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Wearing multiple hats—The role of working group chairs' affiliation in standards development

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ABSTRACT

Standards Development Organizations (SDO) make critical decisions shaping the direction of technological innovation. SDOs are usually considered to offer a neutral venue for the collaborative efforts of different stakeholders, which often pursue competing particular interests. Nevertheless, individuals acting on behalf of the SDO, such as working group chairs, are themselves often employees of individual SDO stakeholders. Recently, there have been concerns that over-representation of the employees of certain powerful stakeholders in SDO leadership positions may undermine the objectivity of SDO decision making. Nevertheless, to date, there exists no empirical evidence to corroborate these concerns. We find that being affiliated with one of the largest SDO stakeholders significantly increases an individual's likelihood of being appointed to a leadership position at IETF, but not at 3GPP. At the same time, in both SDOs, working groups whose chairs are affiliated with leading stakeholders produce standards that are *less* cited and *less* referenced than standards produced by other working groups, in particular those chaired by university affiliates. Our findings suggest that the commercial interests of individuals' employers may facilitate these individuals' ascension to SDO leadership positions, but the potential for conflicts between these commercial interests of chairs' employers and the organizational goals of the SDO may negatively impact the success of the working group's standards.

1. Introduction

Standards Development Organizations (SDO) play a crucial role in technological innovation, in particular in the field of Information and Communication Technologies (ICT). Standardization through SDOs promotes innovation (Swann, 2000), and the wider diffusion of new technology (Teece, 2018). Technical standardization decisions in SDOs also shape the direction of technological innovation, and determine which technical inventions are widely implemented in complex ICT products (Blind, 2016, 2017; Foucart and Li, 2021). Given this role of SDOs as crucial decision-makers in the process of technological innovation, understanding *how* SDOs make decisions becomes increasingly important.

The largest part of standardization work is carried out in SDO working groups. These committees, which bring together technical experts from the relevant commercial stakeholders, are headed by working group chairs with significant decision-making power. Individuals occupying such chair positions usually have dual allegiance. When acting in their SDO role, they are expected to represent the SDO and all its stakeholders; while at the same time, they remain employed and paid by individual stakeholders of these SDOs.

Neutrality of SDO leadership with respect to the interests of different stakeholders (including their employer) has long been understood as crucial to good standardization practice.[3] Recently, questions surrounding the appointment of individuals to SDO leadership positions

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[3] A finding that a working group chair of the American Society of Mechanical Engineers (ASME) had abused its position to benefit his employer has led to a seminal US Supreme Court decision establishing the principle that SDOs may be held liable for the anticompetitive conduct of individuals holding SDO leadership positions (American Society of Mechanical Engineers v. Hydrolevel Corporation, 456 U.S. 556 [1982] para 43). Marpet (1998) suggest that volunteers in standards development committees should be held to high ethical standards and subjected to a stricter control to prevent abuse of SDO processes.

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have moved to the forefront of the policy debate on SDOs.[4] In particular, it has been suggested that SDO decision-making may be impaired by the fact that powerful stakeholders are actively pursuing SDO leadership positions for their employees as a means to gain control over SDO decision-making.[5] However, other voices suggest that concerns over undue stakeholder influence at the level of SDO leadership are unfounded due to the intrinsic neutrality and expertise-focused character of SDOs.[6]

These two divergent views call for very different policy responses. On the one hand, if the impartiality of SDOs is indeed impaired by competitive strategies of large SDO stakeholders pursuing SDO leadership positions, the neutrality of SDO standards and, consequently, their ability to promote development and diffusion of innovation, are at risk. In light of these potential risks, there have been calls for policy initiatives aiming to curtail stakeholders' efforts to pursue and strategically use SDO leadership positions held by their employees.[7] On the other hand, if concerns of SDO neutrality and objectivity are unfounded, any regulatory and policy intervention risks upsetting the SDO private ordering that is based on longstanding organizational and cultural traditions.

In spite of the policy relevance of this divergence of views, there is a lack of extensive empirical work on the role of SDO leadership (and their affiliations) in SDO decision-making. While there is a growing literature on competitive strategies, stakeholder alliances and (strategic) patenting of SDO members, it has so far paid scant attention to the role of individuals tasked with representing the SDO itself. Existing theoretical models of decision making in SDOs similarly focus on voting and/or consensus finding among SDO members, but largely ignore the potentially significant influence of SDO leadership. As a consequence, the existing scholarly literature on SDOs provides little guidance to the significant policy questions surrounding SDO leadership, the dual allegiance of SDO chairs to the SDO and to their employers, and the implications of any potential tensions between these roles for the objectivity of technical decision-making in SDOs.

To fill this literature gap, we study the determinants and consequences of individuals' appointments to SDO leadership positions. In particular, we ask two questions: first, are individuals appointed to SDO chair positions because of who they are, or who they work for? Second, does the affiliation of the chair, i.e. the identity of the individual's employer, affect the success of the SDO's technical work (in particular the ability of SDOs to produce standards that promote technological innovation)?

To answer these questions, we analyze two different prominent SDOs in the ICT sector, namely the Third Generation Partnership Project (3GPP) and the Internet Engineering Task Force (IETF). Both organizations play a pivotal role in shaping global technological innovation in ICT, and both have working groups where engineers affiliated with a large number of diverse and primarily commercial stakeholders carry out the technical work. In spite of these important similarities, which allow for a general comparison, the two SDOs represent two different institutional models: 3GPP is an *entity-based* SDO, i.e. individuals may only participate as representatives of an SDO member firm; whereas IETF is an *open* consortium, i.e. any interested individual may participate in the technical work, and barriers to participation are low.

We have created a large database with 310,685 individual meeting attendance records and 19,022 observations of working group leadership (individuals holding the chair during a working group meeting). We have collected rich data on the 43,209 individuals in the dataset, including information on their individual and affiliation-level characteristics. We can thus assess for each SDO which factors matter for appointments to working group chair positions, and how working group chairs' characteristics affect the output quality of SDOs' technical work. In particular, we document the role of chairs' affiliation for the ability of standards to spurn follow-on innovation, which we measure using patent citations and references from ulterior standards.

Our findings provide new insights into standardization as a process of collaborative innovation driven by a community of subject matter experts. Our analysis demonstrates that regardless of SDOs' institutional model, individual characteristics (experience and expertise) are the main determinants for appointments to leadership positions. At the same time, they also demonstrate that individuals' affiliation plays a role in leadership selection, reflecting the importance of commercial vested interests as an incentive for costly SDO participation. This affiliation effect contributes to a concentration of leadership positions being held by a small number of SDO stakeholders.

This overrepresentation does not seem to be aligned with the broader interests of the SDO and its community. At both SDOs, affiliation of the chair with one of the leading SDO stakeholders is associated with lower working group output quality: working groups whose chairs are affiliated with top SDO stakeholders produce standards that are less often referenced by other standards, and less cited by patents. The standards produced by working groups whose chairs are affiliated with an academic institution receive the largest number of citations from patents and references from ulterior standards.

Our findings highlight a tension that is crucial for SDO governance: on one hand, employers' vested interests in the SDO fuel participation, and promote the individual's ascension to leadership positions within the SDO. On the other hand, the SDO's legitimacy hinges on its ability to provide a nonpartisan venue for technical decision-making. The SDO's dependency on critical human capital held by its principal stakeholders potentially undermines the neutrality of the SDO, which is critical to its ability to spurn innovation.

SDOs pursue different institutional strategies to deal with this fundamental tension. In very general terms, 3GPP pursues balance in the representation of different commercial interests; whereas IETF seeks an "apolitical" model, in which individuals are encouraged to represent their personal views, and consideration of particular interests in the deliberation on technical standards is discouraged.

Intriguingly, the causal effect of affiliation with a leading commercial stakeholder on appointments to an SDO leadership position is significant at IETF, but not at 3GPP. Overall, our findings suggest that a culture of individual independence and meritocracy may develop even in an institutional context in which individual experts are tasked with representing certain commercial stakeholders. At the same time, an institutional setting encouraging individuals to participate on their own behalf may not necessarily achieve independence from particular interests. Unless the expert community has the ability to effectively neutralize the incentives of individual experts to align themselves with the interests of commercial stakeholders, the general interest may be better served by balance in the representation of different

[4] One important driver of this increased interest in SDO leadership has been extensive debate about competition for SDO leadership positions (such as chairmanships or secretariats) between Chinese and other, particularly US stakeholders (Nanni, 2021; Teleanu, 2021; Russel and Berger, 2021).

[5] In a U.S. Senate Hearing, the Director of the Cybersecurity and Infrastructure Security Agency testified: "Foreign nationals representing foreign companies, including Chinese companies China Mobile Communications Corporation and Huawei, hold key leadership positions on the ITU and 3GPP standards bodies for 5G. These individuals may be able to influence ITU and 3GPP to adopt standards that favor their own companies and put U.S. companies at a competitive disadvantage." https://www.judiciary.senate.gov/imo/media/doc/Krebs%20Responses%20to%20QFRs.pdf.

[6] See e.g. the 'Comments of the American National Standards Institute on FR Doc. 2021-24090: "The quantities of leadership positions taken or the standards proposed do not necessarily lead to more influence". Similarly, the Atlantic Council argues that "The structural integrity of SDOs is sound and has been proven time and time again". (Labucay, 2022).

[7] "The United States can help mitigate abuse of international standards bodies by advocating for reforms. Near-term priorities should include reforming leadership-selection processes at the ITU and reinforcing expectations regarding impartiality in consensus-driven standards-development processes." (Thompson and Montgomery, 2022).

rivaling interests, rather than an ethos of individual independence. This finding may carry broader implications for the legitimacy of decision-making by experts in specialized committees, such as expert gremia of regulatory bodies or industry or professional associations.

2. Literature review

Our study is situated at the intersection of different streams of literature on standardization, innovation and governance of non-profit organizations:

2.1. Stakeholder participation in SDOs

A large number of studies have studied the determinants and consequences of *companies'* engagement in SDOs, such as meeting attendance (Fleming and Waguespack, 2009); submission of technical contributions (Fischer and Henkel, 2013); SEP declarations (Bekkers et al., 2011); and SDO committee memberships (Baron et al., 2019b; Blind and Mangelsdorf, 2016).

The existing literature has highlighted the role of companies' *vested interests* as an important driver of firms' SDO participation (DeLacey et al., 2006), but also stressed the potential adverse consequences of firms' strategic behavior for the functioning of SDOs (David and Shurmer, 1996). Farrell and Simcoe (2012) and Simcoe (2012) analyze the tensions resulting from firms' pursuit of vested interests in consensus standardization, and find that increased vested interests are associated with delays, but higher output quality of SDOs.

2.2. Individual SDO participants

Our study also contributes to the limited body of quantitative empirical research on *individual* participation in SDOs. Some studies linked composition of SDOs' working groups and the quality of their standards (Simcoe, 2012), and analyzed the role of team composition and individual authors' experience for technical decision-making (Ganglmair et al., 2018). Analysis of the determinants and/or consequences of individuals' participation in SDO leadership positions is more limited.[8] The focus on company-level rather than individual-level determinants of participation and conduct in SDOs in the empirical literature contrasts with detailed historical accounts of SDOs (Russell, 2014; Yates and Murphy, 2019), which highlight that standards development is traditionally characterized by a set of norms and rules widely shared in a community of individual participants.

There has been growing interest in the interactions between individuals' membership in this expert community on one hand, and their relationship with their employer on the other hand. Gupta and Rosenkopf (2019) study the role of joint SDO participation for company network formation, and document the importance of personal interactions between individuals in high managerial positions in their respective companies. Isaak (2006) argue that individuals acquire social capital through their participation in SDOs, and Dokko and Rosenkopf (2010) find that companies may acquire this social capital through recruitments of individuals with SDO experience. We extend this existing literature on the boundary-spanning role of firms' individual employees' participation in SDOs by focusing on the different *roles* that individuals may hold in SDO processes. These different roles are associated with different *foci of commitment* to the employer or the SDO and its community.[9] In turn, individuals' standing in an SDO (including their ascension to SDO leadership roles) is determined both by their individual experience, and the influence of the stakeholder they represent. To the best of our knowledge, this interaction of commitments towards the SDO and towards the employer has not yet been formally studied in the context of SDOs.

We can however build on a broader literature on dual allegiances of firms' employees participating in collaborative innovation, and the pressure on these individuals to show loyalty both to their employer as well as to their collaborators in the community (Husted and Michailova, 2010; Husted et al., 2013).[10] For companies, employing individuals with an established position in the relevant community ("men on the inside") is an effective strategy to gain influence over the progress of collaborative innovation (Dahlander and Wallin, 2006; Lee and Herstatt, 2015). Tensions between individuals' dual allegiances may however negatively affect the way they share knowledge with their collaborators (Chan and Husted, 2010; Husted et al., 2013).

