecomer's innovation capability building (Mathews, 2002, 2006; Luo and Tung, 2007, 2018). This might be a way to build standardization capabilities in the long run and lead to independence from collaborations. However, no prescriptive conclusions can be drawn based on our results and further comprehensive research is needed to validate these claims regarding the role of experience and collaborations. Whether the quality of a CR increases as a result of grouping or successful organizations being more likely to team up with those that generally make higher quality contributions cannot be causally determined here. The reasons for collaborating on CRs can be manifold, both from the perspective of Chinese actors as well as from more established stakeholders. These motives of group formation could not be endogenized in our models. For example, in addition to access to technical and organizational expertise, access to extensive R&D resources may also play an important role in this context. The robustness check conducted with a small subsample suggests, for instance, that the effect size of the positive collaboration coefficient *China & IC* decreases once we control for R&D expenditures.

An aspect that needs to be taken into account when interpreting our results in general is the role of geopolitical disputes in the context of telecommunications infrastructure standardization. The most prominent dispute in recent years has been between Chinese telecommunications company Huawei and the US government, which has perceived Huawei's 5G standardization efforts as a threat to its national security and its technological and market dominance and therefore banned the company from selling equipment to US firms (Kim et al., 2020). A similar critical and restrictive approach to the actions of Chinese companies in the context of telecommunications infrastructure can also be observed in various other countries such as Japan, Australia or the EU (Kaska et al., 2019). When interpreting our results, it is therefore important to bear in mind that the effects might partially reflect a bias against particular Chinese companies such as Huawei or ZTE. Considering China's particular geopolitical role, among other factors, our results may be unique to China and not generalizable to other latecomers in standardization. Our analysis does not allow to identify causal mechanisms, but rather reveals the larger patterns of relationships and dynamics in standardization contribution providing clues which relations need to be examined more in detail in future research. In this context, it is imperative that further qualitative research on the influence of Chinese actors in international standardization shed more light on the causal relationships and the context underlying the findings of this study. For this purpose, interviews with relevant actors from the international standardization landscape could provide comprehensive insights into the barriers and mechanisms that keep latecomers from successfully participating and contributing.

In terms of limitations, given that we focus specifically on the ICT industry and 3GPP data, our results may only apply to the type of technical specifications being developed within this SSO. We should therefore be cautious in generalizing our results beyond this particular organizational setting. Other studies have focused on standardization organizations such as the IETF (see, e.g., Simcoe and Waguespack, 2011; Contreras, 2014 or Baron and Kanevskaia Whitaker, 2021) and have analyzed how the engagement of different East Asian players has changed over time using various quantitative metrics, such as attendance or authorship. Nevertheless, in light of our research questions, we are convinced that 3GPP, with its broad and rich data availability as well as the global economic importance of the consortium, can provide a promising insight into the dynamics as well as the prevailing patterns and structures of international ICT standardization.

Even if our approach of locating an organization based on the geographic location of its headquarters is widely used in the literature (e.g. Cooper and Ovtchinnikov, 2017) it might still have implications for interpreting the results. Although rare, companies may move the location of their headquarters or make use of tax havens and therefore fall into the wrong location category. Even though we cannot completely rule out this effect, we assume that this does not override the observed effects in our models. With regard to a potential lack of language proficiency possibly influencing the acceptance of contributions, we can state that this aspect can be considered negligible, at least in the context of China's participation in 3GPP. Although this aspect is frequently mentioned in the literature as an obstacle to participation for actors from emerging countries, according to actors involved in the administration of 3GPP, it does not seem to pose a problem in this case. The underlying reason for this is, on the one hand, that individuals with excellent English language skills are specifically recruited and appointed for this purpose, and, on the other hand, that it is common practice for the delegates to support each other collegially in making linguistic corrections if the WG members feel that a CR has technical merit. Nonetheless, the broader examination of individual influencing factors could provide an interesting perspective into the discussion around success and influence in international SSOs (e.g. Jakobs, 2013).

Finally, we would like to emphasize the need for promoting standardization capability building and institutional support for latecomers, and reiterate the need for further qualitative research to explore the mechanisms behind the observed patterns in more detail, particularly with respect to Chinese latecomers.

CRediT authorship contribution statement

Lennart Schott: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Kerstin J. Schaefer:** Conceptualization, Methodology, Software, Validation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

First and foremost, we would like to thank the participants of the Second Annual Empirical Research Conference on Standardization and the 25th EURAS Annual Standardisation Conference for their helpful feedback and numerous comments on previous versions of this paper. Furthermore, we would like to thank Davide Rigo, Louis Knüpling, Kerstin Nolte, Balkrishna Rao and Teresa Dickler for the fruitful and profound discussions, as well as Joy Ramos-Gonzalez and Christian-Martin Czypull for professional language editing.

On a final note, we would like to thank the two anonymous reviewers and the editors for their valuable suggestions for improvement of this work.

The project received funding from Leibniz University Hannover within the framework of the *Leibniz Young Investigator Grant (LYIG-06-2019-11)*.

Appendix A

Table A.1
CR status values removed from the data set.

CR status value	Usage	Number of observations
Withdrawn	Either never produced, or retracted by author prior to WG/TSG discussion	17,127
Noted	Not presented for decision at the present time, therefore just taken as information	8097
Not treated	Not yet seen, no decision reached	6974
Postponed	Decision deferred to later date; normally indicates that WG will re-examine the issue	6039
Revised	Modified to new revision of same CR	5219
Merged	Combined with (a revision of) one or more other CRs	2348
Other	CRs that have not been assigned an (official) status	131

Table A.2
Variance inflation factor (based on model 2).

Parameter	VIF	Increased SE
Origin (China Only)	1.20	1.10
Origin (China & IC)	2.16	1.47
Experience	1.06	1.03
n_contributors	1.92	1.39
Diversity	2.98	1.73
CR category	1.02	1.01
n_revisions	1.04	1.02
Similarity	1.03	1.01

Table A.3
Robustness checks.

	Dependent variable:				
	Status CR: agreed/endorsed				
	(7)	(8)	(9)	(10)	(11)
Independent variables					
China Only	−0.330***	−0.301***	−0.556***	−0.482***	−0.383***
	(0.036)	(0.038)	(0.078)	(0.082)	(0.057)
China & IC	0.323***	0.310***	0.123	0.155	0.298*
	(0.085)	(0.089)	(0.101)	(0.104)	(0.176)
ln(experience total)	0.061***	0.146***			
	(0.021)	(0.021)			
ln(experience)			0.169***	0.208***	0.111***
			(0.047)	(0.046)	(0.025)
n_contributors	0.126***	0.009	0.076**	0.001	0.028
	(0.026)	(0.025)	(0.030)	(0.030)	(0.047)
diversity	0.804***	0.851***	1.028***	1.135***	0.409*
	(0.144)	(0.150)	(0.181)	(0.183)	(0.235)
Control variables					
CR category		*Included*		*Included*	*Included*
n_revisions		*Included*		*Included*	*Included*
similarity		*Included*		*Included*	*Included*
R&D intensity			0.010***	0.007**	
			(0.003)	(0.003)	
Constant	5.043***	4.589***	4.128***	3.765***	4.068***
	(0.433)	(0.546)	(0.538)	(0.674)	(0.695)
Observations	116,977	116,977	52,728	52,728	61,530
Time fixed effects	Yes	Yes	Yes	Yes	Yes
WG fixed effects	Yes	Yes	Yes	Yes	Yes
Huawei, Nokia & Ericsson excluded	No	No	No	No	Yes
Log Likelihood	−16,939.260	−15,143.080	−8614.518	−7759.728	−7245.357
Akaike Inf. Crit.	33,894.520	30,314.170	17,247.040	15,549.460	14,518.720
Bayesian Inf. Crit.	33,971.880	30,449.540	17,326.890	15,682.550	14,645.100

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table A.4
Linear probability models corresponding to models (1) to (6) for reference.