2.3. Role of technology standards in the process of technological innovation

There is a growing literature on the role of standardization for technological innovation. Technology standards often define complex technological systems and provide a stable technical foundation for follow-on innovation. Since standards often provide technical infrastructure on which a wide diversity applications can be built (Allen and Sriram, 2000; Blind, 2016; Blind et al., 2017), they may impact not only the pace, but also the direction of technological change, (e.g. towards more incremental and less radical technological innovation Foucart and Li, 2021.)

Standards development has been extensively studied as a form of collaborative and open innovation (Allen and Sriram, 2000; Grø tnes, 2009), as SDOs coordinate the R&D efforts of different firms (Delcamp and Leiponen, 2014; Baron et al., 2014). At firm level, participation in standards development and inventive activity are thus often complements (Blind and Thumm, 2004; Fischer and Henkel, 2013). The development of a standard specification itself has been analyzed as a process of technological innovation, characterized by search and learning (Ganglmair et al., 2018).

Nevertheless, ours is one of the first studies analyzing how an aspect of SDO governance, in this case the selection of SDO leadership, may impact SDOs' ability to promote technological innovation.

2.4. SDO decision-making

There is a significant literature on decision-making in SDOs, including models of consensus building (Farrell and Saloner, 1988; Farrell and Simcoe, 2012; Simcoe, 2012), coalition formation (Llanes and Poblete, 2020) or voting (Goerke and Holler, 1995; Lehr, 1996; Bonatti and Rantakari, 2016; Spulber, 2019) . By focusing on SDO leadership, our contribution sheds light on the yet understudied role of the SDO itself, i.e. the role of the individuals representing and/or acting on behalf of SDOs.

A number of recent books have investigated the history and governance principles of SDOs in the field of ICT (DeNardis, 2014; Harcourt et al., 2020; Russell, 2014; ten Oever et al., 2020; Kanevskaia, 2022), and detailed case studies examined the processes and institutional evolution of single SDOs, e.g., ISO (Murphy and Yates, 2009; Delimatsis, 2018), IEEE (Zingales and Kanevskaia, 2016), and W3C (Halpin, 2017). Baron et al. (2019a) compared the governance rules of 17 SDOs, including leadership election processes. Prior research has found that different standardization governance models are associated with different innovation patterns (Grø tnes, 2009).

Nevertheless, our study provides one of the first empirical analyses linking SDO governance mechanisms to empirically observable standardization outcomes. Our focus on the effect of the chair's neutrality

[8] Baron et al. (2021) studied the role of supportive norms for the appointments of women to IETF leadership.

[9] For a general analysis of multiplicity of foci of commitment in the knowledge economy, see Kinnie and Swart (2012).

[10] Many of the existing studies of dual allegiance in collaborative innovation focus on companies' participation in Open Source Software (OSS) communities (Chan and Husted, 2010; Homscheid and Schaarschmidt, 2016; Schaarschmidt and Stol, 2018).

with respect to the principal SDO stakeholders on the ability of the standard to spurn follow-on innovation sheds light on the epistemic function of SDO governance — i.e. the role of the SDO as a nonpartisan, objective forum is relevant to the technical quality and impact of the SDOs' standards.

3. Institutional background

3.1. Entity-based vs individual institutional models

We study two SDOs, which are representative of two very different institutional models: 3GPP and IETF.

3GPP is a global partnership of seven regional SDOs operating in the telecommunications and ICT sectors. Stakeholders participate in 3GPP processes by virtue of their membership in partner-SDOs. 3GPP is rooted in the principle of direct representation of commercial stakeholders: experts serving in 3GPP committees represent the interests of their affiliations. In turn, IETF is a loosely organized group of Internet experts with no formal membership requirements. IETF processes are rather informal, with most standards work taking place in IETF mailing lists, and are open to all interested parties or individuals (Weiser, 2001), irrespective of which interests or views they wish to represent.

3GPP and IETF approaches to SDO participation are thus highly different: whereas the entity-based approach of 3GPP seeks to reflect consensus of all relevant stakeholders and assure sufficient representation of different types of (commercial) interests, the individual-based approach of IETF seeks to reflect a technical consensus among subject matter experts. Leadership appointments in 3GPP and IETF thus present an interesting case study for our analysis, as the two SDOs represent two very different institutional strategies to the shared goal of achieving objectivity in technical decision-making.

3.2. Role and selection of SDO leadership

Individuals may perform various administrative and management functions within SDOs. The most common leadership position within SDOs is the role of working group chair. A working group chair position carries considerable power: chairs coordinate the work of the working group, decide on acceptance of technical contributions,[11] and determine whether consensus has been achieved. Chairing a working group requires specific knowledge of and experience within the particular SDO, as well as specialized technical knowledge of the subject matter.

Next to professional expertise, neutrality and impartiality are the main requirement for chairs in both 3GPP and IETF.[12] Chairs are responsible for ensuring a balanced representation of different interests (Marpet, 1998). At the same time, chairs' actions and decisions may generate significant delays in the working groups (Harcourt et al., 2020), and partisan exercise of the chair function may lead to profound adverse effects (including antitrust liability) for an SDO.

The roles and responsibilities of Working Group chairs in 3GPP and IETF are thus very similar. Nevertheless, the two SDOs have very different processes for chair selection. While working group chairs at 3GPP are elected by the working group members, IETF working group chairs are appointed by the responsible area directors (who in turn are selected by a Nominating Committee, or NomCom). The procedures for chair appointments in the two SDOs demonstrate further notable differences. Indeed, affiliation is explicitly taken into account for chair appointments in 3GPP, which requires companies to take necessary steps to ensure the candidate's appointment, as well as sets limitations to secure commercial and regional balance. There is no equivalent to these requirements at IETF.

A more detailed technical description of the chair appointment processes in both SDOs is available in Appendix A.1.

4. Research questions

We seek to shed new light on SDO decision making by analyzing the role of working group chairs' affiliation. In particular, we ask two questions: (1) what is the role of an individual's affiliation for the likelihood to be appointed to an SDO leadership position, and (2) what is the role of the chair's affiliation for the output quality of an SDO working group? For both questions, we wish to analyze the possible mediating role of SDOs' institutional model — i.e. whether SDOs follow an entity-based or individual-based approach.

Our analysis focuses on the role of individuals' affiliation with SDOs' *top stakeholders*. Many companies participate in standards development; nevertheless, only a subset of these companies actively contribute.[13] Even fewer companies are sufficiently invested in ICT standardization to seek to influence the governance and overall direction of the SDO's work. Volunteering employees for SDO leadership positions may only pay off for the companies with the largest stakes in the SDO. Furthermore, SDO leadership is characterized by indivisibilities (achieving and carrying out any significant SDO leadership positions requires a large share of the work time of an accomplished technical expert) and positive returns to scale (individuals affiliated with a large company may rely on support from their employer's other established experts within an SDO to pursue their agenda). For these reasons, we believe that the role of SDO leadership's affiliation crystallizes around a few very large stakeholders.[14]

4.1. Effect of affiliation on appointments to leadership positions

As a first step, we analyze whether individuals' affiliation impacts their chances of being appointed to SDO leadership positions. This question is central to the recent policy debate on SDO leadership appointments, but also to our more general understanding of SDO decision making.

Several commentators have highlighted the large number of individuals in SDO leadership affiliations that are affiliated with certain large commercial stakeholders. Nevertheless, it is not clear whether there is a causal relationship — do individuals become SDO working group chairs *because* they work for a certain company; or are employees of large stakeholders more likely to possess individual characteristics and qualifications that are required of a working group chair?

If individuals are appointed to SDO leadership positions because of the corporate stakeholders they represent, these stakeholders may effectively own the social capital inherent to their employees' leading position in an SDO, and use this to exert significant control over the SDO and its leadership. Corporations may lend their support to the candidate most likely to pursue their interests; and individuals are

[11] Trueposition, Inc. v. LM Ericsson Tel. Co. (Jan 6, 2012), No. 11-4574, 2012 WL 33075 [2012]

[12] In both SDOs, the impartiality and neutrality of hairs have been challenged on a number of occasions. At IETF, allegations of abuses of chair functions have been raised in different occasions, but neither IESG nor UAB, the IETF's appeal bodies, found any evidence of conflict of interests stemming from the chairs' affiliation. See e-mail exchange titled "Continued Abuse of Process by IPR-WG Chair", December 26, 2007 https://www6.ietf.org/iesg/appeal/anderson-2007-12-26.txt and Appeal Against the Removal of the Co-chairs of the Geopriv Working Group, April 23, 2007 https://www6.ietf.org/iesg/appeal/gellens-2007-06-22.pdf. For 3GPP, see the TruePosition case, where the decisions of the chair were not considered conflicting with 3GPP/ETSI procedures by these SDOs' governing bodies.

[13] Smaller and younger companies may primarily participate in SDOs to build networks with established industry leaders and keep abreast of the latest technological developments (Fleming and Waguespack, 2009).

[14] We note that this is also the focus of the policy debate on the affiliations and potential conflicts of interests of SDO leadership; which similarly focuses on a small number of large and salient corporate stakeholders.

primarily incentivized to be useful to their employer. If individuals however gain influence within SDOs because of their individual characteristics, this may significantly reinforce SDOs' independence from their stakeholders. Employers of individuals in SDO leadership positions cannot fill SDO leadership positions at will. Individuals in SDO leadership positions are incentivized to be useful to their employer, but they also have an incentive not to endanger their individual standing within the SDO by taking actions that are in contradiction with the neutrality expected of a chair.

It is thus important to analyze the *causal* effect of individuals' affiliation on their likelihood to be appointed to SDO leadership positions. We will also analyze how the effect of affiliation characteristics on appointments to leadership positions is moderated by SDOs' governance rules and informal norms. In particular, we compare the role of affiliation characteristics for appointments to similar roles in two different SDOs, entity-based 3GPP and individual-based IETF. These two models represent different institutional strategies to achieve objectivity in technical decision-making — either through balancing the representation of different interests, or by encouraging individual experts to represent their own personal views.

4.2. Role of chair affiliation for output quality

In a second step, we analyze the role of chairs' affiliation for the output quality of the working group that they chair. We measure the success of the group's technical standards by identifying and counting patent citations and standards references to these standards.

Establishing that being affiliated with a large stakeholder increases an individual's chances of being promoted to an SDO leadership position may indicate that certain large stakeholders indeed actively pursue SDO leadership positions for their employees. This alone may not necessarily be a concern or antithetical to SDOs' neutrality. To examine whether policy concerns about the concentration of SDO leadership positions in the hands of a smaller number of large SDO stakeholders are warranted, it is thus necessary to also assess whether there is a link between working group chairs' affiliation and the technical quality and success of SDOs' standards.

5. Empirical analysis

5.1. Data and methodology

5.1.1. Data on attendees and chairs

We collected meeting attendance and working group chair information from the websites of 3GPP and IETF. We standardized the individual attendee and chair names, and collected information on individuals' *primary affiliation*, i.e. the organization which we consider to be the most likely primary employer of the individual.[15] In the case of companies, we standardized this affiliation information to the level of the global ultimate owner (GUO).[16]

In the case of 3GPP, we retrieved attendance records of working group meetings. The data includes the meeting reports of the meetings of six 3GPP Technical Specification Groups (TSG) as well as their 31 working groups. During our observation period (1999 to early 2019), there were a total of 2,720 meetings at these groups. In the case of IETF, we collected attendance records from 75 IETF meetings from 1994 to 2019, inclusive. IETF working groups meet during the general IETF meetings. While in some cases there is attendance data for individual working group meetings, this information is not sufficiently systematically available. IETF attendance data (but not the data on chairs) is thus limited to observations of attendance at the 75 general meetings. In total, we collected 310,685 attendance records from 2795 different meetings, with information on 43,209 different individuals and 7,566 different affiliations (at the parent level).

Table 1
Descriptive statistics by type of standards organizations.

	3GPP	IETF	Total
Attendance			
Meetings	2,720	75	2,795
Attendance records	202,451	108,234	310,685
Individual attendees	14,441	30,172	43,209
Different affiliations	985	6,609	7,566
Chairs			
Meetings	2,232	7,000	9,232
Chair observations	4,841	13,076	17,917
Chair persons	374	916	1,286
Observation period	1999–2019	1994–2019	1994–2019

Similarly, we collected data on working group chair names. We consider "Chair", "Vice chair", and "Convenor" as chair positions. Overall, we collected 17,917 chair observations from 9,232 meetings; with 1,286 different individuals serving as chair, and 2,520 different chair positions (i.e. unique combinations of individual chair name and working group name). Of these positions, 1,274 were appointments to chair positions of already existing groups. For most of our analysis, we will focus on these appointments to open positions in existing groups; which allows us to observe the past participants in the group. In almost all cases, the new working group chair is drawn from this population of past group attendees (for an overview of the chair and attendee observations in our dataset, see Table 1) .

5.1.2. Independent variables

For each of these individuals, we collected information on explanatory variables at the individual and affiliation level. We build several variables from the SDO attendance data: **seniority** measures the time elapsed since the first meeting attendance, and **attendance** measures the number of meetings attended (in total, at individual SDOs, and in individual working groups). We do not observe working group attendance in IETF. Nevertheless, we observe the cumulative number of authorships of *requests for comments*, or RFC (**RFC_author**), and e-mail authorships in IETF mailing lists (Ganglmair et al., 2018).[17] RFCs are the deliverables of IETF, including its standards and non-standard output (Simcoe, 2012). Unlike meeting attendance, RFCs and e-mails can be attributed to individual working groups.[18]

For a general measure of relevant technical expertise, we collect information on patent inventorship in the related technical field.[19] We count the cumulative number of patents by inventor over time, by date of first application (**number_patents**). The count is limited to the 20 International Patent Classification (IPC) classes most relevant to the

[15] We used individuals' listed affiliation, contact information, and working group name, for name disambiguation and standardization. We infered individuals' affiliation from the listed affiliation and/or the domain of the e-mail address. The steps for the standardization of individual and firm names are explained in greater detail in Baron (2020).

[16] Standardization of affiliations at the GUO level reflects the standard assumption in economic research that firm conduct is determined at the level of the corporate group.

[17] The authors are grateful for permission to Bernhard Ganglmair, Tim Simcoe, and Emanuele Tarantino for permission to use this data.

[18] The matching between IETF mailing lists and working groups results from the author's research for Baron et al. (2021).

[19] In order to make patent counts comparable across different World regions, and to account for heterogeneity in patent value, we count *triadic patent families*, or TPF; i.e. inventions for which a patent was granted by at least the following three patent offices: the US Patent and Trademark Office (USPTO), the European Patent Office (EPO), and the Japanese Patent Office (JPO). TPF are generally considered to be patents of higher quality and higher value (see Sternitzke, 2009 for a discussion). We use the OECD Database of TPF (Dernis and Khan, 2004).

Table 2
Indicators of standards' impact on innovation — patent citations and references from ulterior standards.

	3GPP		IETF	
	# citations	# citing pats	# citations	# citing pats
NPL Patent citations				
any citation with name of SDO	369,995	61,092	150,570	41,956
matched citation to individual standards	142,465	38,116	109,880	30,112
citations to contributions	203,620	37,469		
matched citation to standard doc itself	139,984	37,808		
	# references	# referencing docs	# references	# referencing docs
Standard references				
Number of references	349,089	25,148	152,074	16,590
Unique references	2,065	18,442	7,990	73,306
External references	365	153	96,756	12,538
Unique ext. references	344	150	22,871	3,938

standards of the SDOs in our sample.[20] We also count the number of patent families for which at least one member was declared essential to an SDO, by date of first declaration (**number_sep**) (using the SEP declaration data collected by Baron and Pohlmann, 2018).

At the affiliation level, we categorize affiliations by the following types: company, university, public administration (including military, but excluding public research institutes), public research institutes, membership organizations, and other (or unknown). We identify the five affiliations accounting for the largest number of attendance records in our two SDOs: Cisco, Ericsson, Huawei, Nokia, and Qualcomm (in alphabetical order).[21]

To measure the extent of involvement in the SDO, we count cumulative attendance in the SDO and in the working group at the affiliation level.[22] We count current memberships in standards organizations as a measure of a firm's involvement in ICT standardization in general, using the Searle Center Database (Baron and Spulber, 2018).[23] In addition, we use information on the number of declared SEP collected by Baron and Pohlmann (2018).[24]

5.1.3. Indicators of impact on technological innovation — citations and references to standards documents

To study the impact of standards on technological innovation, we selected two indicators that are objective, quantitative, and available for standards developed by both 3GPP and IETF:

First, we counted the number of patents citing individual standards as part of the non-patent literature (NPL). We used the USPTO's dataset of "other references" in granted US patents, available from PatentsView, and identified citations to specific standard documents using a regular expression script.[25] Patent citations to standards documents indicate that the technical information in the standard has influenced subsequent inventive activity. Similar to us, Ganglmair et al. (2018) studied the role of standards for follow-on innovation using patent citations.

Second, we used the Searle Center Database (Baron and Spulber, 2018) to count standards references to IETF RFCs and 3GPP TS.[26] Standards references indicate that using the referenced standard is helpful or necessary in order to comply with the referencing standard. Standards references are thus a measure of the extent of implementation of a standard (Baron and Spulber, 2018).

Table 2 provides a summary overview over our datasets with information on patent citations and standard references to IETF and 3GPP standard documents. Both IETF and 3GPP documents have spurned significant follow-on innovation, as evidenced by the more than 30,000 granted US patents citing each SDO's standards. While we have processed almost 350,000 different references to 3GPP standard documents, there is a large amount of repetition, i.e. different versions of a specification being referenced by different versions of another specification; IETF RFCs receive a larger number of *unique* references. Most references are SDO-internal; but especially IETF RFCs also receive a significant number of references from other SDOs' standards (including many references from 3GPP TS).

5.2. Descriptive statistics

5.2.1. Evolution of attendance and chair patterns over time

Fig. 1 displays the evolution of attendee and chair demographics at 3GPP and IETF. There are pronounced differences in the composition of attendee populations in terms of affiliation: 3GPP attendees are almost exclusively affiliated with companies, and attendance is dominated by the "Top 20" affiliations. At IETF, by contrast, there is a significant portion of non-corporate attendance,[27] and the share of Top 20 affiliations in the corporate attendee population is smaller.[28] In spite of these pronounced differences between SDOs, the composition of the attendee population has remained fairly constant over time at both SDOs.

Top 5 and Top 20 entities are even more dominant among chairs at 3GPP than among attendees, and the share of non-corporate affiliations is smaller among IETF chairs than among attendees. Differences

[20] We matched the TPF patent numbers with the Searle Center data on declared SEP (Baron and Pohlmann, 2018), and identify the 20 IPC classes with most patents in TPF declared essential to these SDOs' standards.

[21] Alternatively, we also use the list of the "Top 20" affiliations, also including Alcatel-Lucent (prior to acquisition by Nokia), AT&T, Blackberry, Deutsche Telekom, Fujitsu, Intel, LG Electronics, Motorola (prior to acquisition of Motorola Mobility by Google), NEC, NTT, Orange, Panasonic, Samsung, Vodafone, and ZTE.

[22] All cumulative counts at the affiliation level are transferred along with the firm in the case of M&As, i.e. the acquired firm's stock is added to the stock of the acquiring parent company after the date of acquisition.

[23] To account for observation gaps in the membership data, we interpolate the membership information.

[24] We match the information on declared SEP with the OECD TPF database; and count TPF with at least one member declared to be potentially essential.

[25] As we wish to track changes in the quality of technical specifications over time, we identified which version of a 3GPP technical specification (TS) is cited, and then identified the publication date of that particular version to assign the document to a particular working group chair's tenure. There are no different versions per RFC at IETF.

[26] For the empirical analysis, we use the count of *unique* references to a particular document, i.e. the number of different specifications (and other standard documents) referencing a document, ignoring multiple references resulting from the fact that a document may be referenced by different versions of the same standard; and the count of *new* references to a particular version of a standard, i.e. the number of standard documents that reference this version of a specification, excluding cases in which previous versions of the referencing document already referenced previous versions of the referenced document (i.e. *new* are references that are "added" to the specification with this particular version).

[27] including academics, nonprofit organizations, and different types of government affiliations.

[28] There also is a significant portion of attendees for which the entity type of the affiliation is unknown.

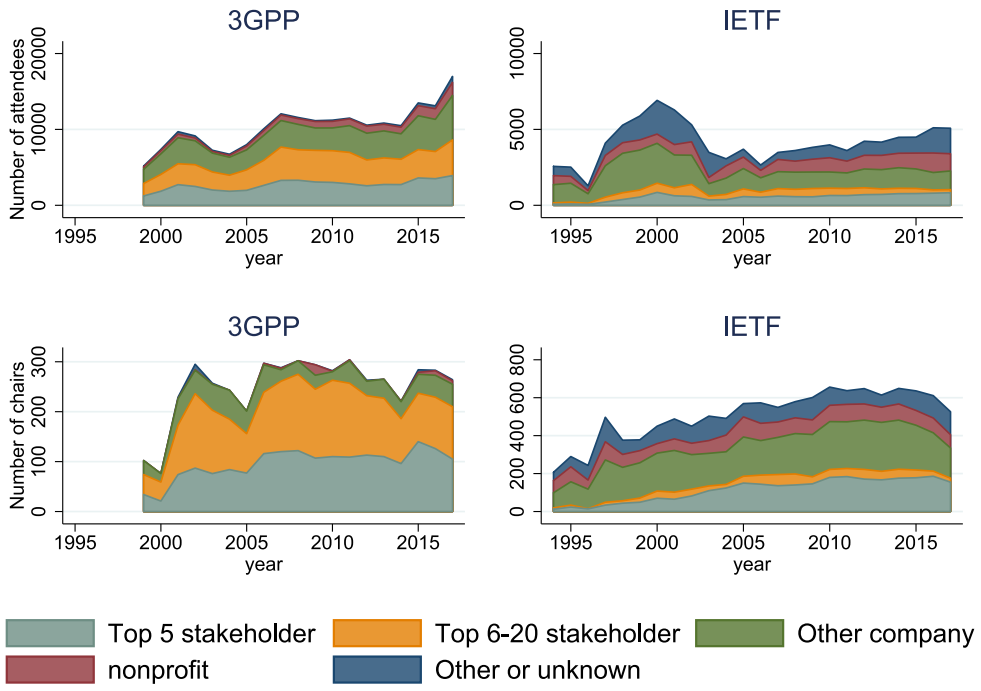

Fig. 1. Composition of attendee population over time — by affiliation type and SDO.

between SDOs are similar to those observed in the attendance data — corporate affiliations, and especially the "Top" affiliations, play a larger role at 3GPP than at IETF; and the composition of the chair population in terms of affiliation entity type has not changed dramatically over time at either SDO.

5.2.2. Characteristics of attendees and chairs

Table 3 compares the characteristics of attendees and chairs, focusing only on the most recent years for which we have untruncated attendance data from both SDOs (2014–2017). Top 5 or Top 20 affiliations are significantly over-represented in chair positions in both SDOs; at 3GPP, 82% of the chair positions were held by one of the Top 20 companies. At IETF, 73% of the chairs have corporate affiliations, as compared to only 52% of the attendees.

Chairs at 3GPP also tend to be affiliated with companies that are more involved in standardization. For instance, on average, approx. 100 other individuals affiliated with the chair's affiliation had previously attended a 3GPP meeting (as compared to 66.5 other individuals also affiliated with the affiliation of meeting attendees); and chairs' affiliations were member of an average of 40 standards organizations (as compared to 30 for attendees). The latter difference between chairs and attendees also exists at IETF.

Working group chairs however differ from attendees also with respect to their individual experience and technical expertise. At both SDOs, chairs have significantly more SDO experience than attendees, both in terms of number of meetings previously attended, and seniority. At 3GPP, chairs are also significantly more prolific patent inventors than attendees. This difference is however unique to 3GPP; chairs are generally less prolific inventors of patents than attendees at IETF. Patent inventorship may however not be a relevant measure of technical expertise at IETF, as the average number of patent inventorships per attendee or chair is also much lower than at 3GPP. Focusing on IETF-specific measures of individuals' technological track record, we see that IETF chairs have authored five to six times as many RFCs and contributions to IETF mailing lists as attendees. These numbers underline that working group chairs positions at 3GPP and IETF are reserved for individuals with a track record as prolific contributors to technical progress in the relevant fields.

Table 3
Descriptive statistics: characteristics of chairs v. attendees.