	Dependent variable:					
	Status CR: agreed/endorsed					
	(12)	(13)	(14)	(15)	(16)	(17)
Corresponding to model:	(1)	(2)	(3)	(4)	(5)	(6)
Independent variables						
China Only	−0.016***	−0.015***	−0.030***	−0.00004		
	(0.002)	(0.002)	(0.003)	(0.004)		
China & IC	0.016***	0.015***		−0.016		
	(0.003)	(0.003)		(0.011)		
IC Only			−0.015***			
			(0.003)			
ln(experience)	0.003***	0.004***	0.004***	0.005***	0.007***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
n_contributors	0.003***	−0.0004	−0.0004	−0.0001	0.003	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
diversity	0.029***	0.027***	0.027***	0.025***		
	(0.005)	(0.005)	(0.005)	(0.005)		
China Only * ln(experience)				−0.007***		
				(0.002)		
China & IC * ln(experience)				0.012***		
				(0.004)		
Control variables						
CR category		*Included*	*Included*	*Included*	*Included*	*Included*
n_revisions		*Included*	*Included*	*Included*	*Included*	*Included*
Similarity		*Included*	*Included*	*Included*	*Included*	*Included*
Constant	0.981***	0.974***	0.989***	0.971***	0.902***	0.956***
	(0.015)	(0.016)	(0.016)	(0.017)	(0.035)	(0.016)
Observations	116,977	116,977	116,977	116,977	22,923	80,690
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
WG fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Log Likelihood	23,523.220	24,694.150	24,694.150	24,696.830	328.872	21,401.530
Akaike Inf. Crit.	−47,028.430	−49,358.300	−49,358.300	−49,359.660	−633.744	−42,779.050
Bayesian Inf. Crit.	−46,941.410	−49,213.260	−49,213.260	−49,195.280	−537.265	−42,667.470

* $p < 0.1$..
** $p < 0.05$.
*** $p < 0.01$.

References

3GPP, 2021a. About 3GPP. https://www.3gpp.org/about-3gpp/about-3gpp. (Accessed 11 March 2021).

3GPP, 2021b. Change Request. https://www.3gpp.org/specifications/change-requests. (Accessed 11 March 2021).

3GPP, 2021c. Change Request Database. https://www.3gpp.org/ftp/Information/Databases/Change_Request/. (Accessed 11 March 2021).

3GPP, 2021d. Specifications. https://www.3gpp.org/specifications. (Accessed 11 March 2021).

Baron, J., Gupta, K., 2018. Unpacking 3GPP standards. J Econ Manage Strat 27, 433–461. https://doi.org/10.1111/jems.12258.

Baron, J., Kanevskaia Whitaker, O., 2021. Global competition for leadership positions in standards development organizations. SSRN J. https://doi.org/10.2139/ssrn.3818143.

Becker, B., Ivković, Z., Weisbenner, S., 2011. Local dividend clienteles. J. Financ. 66, 655–683. https://doi.org/10.1111/j.1540-6261.2010.01645.x.

Bekkers, R., Duysters, G., Verspagen, B., 2002. Intellectual property rights, strategic technology agreements and market structure. Res. Policy 31, 1141–1161. https://doi.org/10.1016/S0048-7333(01)00189-5.

Blind, K., 2016. The impact of standardisation and standards on innovation. In: Edler, J., Cunningham, P., Gök, A., Shapira, P. (Eds.), Handbook of Innovation Policy Impact, EU-SPRI Forum on Science, Technology and Innovation Policy. Edward Elgar, Cheltenham, UK Northampton, MA, pp. 423–449.

Buckley, P.J., Clegg, L.J., Cross, A.R., Liu, X., Voss, H., Zheng, P., 2007. The determinants of Chinese outward foreign direct investment. J. Int. Bus. Stud. 38, 499–518. https://doi.org/10.1057/palgrave.jibs.8400277.

Buckley, P.J., Clegg, L.J., Voss, H., Cross, A.R., Liu, X., Zheng, P., 2018. A retrospective and agenda for future research on Chinese outward foreign direct investment. J. Int. Bus. Stud. 49, 4–23. https://doi.org/10.1057/s41267-017-0129-1.

Buggenhagen, M., Blind, K., 2022. Development of 5G – identifying organizations active in publishing, patenting, and standardization. Telecommun. Policy 46, 102326. https://doi.org/10.1016/j.telpol.2022.102326.