	3GPP			IETF		
	attendees	chairs	t_stat	attendees	chairs	t_stat
meetings_cum_sso	57.03	112.63	−24.7	11.12	32.72	−52.87
meetings_cum_wg	18.46	50.21	−43.62			
seniority	2860.87	4596.61	−24.84	2257.15	5076.62	−38.53
number_patents_4y	4.37	15.35	−17.39	.25	.16	1.83
number_seps_4y	.19	.64	−10.7	0	.01	−2.7
number_mails_cumul				119.68	621.81	−30.22
number_rfc_cumul				2.06	12.07	−45.53
attendees_guo_sso	66.52	99.03	−14.18	122.13	80.3	6.61
attendees_guo_wg	11.66	11.04	1.4			
top5	.25	.45	−13.91	.15	.32	−16.01
top20	.52	.82	−17.5	.2	.37	−14.57
sso_count_2014	30.1	39.76	−15.28	25.04	31.31	−8.56
company	.86	.97	−9.22	.52	.73	−14.55
networkprovider	.16	.22	−5.25	.07	.05	1.5
university	0	0	2.09	.14	.08	6.43

5.2.3. Characteristics of affiliates of top SDO stakeholders and other attendees

We have thus seen that – in both SDOs – employees of the leading SDO stakeholders are over-represented in working group chair positions (as compared to their share in the attendee population). At the same time, in both SDOs, individuals affiliated with one of the leading stakeholders have significantly more SDO experience, invented more patents, and at IETF, they also authored more RFCs and contributions to IETF mailing lists (Table 4). As we have seen, these individual characteristics are associated with a higher likelihood of being appointed to chair positions. The descriptive statistics alone therefore do not allow

Table 4
Descriptive statistics: attendee characteristics, affiliates of Top 5 competitors for SDO leadership v. all other attendees.

	3GPP			IETF		
	all	top5	t_stat	all	top5	t_stat
meetings_cum_sso	57.14	61.28	−5.55	12.27	17.39	−14.82
meetings_cum_wg	16.9	25.68	−36.43	12.27	17.39	−14.82
seniority	2790.84	3210.27	−18.19	2370.44	3263.19	−15
number_patents_4y	3.82	6.9	−14.83	.17	.59	−11.06
number_seps_4y	.18	.26	−5.87	0	.01	−6.12
number_rfc_cumul				2.56	5.15	−14.23
number_mails_cumul				158.12	205.75	−3.56

disentangling whether employees of top SDO stakeholders are over-represented in chair positions *because* of their affiliation, or simply because they tend to be more prominent experts and more experienced SDO participants than affiliates of other organizations.

5.3. Regression analysis: who becomes a chair?

As a first step to disentangle the causal effects of individual and affiliation characteristics, we conduct a conditional logit regression analysis of chair *appointments*. The overwhelming majority of new working group chairs are drawn from the working group's past attendees. We thus identify for each new appointment the attendees of the working group's meetings of the preceding year, and analyze the factors determining which of these individuals is appointed to fill the chair position.[29]

The results of the conditional logit analyses are presented in Table 5. Not controlling for characteristics of the individual or general characteristics of the affiliation, affiliates of the "Top" companies competing for SDO leadership are significantly more likely to be appointed to working group chair positions than attendees with other affiliations (Models 1 and 4).[30]

Controlling for individuals' past SDO experience and technical expertise in the field (as measured by patent inventorship), the chances of appointment become more similar between affiliates of top affiliations and other attendees, even though the advantage of affiliates of top affiliations does not vanish entirely (Models 2 and 5). At 3GPP, these remaining differences may be fully explained by general characteristics of the affiliation, such as the number of employees who have participated in the SDO (Model 3). At IETF, there continues to be a significant residual advantage of affiliates of the top 5 leading affiliations, which is robust to linear controls for standardization involvement (Model 6). This suggests that the likelihood of appointments to leadership positions does not increase linearly in the extent of an organization's involvement in standardization; rather, greater likelihood of ascending to leadership positions is specifically associated wit a very small number of top affiliations.

Controlling for a large range of affiliation-level characteristics does not reduce the significance of individual-level characteristics. In particular, experience (both within the working group, and the SDO more generally) is a relevant predictor of appointment to chair positions. Patent inventorship is a significant and relevant predictor of chair appointments at 3GPP, but not at IETF. Chair appointments at IETF are, however, significantly predicted by past contributions to IETF, such as RFC authorship and participation in the working group-specific mailing lists.[31] While the specific types of expertise and experience that matter thus differ between 3GPP and IETF, individual characteristics are highly relevant at both SDOs.

5.4. Within-variation in individuals' likelihood of being appointed to SDO leadership positions

5.4.1. Different specifications

The conditional logit analyses described in Section 5.3 can identify the role of different *observable* firm- and individual-level characteristics. They cannot, however, account for unobservable individual characteristics (e.g. "ability") that may be more common among individuals with certain affiliations. To disentangle affiliation- and individual-level *causal* effects, we take advantage of individuals' changes of affiliation.[32] Many unobserved individual-level characteristics are likely to be largely constant over time (such as intrinsic ability), or pre-determined with respect to the period of the individual's participation in SDOs (e.g. education). As we observe the same individuals' careers across different affiliations, we can test whether a given individual is more likely to be appointed to a chair position while being affiliated with an organization of certain characteristics.

We thus build a yearly panel dataset, in which we track individuals' current affiliation (at the beginning of the year) and new SDO leadership appointments over time, and we run a fixed-effect OLS regression to analyze the *within variation* in new leadership appointments.[33]

Specifically, we explain the likelihood of individuals' appointments to leadership positions as a function of the characteristics of their current affiliation, controlling for time-invariant heterogeneity in individual characteristics by including individual fixed effects. The results of the fixed effect logit analysis of new chair appointments at 3GPP are presented in Tables 6, and the results of our fixed effect analysis of chair appointments at IETF are presented in Table 7.

One potential concern with the fixed-effect approach described above is that several important individual characteristics do change over time. Especially for individuals observed over long stretches of time, individual fixed effects may not fully control for unobserved heterogeneity in individual characteristics. Furthermore, fixed effects do not eliminate the potential for reverse causation. It is plausible that an individual participant's observable performance and influence in an SDO, which are good predictors of future appointments to SDO leadership positions, may cause affiliation changes.

In order to corroborate the robustness of our results to concerns about reverse causation, we identify and use affiliation changes resulting from changes in corporate structure (mergers, acquisitions, spinoffs,

[29] For IETF, we include all attendees of the IETF's general meetings of the preceding year — a substantially larger "risk set" including numerous irrelevant observations. By including e-mail contributions to working group-specific mailing lists, we are able to significantly improve the precision of our analysis of new chair appointments.

[30] Affiliates of Top 5 companies are significantly more likely to be appointed than affiliates of other Top 20 companies at both 3GPP and IETF; at 3GPP, affiliates of Top 20 companies are furthermore more likely to be appointed than other attendees (at IETF, it is only affiliates of Top 5 companies that are more likely to be appointed than other attendees).

[31] We are concerned about a potential reverse causality for this variable, as individuals who have already learned that they will be the group's next chair may begin sending larger numbers of messages to the group's mailing list (partly administrative in nature). To attenuate this concern, we generally exclude e-mails from the six months preceding the meeting at which we observe the new chair from the count.

[32] We use a somewhat narrower sample of individuals with multiple SDO attendance records, and without irresolvable data conflicts.

[33] In order to focus exclusively on affiliation changes as sole source of variation in affiliation characteristics, we hold each affiliation's characteristics constant at the levels of the beginning of each individual's career; e.g. if we observe individual i from 2002 to 2009, with affiliation A from 2002 to 2006 and affiliation B from 2006 to 2009; individual i's affiliation characteristics from 2002 to 2006 are the characteristics of affiliation A in 2002, and individual i's affiliation characteristics from 2006 to 2009 are those of affiliation B in 2002. This way, we exclusively capture variation in affiliation characteristics attributable to individual i's affiliation changes, as opposed to changes in affiliations' characteristics over time.

Table 5
Conditional logit regression analysis: who is appointed to become working group chair — affiliates of top competitors for SDO leadership, and other attendees.

	(1) 3GPP	(2)	(3)	(4) IETF	(5)	(6)
company	0.938 (1.52)	0.947 (1.48)	1.008 (1.54)	0.577*** (5.61)	0.320** (3.12)	0.350** (2.90)
top5	0.506* (2.30)	0.327 (1.40)	−0.134 (−0.41)	0.852*** (4.82)	0.504** (2.83)	0.704** (2.78)
top20	0.775** (2.85)	0.411 (1.47)	0.355 (1.03)	−0.561*** (−3.38)	−0.407* (−2.44)	−0.182 (−0.91)
network_op			−0.0847 (−0.27)			−0.369 (−1.76)
university			−7.793 (−0.01)			−0.0828 (−0.47)
decl_sep_tpf			0.000593 (0.92)			−0.000142 (−0.32)
sso_membership_count			−0.00251 (−0.23)			0.000206 (0.05)
#other_attendees_guo			0.0830* (2.25)			−0.00656** (−2.64)
attendance_wg_lastyear		0.570*** (9.23)	0.574*** (9.25)			
attendance_wg_prior		0.0443*** (5.87)	0.0430*** (5.69)			
attendance_plen_lastyear		0.555*** (6.72)	0.559*** (6.74)		1.109*** (18.32)	1.112*** (18.28)
attendance_plen_prior		−0.0299* (−2.04)	−0.0285 (−1.93)		0.0237*** (6.11)	0.0237*** (6.05)
#patents_field		0.00488* (2.37)	0.00461* (2.13)		−0.0318 (−1.71)	−0.0362 (−1.87)
sep_inventor		0.0124 (0.05)	−0.0874 (−0.35)		0.0686 (0.33)	−0.0465 (−0.22)
numbermails_wg_6m					0.00138*** (7.01)	0.00141*** (7.16)
number_rfcs					0.0130*** (4.04)	0.0132*** (4.01)
N	37,982	37,982	37,982	1,383,290	1,383,290	1,383,290
Groups	110	110	110	585	585	585

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6
Individual-level fixed effect regressions: 3GPP.

	(1)	(2)	(3)	(4)	(5)	(6)
company	0.000111 (0.07)	−0.000201 (−0.12)	−0.000159 (−0.09)	−0.000940 (−0.48)	−0.000986 (−0.50)	−0.00102 (−0.52)
top5		0.00140 (0.57)				
top20			0.000632 (0.23)	0.00127 (0.44)	0.00168 (0.49)	0.00128 (0.44)
network_op				0.00630 (1.64)	0.00644 (1.70)	0.00629 (1.64)
sep_3GPP_guo				−0.00000881 (−1.77)	−0.00000515 (−0.59)	−0.00000868 (−1.76)
wgchairs_guo_3GPP					−0.000250 (−0.35)	
attendance_3GPP						0.000154 (0.34)
guo_cumul	0.000572 (0.31)	0.000555 (0.30)	0.000583 (0.31)	0.000590 (0.32)	0.000519 (0.28)	0.000576 (0.31)
_cons	0.00105 (0.25)	0.00122 (0.29)	0.00111 (0.27)	0.00138 (0.33)	0.00158 (0.38)	0.00119 (0.28)
N	27,882	27,882	27,882	27,882	27,882	27,882

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Year fixed effect included but not reported.

Table 7
Individual-level fixed effect regressions: IETF.

	(1)	(2)	(3)	(4)	(5)	(6)
company	0.00691* (2.33)	0.00588 (1.91)	0.00496 (1.58)	0.00413 (1.30)	0.00417 (1.30)	0.00348 (1.11)
top5		0.00583 (1.53)				
top20			0.00694 (1.94)	0.00647 (1.85)	0.00680 (1.92)	0.00585 (1.68)
network_op				0.0127 (1.57)	0.0125 (1.56)	0.0129 (1.63)
sep_IETF_guo				0.00159* (2.04)	0.00158* (2.04)	0.00168* (2.15)
wgchairs_IETF_guo					−0.0000937 (−0.52)	
attendance_IETF						0.0180*** (8.84)
guo_cumul	−0.00330 (−1.73)	−0.00334 (−1.75)	−0.00329 (−1.72)	−0.00327 (−1.71)	−0.00331 (−1.72)	−0.00532** (−2.72)
_cons	0.0537*** (5.51)	0.0539*** (5.53)	0.0537*** (5.51)	0.0535*** (5.48)	0.0536*** (5.49)	0.0261* (2.55)
N	44,665	44,665	44,665	44,665	44,665	44,665

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Year fixed effect included but not reported.

Table 8
New chair appointments, 3 years before and after change of affiliation – mergers, acquisitions, and spinoffs – 3GPP.