CCSA, 2022. About Us. http://www.ccsa.org.cn/english/aboutUs. (Accessed 12 March 2022).

Child, J., Rodrigues, S.B., 2005. The internationalization of Chinese firms: a case for theoretical extension? Manag. Organ. Rev. 1, 381–410. https://doi.org/10.1111/j.1740-8784.2005.0020a.x.

Choung, J.-Y., Hameed, T., Ji, I., 2012. Catch-up in ICT standards: policy, implementation and standards-setting in South Korea. Technol. Forecast. Soc. Chang. 79, 771–788. https://doi.org/10.1016/j.techfore.2011.10.007.

Choung, J.-Y., Hameed, T., Ji, I., 2011. Role of formal standards in transition to the technology frontier: Korean ICT systems. Telecommun. Policy 35, 269–287. https://doi.org/10.1016/j.telpol.2011.02.001.

Contreras, J.L., 2017. National disparities and standards essential patents: considerations for India. In: Bharadwaj, A., Devaiah, V.H., Gupta, I. (Eds.), Complications and Quandaries in the ICT Sector. Springer Singapore, Singapore, pp. 1–17. https://doi.org/10.1007/978-981-10-6011-3_1.

Contreras, J.L., 2014. Divergent patterns of engagement in internet standardization: Japan, Korea and China. Telecommun. Policy 38, 914–932. https://doi.org/10.1016/j.telpol.2014.09.005.

Cooper, M.J., Ovtchinnikov, A.V., 2017. Geographical vibrancy and firm performance. SSRN J. https://doi.org/10.2139/ssrn.2580563.

Coval, J.D., Moskowitz, T.J., 1999. Home bias at home: local equity preference in domestic portfolios. J. Financ. 54, 2045–2073. https://doi.org/10.1111/0022-1082.00181.

Deng, P., 2013. Chinese outward direct investment research: theoretical integration and recommendations. Manag. Organ. Rev. 9, 513–539. https://doi.org/10.1111/more.12030.

Di Minin, A., Zhang, J., Gammeltoft, P., 2012. Chinese foreign direct investment in R&D in Europe: a new model of R&D internationalization? Eur. Manag. J. 30, 189–203. https://doi.org/10.1016/j.emj.2012.03.004.

Dokko, G., Rosenkopf, L., 2010. Social capital for hire? Mobility of technical professionals and firm influence in wireless standards committees. Organ. Sci. 21, 677–695. https://doi.org/10.1287/orsc.1090.0470.

Ernst, D., 2011. Indigenous Innovation and Globalization: The Challenge for China's Standardization Strategy. UC Institute on Global Conflict and Cooperation & East-West Center, Honolulu.

Ernst, D., Lee, H., Kwak, J., 2014. Standards, innovation, and latecomer economic development: conceptual issues and policy challenges. Telecommun. Policy 38, 853–862. https://doi.org/10.1016/j.telpol.2014.09.009.