	(1)	(2)	(3)	(4)	(5) (M&A)	(6) (Spinoffs)
top5	−0.00748 (−1.21)					
top20		0.0203 (1.06)				
network_op			−0.0144 (−0.93)			
#decl_SEP				−0.0000202* (−2.01)		
after	0.0351 (1.11)	0.0330 (1.10)	0.0349 (1.10)	0.0387 (1.15)	0.0422 (0.91)	0.00689 (0.93)
seniority	−0.0000254 (−1.23)	−0.0000248 (−1.23)	−0.0000254 (−1.23)	−0.0000252 (−1.18)	−0.0000281 (−0.94)	−0.00000555 (−1.25)
_cons	0.0542 (1.64)	0.0448 (1.73)	0.0543 (1.60)	0.0536 (1.61)	0.0549 (1.30)	0.0176* (2.03)
N	2,567	2,567	2,567	2,460	1,711	1,546
Groups	254	254	254	254	173	87

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

and transfers of firms from one parent to the other).[34] Causation of these changes in corporate structure is established at a significantly higher level of aggregation, ruling out that affiliation changes are immediately caused by factors that correlate with an individual's impending appointment to an SDO leadership position.

In our preferred specification, we thus focus on changes in the likelihood that an individual is appointed to a chair position, comparing the three years prior and after a change of affiliation that is attributable to a change in the employer's corporate structure, to identify the effect of the characteristics of the individual's employer before and after the corporate structure event. The results are presented in the following Tables 8 and 9.

[34] We hand-collected information on 262 mergers, acquisitions, and spinoffs; e.g. an attendee changing affiliation from Google to Lenovo concurrently with Motorola Mobility's acquisition by Lenovo is identified as having changed affiliation due to a change in corporate structure.

5.4.2. Findings

The results of our analyses are largely consistent between the different specifications, but differ between SDOs. Being affiliated with a leading (Top 5) SDO stakeholder increases an individual's chances of appointment to a working group chair position at IETF.[35] This is consistent with significant positive effects associated with changes to a company affiliation (e.g. from a university or public administration).[36] Moving to affiliations with larger numbers of declared SEPs[37] is also

[35] Significant at 10% for both affiliation changes resulting from corporate structure events, and in the fixed effect estimation.

[36] Significant at 5% in the fixed effect analysis.

[37] Counts of declared SEP are measured at the beginning of the individual's SDO career in the fixed effect analysis, and in the year of affiliation change for the broader affiliation change analysis. For the narrower analysis of affiliation changes resulting from corporate structure events; the declared SEPs of the acquired firm are added to the stock of the acquiring parent company.

Table 9
New chair appointments, 3 years before and after change of affiliation – mergers, acquisitions, and spinoffs – IETF.

	(1)	(2)	(3)	(4)	(5) (M&A)	(6) Spinoffs
top5	0.0162 (1.95)					
top20		0.00320 (0.37)				
network_op			0.00461 (0.73)			
#decl_SEP				0.00117 (1.60)		
after	−0.0110 (−1.06)	−0.00861 (−0.81)	−0.00797 (−0.83)	−0.00878 (−0.95)	−0.00849 (−0.85)	−0.0203 (−1.50)
seniority	0.00000290 (0.39)	0.00000320 (0.43)	0.00000325 (0.43)	0.00000320 (0.39)	0.00000601 (0.79)	0.00000878 (1.16)
_cons	0.0139 (1.02)	0.0130 (0.94)	0.0133 (0.98)	0.00920 (0.57)	0.00732 (0.56)	−0.00256 (−0.22)
N	2,953	2,953	2,953	2,441	2,763	1,463
Groups	289	289	289	289	270	80

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

associated with significant increases in the likelihood of appointments to chair positions.[38] Overall, these results present a fairly consistent picture — affiliation with an entity that has significant stakes in ICT standardization increases the likelihood of appointment to IETF chair positions.

No such consistent positive effect is observable at 3GPP. Affiliation with one of the Top 5 or Top 20 leading affiliations has no significant effect in any of the specifications. If anything, other measures of an affiliation's stakes in standardization point to a negative effect of being affiliated with a more influential stakeholder. Being affiliated with a company owning larger numbers of declared SEPs is associated with a negative effect on the likelihood of being appointed to a 3GPP chair position in the corporate structure event analysis and the fixed effect regression.

We thus find that an individual's affiliation with a leading SDO stakeholder increases the individual's chances of being appointed to chair positions at IETF, but not at 3GPP. While we cannot formally compare the magnitude of effects across SDOs, and general heterogeneity in the institutional setting makes it more difficult to pinpoint individual causes for differences in chair appointment patterns in different SDOs, the fact that we consistently identify significant positive top-affiliation effects at IETF but not at the explicitly entity-based 3GPP is remarkable.

5.4.3. Extensions

Heterogeneity in groups

It is plausible that the determinants of chair appointments differ not only between SDOs, but also between different groups within SDOs. At 3GPP, our data spans working groups and TSG plenaries, where TSG plenaries are larger, and have the final say on the adoption of 3GPP TS. There are also important differences between different TSGs. For instance, the overwhelming majority of SEP declarations at 3GPP are related to only one TSG (RAN), potentially indicating that commercial stakes are particularly pronounced at RAN and its various working groups. Nevertheless, we find no indication that being affiliated with a company or a top SDO stakeholder has a particularly pronounced effect on the likelihood of appointments to TSG plenary or RAN chair positions.

At IETF, different working groups differ in the extent of commercial orientation. Following Simcoe (2012), we use the share of academic participants in working group mailing lists (what he calls the "beard-to-suit ratio") to identify the relative commercial orientation of an IETF working group. The effect of being affiliated with a company on an individual's likelihood to be appointed to an IETF working group chair position increases in the working group's suit-beard-ratio (significant at 10%), and the baseline effect (i.e. the effect of company affiliation on chair appointments in a working group with a predominantly academic participation) is not significantly different from zero. Nevertheless, we do not find that the effect of affiliation with a Top 5 or Top 20 stakeholders on the likelihood of appointments to chair positions significantly depends on the working group's suit-beard-ratio.

Results are presented in Table 16 in Appendix A.2.

Heterogeneity in firms

So far, we have discussed the (average) effects of being affiliated with top 5 and top 20 SDO stakeholders. These effects however may vary significantly between top stakeholder firms. To test for such heterogeneity, we estimate an alternative fixed effect conditional logit specification with 20 company-specific dummy variables. We plot the company-specific coefficients, and their 95% confidence intervals, in Fig. 3 in Appendix A.3.

The positive effect of affiliation with a Top 20 stakeholder on appointment to IETF leadership positions has broad support in this group of 20 companies. 15 of the 20 companies are associated with an increased likelihood of appointments to chair positions, and for seven of these 20 companies, this increased likelihood is individually significant. Notably, this is true for four of the five Top 5 stakeholders.[39] The increased likelihood of appointment to IETF chair positions that is associated with being affiliated with a leading SDO stakeholder is thus not limited to any particular company, country, or business model.

We do not find significant effects of affiliation with any of the Top 20 top stakeholders at 3GPP, with the exceptions of AT&T and Deutsche Telekom (potentially indicating a role of affiliation with a large network operator).

5.5. The role of chairs' affiliation for the impact of standardization outcomes

In this section, we analyze the role of the chair's affiliation for the quality of an SDO working group's output (standards). As discussed in

[38] Significant at 10% in the corporate structure event analysis, at 1% and 5% in the fixed effect analysis.

[39] The exception is Qualcomm — while Qualcomm is overall a Top 5 stakeholder because of its very significant presence in 3GPP, its role in IETF is much more limited.

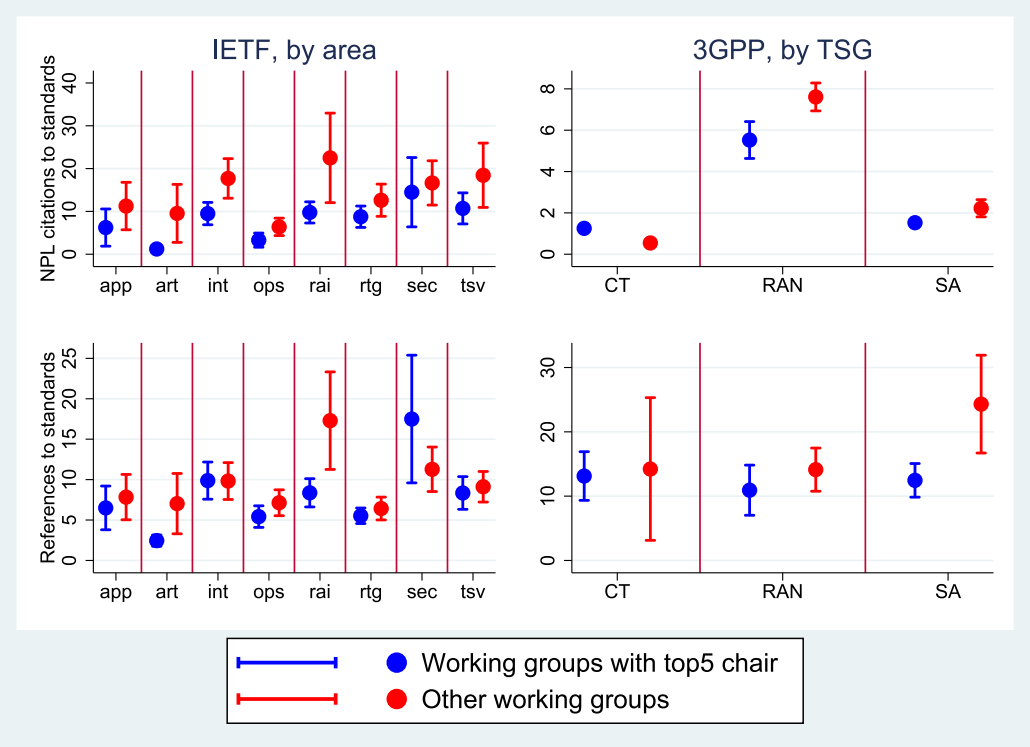

Fig. 2. Output quality of standards with and without a chair with Top 5 affiliation; by TSG/Area.

the methodology section, we have produced a large dataset of patent citations and standard references to standards documents published by IETF and 3GPP. For each document published by these SDOs, we identify the chairs of the responsible working group that were active at the time of publication.[40] There can be multiple active chairs for a particular document[41]; we thus compute all variables on chairs' affiliations as indicator variables reflecting that at least one chair's affiliation has certain characteristics.[42]

We start by descriptively comparing the characteristics of different standards documents, depending on the type of affiliation of the responsible working group chairs. As reflected in Tables 10 and 11, standards documents produced by working groups chaired by individuals affiliated with top (top 5 or top 20) SDO stakeholders receive less patents citations and less standards references, on average, than documents produced by working groups whose chairs are not affiliated with top SDO stakeholders. This is generally true at both SDOs.[43] At IETF, it is possible to furthermore identify documents produced by a working group whose chairs include at least one academic (individual affiliated with a university).[44] These documents receive much larger numbers of patent citations and technical specifications than documents produced by working groups without university-affiliated chairs.

Table 10
Output quality of 3GPP standards by chair affiliation.

Variable	top 5			top 20		
	at least one	others	t-stat	at least one	others	t-stat
references	12.393	15.676	−1.873	12.942	20.486	−2.591
3gpp_ref.	11.999	15.355	−1.929	12.587	20.024	−2.574
outside_ref.	.393	.321	1.159	.355	.463	−1.032
new_ref.	.736	.624	1.551	.673	.879	−1.713
npl_cits	2.182	5.79	−15.591	3.26	6.55	−8.524
N	12,585	7,885	20,470	18,529	1,941	20,470

These differences reflect a mix of within-group- and between-group-variation: the between-variation results from the fact that certain affiliations are more strongly represented in certain areas or working groups of the two SDOs in our data than in others. Within-variation results from changes in working groups' chairs over time (including changes in the identity of chairs, and changes in the affiliation of incumbent chairs). Generally, between-variation is more sensitive to unobserved variable bias: areas in which top SDO stakeholders participate more frequently may be associated with higher or lower numbers of citations and references. We therefore focus on increasingly narrowly defined within-variation.

As a first step, we compare the number of patent citations and standards references to IETF and 3GPP standards documents within broader technical areas (*Areas* in the case of IETF, and *Technical Specification Groups* in the case of 3GPP). The results (presented in Fig. 2)

[40] As our data on working group chairs is based on meeting attendance records, we characterize a chair as active at the time of publication if there is at least one meeting before and at least one meeting after the document's publication date at which that individual was listed as the working group's chair. This assignment of documents to chairs is clearly imperfect — chairs' tenure may have started before the first meeting at which they were the chair, or ended after the last meeting. Also, chairs may have influenced the work of the working group on a document that was published after their time as chair.

[41] At IETF, there typically are two individuals listed as chairs at any point in time; at 3GPP, there usually is only one chair (we do not consider vice-chairs).