Fägersten, B., Rühlig, T., 2019. China's standard power and its geopolitical implications for Europe (No. 02/2019). In: UI Brief. The Swedish Institute of International Affairs, Stockholm.
Farrell, J., Simcoe, T., 2012. Choosing the rules for consensus standardization. RAND J. Econ. 43, 235–252.
Gao, X., 2014. A latecomer's strategy to promote a technology standard: the case of Datang and TD-SCDMA. Res. Policy 43, 597–607. https://doi.org/10.1016/j.respol.2013.09.003.
Hart, M., Link, J., 2020. There is a Solution to the Huawei Challenge. Center for American Progress, Washington, D.C.
Henson, S., Preibisch, K., Masakure, O., 2001. Review of Developing Country Needs and Involvement in International Standards-setting Bodies. Centre for Food Economics Research, The University of Reading.
ITU, 2021. Bridging the Standardization Gap. https://www.itu.int/en/ITU-T/gap/Pages/default.aspx#/es. (Accessed 25 February 2021).
Ivković, Z., Weisbenner, S., 2005. Local does as local is: information content of the geography of individual investors' common stock investments. J. Financ. 60, 267–306. https://doi.org/10.1111/j.1540-6261.2005.00730.x.
Jakobs, K., 2013. Success in ICT standards setting - a closer look at some influencing factors. In: 2013 8th International Conference on Standardization and Innovation in Information Technology (SIIT). Presented at the 2013 8th International Conference on Standardization and Innovation in Information Technology (SIIT). IEEE, Sophia-Antipolis, France, pp. 1–10. https://doi.org/10.1109/SIIT.2013.6774573.
Jansen, M., 2010. Developing countries, standards and the WTO. J. Int. Trade Econ. Dev. 19, 163–185. https://doi.org/10.1080/09638190903327492.
Johansson, M., Kärreman, M., Foukaki, A., 2019. Research and development resources, coopetitive performance and cooperation: the case of standardization in 3GPP, 2004–2013. Technovation 88, 102074. https://doi.org/10.1016/j.technovation.2019.04.001.
Jones, S.L., Leiponen, A., Vasudeva, G., 2021. The evolution of cooperation in the face of conflict: Evidence from the innovation ecosystem for mobile telecom standards development. Strateg. Manag. J. 42, 710–740. https://doi.org/10.1002/smj.3244.
Kang, B., Bekkers, R., 2015. Just-in-time patents and the development of standards. Res. Policy 44, 1948–1961. https://doi.org/10.1016/j.respol.2015.07.001.
Kao, J., 2009. Tapping the world's innovation hot spots. Harv. Bus. Rev. 87, 109–114.
Kaska, K., Beckvard, H., Minárik, T., 2019. Huawei, 5G and China as a Security Threat. NATO Cooperative Cyber Defence Centre of Excellence, Tallin.
Kim, M., Lee, H., Kwak, J., 2020. The changing patterns of China's international standardization in ICT under techno-nationalism: a reflection through 5G standardization. Int. J. Inf. Manag. 54, 102145 https://doi.org/10.1016/j.ijinfomgt.2020.102145.
Kolstad, I., Wiig, A., 2012. What determines Chinese outward FDI? J. World Bus. 47, 26–34. https://doi.org/10.1016/j.jwb.2010.10.017.
Leiponen, A., 2008. Competing through cooperation: the organization of standard setting in wireless telecommunications. Manag. Sci. 54, 1904–1919. https://doi.org/10.1287/mnsc.1080.0912.
Leiponen, A., 2006. National Styles in the Setting of Global Standards: The Relationship between Firms' Standardization Strategies and National Origin. In: Zysman, J., Newman, A. (Eds.), How Revolutionary was the Digital Revolution? National Responses, Market Transistions, and Global Technology. Stanford University Press (Innovation and Technology in the World Economy), Stanford, pp. 338–358.
Luo, Y., Tung, R.L., 2018. A general theory of springboard MNEs. J. Int. Bus. Stud. 49, 129–152. https://doi.org/10.1057/s41267-017-0114-8.
Luo, Y., Tung, R.L., 2007. International expansion of emerging market enterprises: a springboard perspective. J. Int. Bus. Stud. 38, 481–498. https://doi.org/10.1057/palgrave.jibs.8400275.
Luo, Y., Xue, Q., Han, B., 2010. How emerging market governments promote outward FDI: experience from China. J. World Bus. 45, 68–79. https://doi.org/10.1016/j.jwb.2009.04.003.
Mathews, J.A., 2006. Dragon multinationals: new players in 21st century globalization. Asia Pacific J Manage 23, 5–27. https://doi.org/10.1007/s10490-006-6113-0.