[42] Nevertheless, all results discussed in this section hold if using variables indicating the share or number of chairs affiliated with a certain type of entity instead.

[43] At 3GPP, TS only receive a small number of external references from standards covered by our data; there are thus no statistically significant differences to be observed in this variable. The number of *new* references, i.e. the number of references from specifications that did not reference previous versions of the same specification, is statistically significantly different only in the case of chairs affiliated with top 20 stakeholders; and only at 10%.

[44] As discussed above, there are few individuals affiliated with universities participating in 3GPP, and virtually none in 3GPP chair positions.

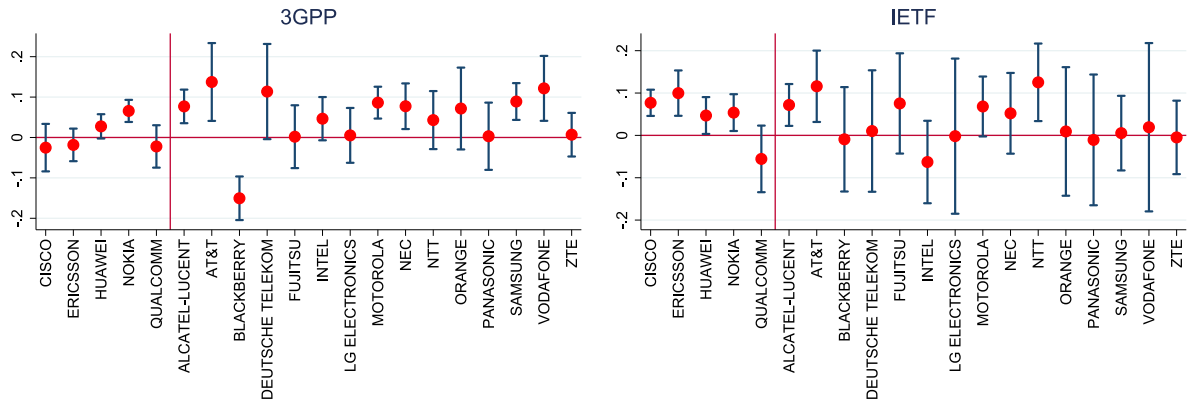

Fig. 3. Firm-specific effects on SDO leadership appointments — coefficients and confidence intervals from OLS regression with individual fixed effects.

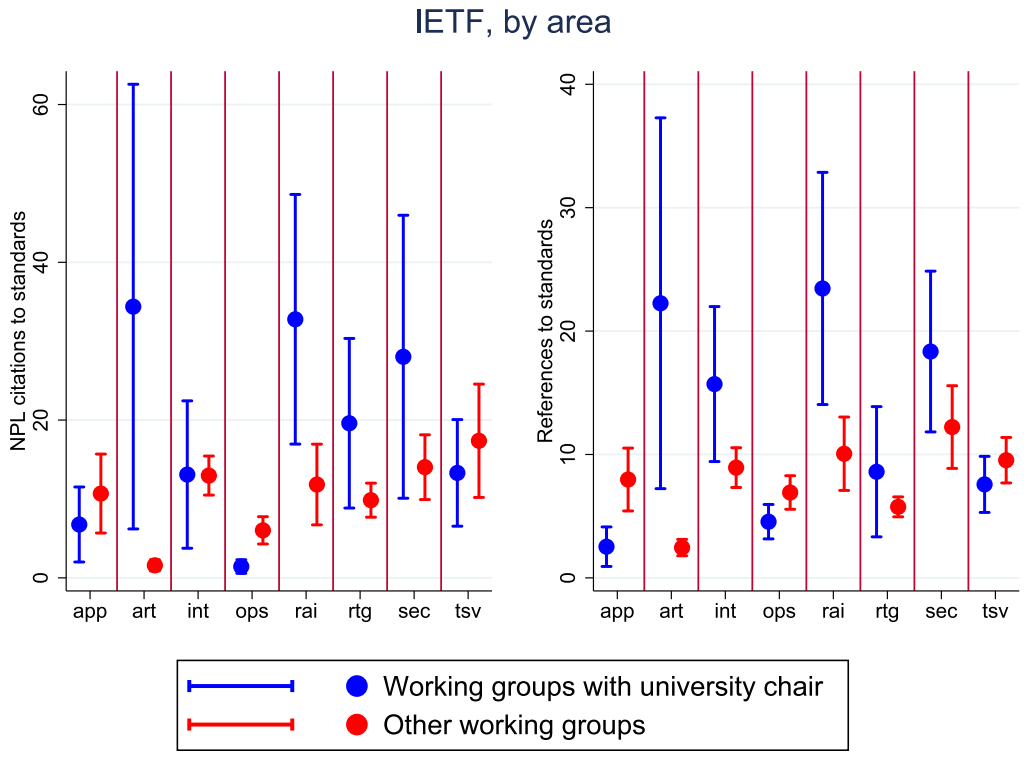

Fig. 4. Output quality of IETF standards with and without a chair with university affiliation; by Area.

Table 11
Output quality of IETF standards by chair affiliation.

Variable	top 5			top 20			university		
	at least one	others	t-stat	at least one	others	t-stat	at least one	others	t-stat
references	8.205	9.208	−1.356	7.687	9.921	−3.07	12.649	8.194	4.177
ietf_ref	6.199	6.43	−.506	5.886	6.791	−2.008	8.413	6.012	3.635
norm._ref	4.578	5.545	−1.804	4.195	6.113	−3.635	7.929	4.712	4.156
outside_ref	2.007	2.778	−2.294	1.801	3.129	−4.017	4.236	2.183	4.234
npl_cits	9.077	13.845	−3.484	8.687	15.117	−4.773	17.3	11.027	3.171
N	2,171	3,067	5,238	2,646	2,592	5,238	703	4,535	5,238

Table 12
Role of chairs for output quality: NPL patent citations to 3GPP standards, at least one chair with top 20 affiliation.

	(1) b/se	(2) b/se	(3) b/se	(4) b/se	(5) b/se	(6) b/se
atleastone_top20	−1.692***	−2.504***	−2.164***	1.263*	−2.666***	−1.326**
	0.443	0.453	0.425	0.545	0.369	0.437
pub_date	0.018***	0.013***	0.018***	0.021***	0.019***	0.018***
	0.002	0.002	0.002	0.002	0.002	0.002
pub_date#pub_date	−0.000***	−0.000***	−0.000***	−0.000***	−0.000***	−0.000***
	0.000	0.000	0.000	0.000	0.000	0.000
av_seniority		−0.001***		−0.000**		−0.000**
		0.000		0.000		0.000
av_threegppage		0.002***		0.002***		0.002***
		0.000		0.000		0.000
av_patent_count		0.002		−0.039***		−0.023***
		0.003		0.003		0.002
av_chaired_groups		0.467***		−0.194**		−0.034
		0.065		0.066		0.052
_cons	−161.616***	−115.595***	−147.024***	−163.264***	−153.855***	−148.644***
	19.245	20.479	17.502	17.665	14.344	15.582
Fixed effects	TSG FEs		WG FEs		TS FEs	
N	20,470	20,470	20,470	20,470	20,470	20,470

are broadly consistent, even if not always individually statistically significant in every single area: focusing on the "Top 5" definition of top SDO stakeholders, in seven of the eight main areas of IETF, RFCs produced by working groups with a top-stakeholder-affiliated chair receive less patent citations than RFCs produced by working groups within the same area that had no such chair; and in seven out of eight areas, RFCs produced by a group with a top-stakeholder-affiliated chair receive less references. At 3GPP, TS produced by working groups with a top-stakeholder-affiliated chair received less patent citations in two out of three TSGs, and less references in each of the three TSGs, than TS produced by working groups in the same TSG without a top-stakeholder-affiliated chair.[45,46]

At IETF, we can once again also compare the impact (in terms of citations and references) of RFCs produced by working groups with at least one university-affiliated chair and other RFCs. The differences within IETF areas are generally much larger than in the previous comparison focusing on top stakeholder companies, but more dependent on the support of individual (large) IETF areas, in particular the Applications and Real-Time (art) and Real-time Applications and Infrastructure (rai) areas (Results presented in Fig. 4 in Appendix A.4).

We can now proceed to confirm these descriptive results using regression analysis. For each SDO, we regress the number of standards references and patent citations received per document on an indicator variable indicating that the document was produced by a group with at least one top-stakeholder-affiliated chair; controlling for the publication date of the document, and an increasingly narrow set of fixed effects: first, fixed effects at the broad, area or TSG level; second, more specific WG fixed effects, and finally, and for 3GPP only, highly specific TS fixed effects (limiting the remaining variation to variation between different versions of the same TS).[47] Clearly, the fixed effects may consume significant parts of the variation of interest,[48] so that the specifications with more narrow fixed effects (while more robust to unobserved variation) are not necessarily more accurate.

In addition, we add a number of variables controlling for relevant individual chair characteristics, such as incumbency (time elapsed since first meeting as chair of this group), seniority (time elapsed since individual's first participation in any capacity in the SDO), patent count, and the cumulative number of groups in which the individual has ever served as a chair. We know from the previous analyses that these variables are significantly associated with the likelihood of being appointed to SDO chair positions. Individual experience or expertise may thus be confounding variables in our analysis of the effect of chair affiliation with a top SDO stakeholder. On the other hand, controlling for these individual attributes, which are much more preponderant among individuals affiliated with a top SDO stakeholder, and may partly be caused by affiliation characteristics, may obscure a real chair affiliation effect. We thus present the results of regressions with and without these control variables.

The results in Table 12 highlight that, at 3GPP, working group chair affiliation with a top SDO stakeholder is generally associated with lower number of patent citations to the working group's TS. Table 13 furthermore indicates a general pattern of negative association between chair affiliation with a top stakeholder and the number of standard references to the working group's TS. The results are not always statistically significant in every specification. Generally speaking, the results are least consistent when controlling for working group fixed effects, i.e. comparing between different TS produced by the same working group at different points in time (and thus under different chairs). The results are however highly robust using more general (TSG-level) or more narrow (TS-level) fixed effects. Without any strong claim to identification of a particular form of causation, we can thus identify a general negative association between a 3GPP working group chair's affiliation with a top SDO stakeholder, and different measures of the working group's output quality or impact.

At IETF, the econometric analysis does not corroborate the significant differences between RFCs produced by working groups with or without a top-stakeholder-affiliated chair that we observed in the descriptive analysis (see Tables 14 and 15). While chairs' affiliation with a top 20 stakeholder appears to be negatively associated with a working group's output quality (references and patent citations) in each of our specifications, this association consistently is statistically insignificant. One possible explanation is that the observed differences between RFCs with different chair characteristics are largely attributable to high-level between-variation — i.e. areas in which more chairs are affiliated with top SDO stakeholders are also generally characterized by lower numbers of citations and references. Time may also play a role —

[45] The number of patent citations and standard references to standards documents produced by groups with a top-stakeholder-affiliated chair is often individually statistically significantly lower, and never statistically significantly higher, than the number of citations/references to documents produced by other groups within the same broader area.

[46] Results using the "Top 20" definition of top SDO stakeholders are similar; but at 3GPP, there are not enough observations of groups without a Top 20 stakeholder chair to perform the comparison. See results in Appendix.

[47] There are no different versions of the same RFC at IETF; therefore this analysis is only possible at 3GPP.

[48] There is significant persistence in the identity of chairs of a working group, and the difference between different groups may partly reflect the role of the different groups' chairs.

Table 13
Role of chairs for output quality: References to 3GPP standards, at least one chair with top 20 affiliation.

	(1) b/se	(2) b/se	(3) b/se	(4) b/se	(5) b/se	(6) b/se
atleastone_top20	−7.279*	−8.613*	−2.438	−2.141	−5.978	−6.863*
	3.388	3.474	3.749	3.988	3.249	3.280
pub_date	−0.016	−0.020	−0.021	−0.017	−0.017	−0.020
	0.017	0.018	0.017	0.018	0.017	0.018
pub_date#pub_date	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
av_seniority		−0.003*		−0.001		−0.003*
		0.001		0.001		0.001
av_threegppage		0.003		0.003		0.003*
		0.002		0.002		0.002
av_patent_count		0.002		−0.025		−0.008
		0.020		0.022		0.017
av_chaired_groups		0.560		−0.273		0.351
		0.497		0.502		0.442
_cons	169.006	211.768	206.258	185.180	173.121	213.023
	147.302	157.208	147.842	158.440	145.579	156.914
Fixed effects	TSG FEs		WG FEs		TS FEs	
N	20,470	20,470	20,470	20,470	20,470	20,470

Table 14
Role of chairs for output quality: NPL patent citations to IETF standards, at least one chair with top 20 affiliation.

	(1) b/se	(2) b/se	(3) b/se	(4) b/se
atleastone_top20	−1.526	−1.489	−0.572	−0.545
	1.453	1.460	1.381	1.393
pub_date	−0.012***	−0.013***	−0.009**	−0.010**
	0.003	0.003	0.003	0.003
pub_date#pub_date	0.000*	0.000**	0.000	0.000*
	0.000	0.000	0.000	0.000
av_seniority		0.002*		0.002*
		0.001		0.001
av_ietfage		−0.001		−0.001
		0.001		0.001
av_patent_count		−0.128		−0.111
		0.337		0.330
av_chaired_groups		0.807		0.691
		0.476		0.463
_cons	148.078***	158.460***	126.058***	135.149***
	26.816	27.549	26.190	26.880
Fixed effects	Area FEs		WG FEs	
N	5,238	5,238	5,238	5,238

Table 15
Role of chairs for output quality: References to IETF standards, at least one chair with top 20 affiliation.

	(1) b/se	(2) b/se	(3) b/se	(4) b/se
atleastone_top20	−0.405	−0.404	−0.377	−0.387
	0.782	0.786	0.743	0.749
pub_date	0.009***	0.008***	0.010***	0.009***
	0.002	0.002	0.002	0.002
pub_date#pub_date	−0.000***	−0.000***	−0.000***	−0.000***
	0.000	0.000	0.000	0.000
av_seniority		0.001*		0.001
		0.000		0.000
av_ietfage		0.000		0.000
		0.000		0.000
av_patent_countl		−0.112		−0.090
		0.182		0.178
av_chaired_groups		0.220		0.298
		0.257		0.249
_cons	−50.776***	−41.323**	−59.112***	−52.243***
	14.442	14.833	14.094	14.465
Fixed effects	Area FEs		WG FEs	
N	5,238	5,238	5,238	5,238

the share of chairs affiliated with a top stakeholder and the number of citations/references per standard may have followed trends in the opposite direction, leading to a spurious negative association. Overall, our regression analysis does not offer conclusive evidence on the role of chairs' affiliation with a Top 5 or Top 20 affiliation for the success of IETF standards.

The differences between RFCs produced by working groups with and without university-affiliated chairs, however, are generally corroborated in the regression analysis (Table 17 in Appendix A.4). University-affiliated chairs are associated with a higher number of standard references and patent citations to IETF RFCs in all our specifications. The association of university-affiliated chairs with a higher number of standard references is consistently statistically significant; whereas the association of university-affiliated chairs with a higher number of patent citations is statistically significant when controlling for working group fixed effects (but not significant when controlling for the more general area fixed effects).

Overall, our analysis thus points to a negative association between chairs' affiliation with top SDO stakeholders and the quality or impact of SDO standards (as measured by references and citations). We certainly do not claim to have identified a specific causal effect of chair affiliation. While there are both sizeable and significant differences between documents published by groups with and without top-stakeholder-affiliated chairs at both SDOs, more scrupulous comparisons within a single working group's standards and controlling for other potentially relevant variables paint a less consistent picture. Nevertheless, at 3GPP, we find consistent negative associations between chairs' affiliation with a top stakeholder and both of our measures of output quality and impact, even within individual TSGs, and even between different versions of the same TS.

The results for IETF are certainly more inconsistent. On one hand, neither of our measures of "top SDO stakeholders" is associated with statistically significant differences in citations or references to RFCs within individual IETF areas or working groups, controlling for publication date and other relevant variables. While we cannot corroborate this interpretation, we can also not exclude that a chair's affiliation with a prominent SDO stakeholder does not have the same negative role that we observed for 3GPP in the specific institutional context of IETF. On the other hand, differences between RFCs produced by groups with university-affiliated chairs and other RFCs are remarkably consistent throughout all our analyses. Within the IETF context, an individual's affiliation with a university has been used as a proxy for the absence of commercial vested interests (Simcoe, 2012); whereas our list of SDO Top stakeholders may arguably better reflect the top stakeholders within 3GPP than IETF. Overall, we thus lean towards the interpretation that working groups with chairs that are unaffiliated

with respect to the SDO's main stakeholders tend to produce more successful standards in both 3GPP and IETF.

6. Discussion

6.1. Causal mechanisms

While documenting the preponderant role of individual characteristics (such as experience and expertise) for chair selection, we find that being affiliated with a leading SDO stakeholder has a positive causal effect on individuals' chances to be appointed to working group chair positions at least at IETF. The causal effect of affiliation could be the result of different mechanisms, as individuals' appointments to leadership positions are determined in at least three steps: first, individuals need to volunteer for chair positions, and may more or less actively pursue such appointments. Second, individuals' employers have to make their employees available for SDO work, and may more or less actively support their employees' candidacies. Third, chairs are selected among available volunteers by the different groups of selectors (3GPP working group members and IETF area directors). Affiliation characteristics may intervene at each of these steps:

- SDO working group chairs have to take time from their regular work, and are compensated by their employers to serve the SDO. Companies that have significant stakes in the outcome of standardization decisions are more likely to be willing to incur the expense of "volunteering" their employees' time for SDO leadership work.
- In addition to other motives, such as enthusiasm and peer recognition, individuals may rely on their position and influence within an SDO to further their career. Leadership experience within a relevant SDO is particularly valued by those companies that are significantly invested in that SDO's activities; so that individuals affiliated with such companies may be particularly motivated to acquire SDO leadership positions.
- Despite concerns over conflicts of interests, the relevant selectors may be more likely to choose individuals affiliated with powerful stakeholders to SDO leadership positions, for different reasons.
  - SDOs may choose representatives of powerful stakeholders for SDO leadership positions to strengthen these stakeholders' commitment to the SDO and its standards.
  - Individuals affiliated with companies that are heavily invested in the SDO are less likely to face conflicts of commitment between their work as chair and other work duties.[49]
  - SDOs may also rely on individuals' affiliation as a signal of valued individual characteristics that are difficult to observe (such as ability).[50]
  - Selectors may give preference to individuals affiliated with large stakeholders for reasons that are not aligned with the SDO's interests; i.e. large stakeholders may rely on their already existing influence over SDO decision making to bias chair appointments and thus further extend their influence within the SDO.

There are thus many possible explanations why individuals' affiliation matters for appointments to chair positions. Irrespective of the specific causal mechanism, the role of the causal effect for individuals' and affiliations' influence within SDOs is largely the same: individuals at least partly owe the leading position they hold in the SDO to the company they work for; and the company may choose to which individual they want to give this support. The social capital inherent to an SDO leadership position is thus partly owned by the individual's affiliation. By contrast, at 3GPP, where we find no causal effect of individuals' affiliation on appointments to chair positions, individuals more fully own the social capital inherent to the position they occupy within the SDO.

Importantly, individuals' affiliation with leading SDO stakeholders may facilitate their ascension to SDO leadership positions for reasons that are fully aligned with the broader interests of the SDO and its stakeholder community; e.g. employees of these companies may face fewer conflicts of commitment and devote more time to SDO work than employees of other firms with less stakes in the SDO. Participation of individual employees of large stakeholders in leading SDO positions may also promote the formation of alliances among these critical stakeholders (Gupta and Rosenkopf, 2019).

Chairs' affiliation with a powerful SDO stakeholder may also be in tension with the goals and interests of the SDO: if SDO stakeholders use their employees in SDO leadership positions to promote their particular interests, this may impair the objective character of the technical decisions of the SDO (result in technical choices that benefit individual stakeholders to the detriment of the SDO at large). Independently of the actual effect of chairs on the specific technical merit of the standards, the *potential* for conflicts of interests and absence of objectivity in the standardization process may erode trust in the SDO's standards, and reduce their uptake.

In addition to the potential negative direct effects of affiliation, affiliation effects may also interfere with meritocracy in the selection of SDO leadership: if employees of powerful SDO stakeholders are chosen for SDO leadership positions over more qualified individuals without such affiliations, SDOs may fail to benefit from the most qualified individual candidates for their leadership positions. Given the prominent role of SDO chairs in the technical work of SDO working groups, this may induce a decline in the quality of SDOs' technical standards.

Our empirical findings suggest that the latter (negative) effects of chairs' affiliation with leading SDO stakeholders prevail. While the aforementioned benefits of chairs' affiliation with SDO stakeholders may still be significant, on balance, chairs' affiliation with a large SDO stakeholder seems to have a negative impact on the working group's ability to produce standards that promote technological innovation. This finding also provides some guidance for the interpretation of the empirical findings regarding the role of individuals' affiliation for their likelihood to be appointed to chair positions. As we find that negative effects of chairs' affiliation with large stakeholders for the SDO's technical work dominate, potential causal effects of individuals' affiliation with such stakeholders on their likelihood to be appointed are less likely to reflect selection by the SDO (i.e. the fact that SDOs explicitly seek individuals affiliated with leading stakeholders to fill leadership positions), but rather affiliation effects on individuals' motivation or in individuals' employers' willingness to make them available.

6.2. Implications for objectivity of SDO decision-making

SDOs are collaborative expert communities with shared norms and values (Bexell, 2014), which heavily rely on commercial stakeholders to contribute with their technical expertise (Shapiro, 2004). At the same time, the objectivity of individual experts participating in SDOs may be tainted by their affiliation with particular, often competing, interests.[51] This tension is inherent to consensus standardization in SDOs.

Traditionally, SDOs are believed to navigate this tension through a combination of two institutional features: diversity in SDO participants,

[49] Conflicts of interest and conflicts of commitment may thus act in opposite directions, and it is a priori undetermined which of these potential tensions prevails.

[50] We are grateful to an anonymous referee for suggesting this potential causal mechanism.

[51] see Levidow and Carr (2007) on the relationship between experts' affiliation and objectivity in a different context.

and neutrality of the setting. On one hand, individuals are generally understood – and even expected – to represent particular interests in standardization activities.[52] On the other hand, the setting in which the individuals representing these competing particular interests convene should be neutral; i.e. the processes, policies, and personnel of the SDO should not give preference to any particular stakeholder. In other words, SDOs should provide for the rules of a competitive game, but the rules of the game themselves should not be gamed.

This dichotomy between the expected conduct of individual participants and chairs is inherently fragile, as chairs and other SDO leadership are recruited from the population of participants. Naturally, many of the individuals selected for chair positions are affiliated with the leading commercial stakeholders.[53] Nevertheless, we also find that (at least in IETF) affiliation with large firms has a positive *causal* effect on individuals' chances to be appointed to SDO leadership — that is, while chairs are supposed to dissociate themselves from the economic interests of their employers, these economic interests still seem to play a significant role in determining who becomes a chair. What is more, this role of corporate interests for leadership selection may not be aligned with the broader goals of the SDO, as working groups whose chairs are not affiliated with corporate stakeholders (or, at 3GPP, not affiliated with one of the leading corporate stakeholders) tend to produce more successful standards. These findings thus cast some doubt on the proposition that SDOs' institutional norms and traditions neutralize the role of chairs' affiliation.

Nevertheless, and more reassuringly, we also find that SDO working group chairs are largely appointed because of their individually held expertise and experience. Working group chairs usually are seasoned members of the SDO's expert community, who presumably enjoy a high degree of professional recognition among their peers. Presumably, many of these individuals genuinely desire to further the interests of SDOs while acting as chair, rather than focusing on narrow particular interests of their employers. Hence, while it is true that experts have incentives to serve the interest of their affiliation in order to advance their individual economic interests, their concern for their reputation and standing in the wider community of peers may at least partly shield them from undue influence by particular interests, and thus also provide a safeguard for the objectivity of technical decision making in SDOs.

Our findings further allow for general comparisons between two SDOs' very different membership models. Intuitively, one may expect that individual characteristics of SDO participants are more relevant within individual-based institutional models, such as IETF, than entity-based SDOs, such as 3GPP. Our findings challenge this intuitive assumption. We demonstrate that SDO models requiring explicit employer representation do not negate the strong effect of individual characteristics: while individuals may only integrate this SDO's community as representatives of an SDO member, their progression within the community (including their ascension to leadership positions) is largely based on their individual track record and expertise. At the same time, institutional models that are based on individual representation do not necessarily result in negating the influence of individuals' employers. Openness to individual participation in the SDO community is thus not necessarily conducive to a culture of individual meritocracy in SDO leadership.