Mathews, J.A., 2002. Competitive advantages of the latecomer firm: a resource-based account of industrial catch-up strategies. Asia Pac. J. Manag. 19, 467–488. https://doi.org/10.1023/A:1020586223665.
Murphree, M., Breznitz, D., 2018. Indigenous digital technology standards for development: the case of China. J. Int. Bus. Policy 1, 234–252. https://doi.org/10.1057/s42214-018-0010-3.
Perea, J.R., Stephenson, M., 2019. Outward FDI from developing countries. In: Cheney, D.M., Silva, A., Tan, A.L., Atkinson, E. (Eds.), Global Investment Competitiveness Report 2017/2018: Foreign Investor Perspectives and Policy Implication. World Bank, Washington, D.C., pp. 101–134
Pirinsky, C., Wang, Q., 2006. Does corporate headquarters location matter for stock returns? J. Financ. 61, 1991–2015. https://doi.org/10.1111/j.1540-6261.2006.00895.x.
Ponte, S., Cheyns, E., 2013. Voluntary standards, expert knowledge and the governance of sustainability networks. Glob. Netw. 13, 459–477. https://doi.org/10.1111/glob.12011.
Ratanawaraha, A., 2006. Late Standardization and Technological Catch-up. Massachusetts Institute of Technology, Cambridge.
Rühlig, T., 2022. Chinese influence through technical standardization power. J. Contemp. China 1–19. https://doi.org/10.1080/10670564.2022.2052439.
Schaefer, K.J., 2020. Catching up by hiring: the case of Huawei. J. Int. Bus. Stud. 51, 1500–1515. https://doi.org/10.1057/s41267-019-00299-5.
Schaefer, K.J., Liefner, I., 2017. Offshore versus domestic: can EM MNCs reach higher R&D quality abroad? Scientometrics 113, 1349–1370. https://doi.org/10.1007/s11192-017-2533-5.
Seaman, J., 2020. China and the New Geopolitics of Technical Standardization, Notes de l'Ifri. French Institute of International Relations, Paris.
Si, Y., Liefner, I., 2014. Cognitive distance and obstacles to subsidiary business success-the experience of Chinese companies in Germany: the experience of Chinese companies in Germany. Tijdschr. Econ. Soc. Geogr. 105, 285–300. https://doi.org/10.1111/tesg.12064.
Simcoe, T.S., Waguespack, D.M., 2011. Status, quality, and attention: what's in a (missing) name? Manag. Sci. 57, 274–290. https://doi.org/10.1287/mnsc.1100.1270.
Swann, G.M.P., 2000. The Economics of Standardisation: Final Report for Standards and Technical Regulations Directorate. Manchester Business School, Manchester.
Tassey, G., 2000. Standardization in technology-based markets. Res. Policy 29, 587–602. https://doi.org/10.1016/S0048-7333(99)00091-8.
van der Loo, M.P.J., 2014. The stringdist package for approximate string matching. The R Journal 6, 111–122. https://doi.org/10.32614/RJ-2014-011.
von Laer, M., Blind, K., Ramel, F., 2022. Standard essential patents and global ICT value chains with a focus on the catching-up of China. Telecommun. Policy 46, 102110. https://doi.org/10.1016/j.telpol.2021.102110.
Wang, P., Kwak, J., Lee, H., 2014. The latecomer strategy for global ICT standardization: Indigenous innovation and its dilemma. Telecommun. Policy 38, 933–943. https://doi.org/10.1016/j.telpol.2014.09.001.
Weiss, M.B.H., Sirbu, M., 1990. Technological choice in voluntary standards committees: an empirical analysis. Econ. Innov. New Technol. 1, 111–133. https://doi.org/10.1080/10438599000000007.
Weithmann, S., 2018. The Evolvement of Standards in China: Insights From the Electric Vehicle Sector, China – Politics and Economics. Nomos Verlagsgesellschaft, Baden-Baden. https://doi.org/10.5771/9783845286235.
Wen, J., Qualls, W.J., Zeng, D., 2020. Standardization alliance networks, standard-setting influence, and new product outcomes*. J. Prod. Innov. Manag. 37, 138–157. https://doi.org/10.1111/jpim.12520.
Wood, S., 2012. The international organization for standardization. In: Utting, P., Reed, D., Mukherjee Reed, A. (Eds.), Business Regulation and Non-state Actors: Whose Standards? Whose Development? Routledge, New York City, pp. 81–94.
Zhao, S., 2017. China Communication Standards Association (CCSA). https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/Events/2017/Oct2017CIIOT/CIIOT/1.Session1-2%20Introduction%20of%20CCSA-%E8%B5%B5%E4%B8%96%E5%8D%93V2.pdf. (Accessed 22 March 2022).