These intriguing comparative findings warrant further investigation; also because they may have significant implications beyond SDOs. Individual-based SDOs are comparable to other models of collaborative innovation within communities of individual experts with a strong ethos of independence (e.g. academic science, and some OSS communities); whereas entity-based SDOs, such as 3GPP, are best understood as the instruments of their member firms (similar to e.g. Research Joint Ventures). Our research thus also contributes to the growing literature on the boundary-spanning role of individual firm employees' participation in such collaborative efforts, and the possible tensions arising out of individuals' dual allegiances to their employer and their community of peers.

7. Conclusion

This paper contributes with an empirical analysis of determinants for leadership appointments in two important international SDOs in the field of ICT: 3GPP and IETF. These SDOs are individually important in their own right, but they are also representative of two different institutional models, which rely on very different governance principles to achieve objectivity in technical decision-making. While 3GPP aims for adequate representation of the principal stakeholders, IETF is open to individual participation of any subject matter expert, without consideration of the particular interests that individuals may choose to represent.

While we document a significant over-representation of the affiliates of large SDO stakeholders in the leadership positions of both SDOs, this over-representation can largely be explained by these individuals' superior expertise and experience. Indeed, individuals' technological track record appears to be the principal determinant of appointments to SDO leadership positions, regardless of the SDO's institutional model. This does not mean that an individual's affiliation does not matter — through a variety of converging econometric analyses, we are able to document and corroborate a positive causal effect of affiliation with a top SDO stakeholder. Intriguingly, this top-affiliation effect is significant at IETF, but not at 3GPP.

Our findings add a new, individual dimension to the existing scholarship on standardization and innovation. Our findings suggest that individuals achieve recognition and influence in their respective SDOs because of their individual qualifications and experience. As individuals' progression to SDO leadership positions is largely a consequence of individual-level characteristics, individual SDO participants have incentives to further their personal reputation within their community of peers in the SDO to promote their career. Individuals' concern for their reputation and their community-embedding may significantly contribute to the independence of SDO leadership, and shield their decision-making from undue influence. Nevertheless, our findings also indicate that these mechanisms may not suffice to fully neutralize the potential for conflicts of interests, which may taint the objectivity of SDO decision making and limit the success of SDOs' standards.

Our results regarding the relative impact of individual and affiliation characteristics on individuals' progression within the two different SDOs furthermore challenge our intuitive understanding of how these different SDOs operate. Significant affiliation effects are observable at IETF, which considers individuals' contributions regardless of whom they represent, whereas affiliation with powerful SDO stakeholders has no significant positive effect on individuals' appointments to leadership positions at entity-based 3GPP. Future research that continues examining SDOs leadership appointments and linking them with SDOs' institutional tenets and formal and informal governance rules may shed more light onto how different SDOs' mechanisms achieve institutional independence and objectivity in decision-making. Likewise, further research is desirable to analyze leadership appointments in SDOs that are not rooted in the tradition of private, decentralized standardization models (such as inter-governmental ITU), and thus to evaluate the consequences of different patterns and tendencies in leadership

[52] Indeed, SDOs such as 3GPP affirmatively require that individual participants represent the interests of a 3GPP member organization, and policies aiming to ensure that the interests of different stakeholder constituencies are represented require that individual participants faithfully represent the particular interests they are supposed to represent.

[53] After all, individuals are selected to the SDO leadership for reasons that are similar to those that make them attractive to employers with vested interests in SDOs, e.g., these individuals possess expertise, social embedding in the professional community, and a proven individual track record of technical contributions to the field (patent inventorships or RFC authorships).

appointments for the overall resilience and legitimacy of the current global standardization ecosystem.

Most generally, our findings show that SDO governance – in our case, the selection of SDO leadership – matters for standardization outcomes. These findings highlight the paramount importance of strong SDO governance principles. In order to derive stronger normative conclusions, however, it is necessary to also analyze how individuals' employment relationship with SDO stakeholders affects their conduct *within* chair positions (as opposed to their likelihood of ascension to chair positions, which is the focus of this paper). Future research may also address how ascension to SDO leadership positions affects individuals' career progression and labor market mobility. Finally, future research may also extend beyond the Top 5 and Top 20 stakeholders, to examine the more general roles of firm size, business models, and other characteristics, for their employees' ascension to SDO leadership positions.

While our study provides the first systematic empirical analysis of appointments to SDO leadership positions, the interaction between individuals' standing and participation in the SDO community and their professional career and employment thus continues to present manifold opportunities for further empirical research.

CRediT authorship contribution statement

Justus Baron: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Olia Kanevskaia:** Conceptualization, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Unrelated research conducted by Justus Baron at the Center on Law, Business, and Economics has benefited from financial support by Qualcomm and Intel, companies mentioned in this article. Justus Baron has provided consultancy (unrelated to this research) to the following entities with a general interest in the topics of this paper: European Commission, 4ip Council. Justus Baron has held an unpaid position in the European Commission's Expert Group on Standard Essential Patents, which has discussed topics generally related to issues analyzed in this research.

Data availability

Data including personal information cannot be shared

Appendix

A.1. Specific rules for appointments of WG chairs

3GPP Working Group officials are bi-annually elected by the members of the respective Working Group.[54] If there are multiple candidates nominated for the chair position, the election of Working Groups' officials occurs through secret balloting, with a threshold of 71% of Working Groups' members voting and present; if the processes is unsuccessful, it is followed by a second ballot between the candidates obtaining highest amount of votes.[55] Individuals can be re-elected as Working Group chairs or vice-chairs for the second term, and exceptionally, their tenure in the office can last even longer; however, there are no restrictions for chairs whose tenure is due to expire to volunteer for vice-chair election and vice-versa.[56] Candidates for (vice)-chairmanship should provide a letter of support from the individual Member that they represent at 3GPP, which should also provide assurance of candidate's compliance with antitrust rules if elected for the office.[57] An incumbent chairman or vice chairman who changes their affiliation is required to present a new letter of support from their new employer. If affiliation is changed due the individual's hire by another company, and not their company's merger or acquisition, the Working Group should also agree by consensus that the individual can remain in their role as a (vice-) chair.[58] Chairs and vice-chairs are also required to maintain impartiality and act in the interests of 3GPP when performing their leadership tasks[59]; Working Group members that question chairs' impartiality may object to chairs' decisions and ultimately voice their objections in the higher hierarchical committee.[60] (Vice-)Chairs can be dismissed through a secret vote of the Working Groups when they fail to effectively perform their duties.[61] To maintain balance in SDO leadership, 3GPP's Working Group's chair and vice-chair, as well as their successive officials, cannot be from the same region, partner-organization or group of companies, unless no other individual is available to hold the office.[62]

IETF Working Group chairs are assigned by the Area Directors who in turn are selected by the IETF's Nomination Committee (NomCom). NomCom members are randomly drawn from a pool of volunteers and approved by the Internet Architecture Board (IAB).[63] While both technical and communication skills of a chair candidate matter, individuals who have been actively participating in the IETF for a long time are more likely to get appointed as chairs, especially if they gained "favorable prominence" by having previously contributed to the documents or volunteered to review them.[64] IETF chairs have a wide discretion in administering Working Group activities and may also take decisions on its behalf, and are expected to balance "progress and fairness" and ensure that the Working Groups move forward while the process remains fair and open.[65]

A.2. Conditional logit analysis by type of appointment

See Table 16.

A.3. Company-specific effects

See Fig. 3.

A.4. Effect of affiliation with academic institutions at IETF

See Fig. 4 and Tables 17 and 18.

[54] 3GPP Working Procedures, April 29, 2021, Art.22.
[55] 3GPP Working Procedures, April 29, 2021, Art. 28.
[56] 3GPP Working Procedures, April 29, 2021, Art. 22.1.
[57] 3GPP Working Procedures, April 29, 2021, Art.22.1, which by analogy apply to working group leadership, Art. 22.2.
[58] 3GPP Working Procedures, April 29, 2021, Art. 22.1.
[59] 3GPP Working Procedures, April 29, 2021, Art.23.
[60] 3GPP Working Procedures, April 29, 2021, Art.29.
[61] 3GPP Working Procedures, April 29, 2021, Art.24.
[62] 3GPP Working Procedures, April 29, 2021, Art.22.1, which by analogy apply to working group leadership, Art. 22.2.
[63] BCP 25, IETF Working Group Guidelines and Procedures, September 1998, https://tools.ietf.org/html/bcp25.
[64] RFC 4144, How to Gain Prominence and Influence in Standards Organizations, https://tools.ietf.org/html/rfc4144.
[65] The Tao of IETF, November 8, 2018, https://www.ietf.org/about/participate/tao/, Art. 4.1.

Table 16
Conditional logit regression analysis by type of appointment.

	(1) 3GPP	(2)	(3)	(4)	(5) IETF	(6)
company	1.168	0.798	1.570*	1.303	0.0964	0.127
	(1.88)	(1.22)	(2.09)	(1.68)	(0.73)	(0.90)
company#RAN	11.57	11.76				
	(0.02)	(0.02)				
company#TSG_plen			−0.909	−2.154		
			(−0.71)	(−1.33)		
company#suitbeard					0.0110	0.0110
					(1.87)	(1.81)
top5		0.332		0.151		0.507*
		(1.25)		(0.59)		(2.08)
top5#RAN		−0.00818				
		(−0.02)				
top5#TSG_plen				1.032		
				(1.66)		
top5#suitbeard						0.00339
						(0.48)
top20		0.382		0.337		−0.434
		(1.21)		(1.15)		(−1.90)
top20#RAN		0.140				
		(0.21)				
top20#TSG_plen				0.999		
				(0.88)		
top20#suitbeard						−0.00238
						(−0.35)
attendance_wg_lastyear	0.575***	0.568***	0.579***	0.570***		
	(9.35)	(9.21)	(9.38)	(9.23)		
attendance_wg_prior	0.0459***	0.0441***	0.0459***	0.0452***		
	(6.10)	(5.85)	(6.10)	(5.94)		
attendance_plen_lastyear	0.556***	0.553***	0.560***	0.560***	1.097***	1.095***
	(6.75)	(6.70)	(6.78)	(6.76)	(15.88)	(15.84)
attendance_plen_prior	−0.0316*	−0.0301*	−0.0314*	−0.0311*	0.0225***	0.0221***
	(−2.14)	(−2.05)	(−2.12)	(−2.11)	(5.05)	(4.90)
field_any_top20	0.00527*	0.00478*	0.00535*	0.00465*	−0.0268	−0.0239
	(2.52)	(2.30)	(2.56)	(2.30)	(−1.33)	(−1.20)
sep_inventor	0.166	0.0128	0.168	0.00160	0.142	0.113
	(0.70)	(0.05)	(0.71)	(0.01)	(0.61)	(0.48)
numbermails_wg_6m					0.00142***	0.00140***
					(7.21)	(7.10)
number_rfcs					0.0129***	0.0122**
					(3.40)	(3.12)
N	37,982	37,982	37,982	37,982	1,030,779	1,030,779
Groups	110	110	110	110	436	436

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 17
Role of chairs for output quality: NPL patent citations to IETF standards, at least one university chair and others.

	(1) b/se	(2) b/se	(3) b/se	(4) b/se
atleastone_university	2.921	3.069	4.449*	4.593*
	1.993	1.997	1.934	1.936
pub_date	−0.013***	−0.014***	−0.009**	−0.011***
	0.003	0.003	0.003	0.003
pub_date#pub	0.000**	0.000**	0.000	0.000*
	0.000	0.000	0.000	0.000
av_seniority		0.002*		0.002*
		0.001		0.001
av_ietfage		−0.001		−0.001
		0.001		0.001
av_patent_count		−0.145		−0.114
		0.336		0.328
av_chaired_groups		0.816		0.700
		0.476		0.463
_cons	152.912***	163.019***	129.571***	138.823***
	26.371	27.163	25.705	26.496
Fixed effects	Area FEs		WG FEs	
N	5,238	5,238	5,238	5,238

Table 18
Role of chairs for output quality: references to IETF standards, at least one university chair and others.

	(1) b/se	(2) b/se	(3) b/se	(4) b/se
atleastone_university	2.610*	2.636*	3.095**	3.138**
	1.073	1.075	1.041	1.041
pub_date	0.009***	0.008***	0.010***	0.009***
	0.002	0.002	0.002	0.002
pub_date#pub_date	−0.000***	−0.000***	−0.000***	−0.000***
	0.000	0.000	0.000	0.000
av_seniority_chair		0.001*		0.001
		0.000		0.000
av_ietfage		0.000		0.000
		0.000		0.000
av_patent_count		−0.106		−0.093
		0.181		0.176
av_chaired_groups		0.225		0.304
		0.256		0.249
_cons	−49.657***	−40.149**	−56.744***	−49.684***
	14.196	14.619	13.828	14.253
Fixed effects	Area FEs		WG FEs	
N	5,238	5,238	5,238	5,238

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