



Article

# SDG 5 and the Gender Gap in Standardization: Empirical Evidence From Germany

Philipp Hess 

Chair of Innovation Economics, Technische Universität Berlin (TU Berlin), 10587 Berlin, Germany;  
philipp.hess@tu-berlin.de

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**Abstract:** Whereas (technical) standards often affect society as a whole, they are mostly developed by men. In the context of the United Nations' Sustainable Development Goal 5 (gender equality), this article motivates research on the gender gap in standardization, focusing in a first step on the under-representation of women in science, technology, engineering, mathematics and leadership positions as one possible cause. A novel data set of more than 8000 organizations that develop formal standards and 28,000 affiliated experts (10.5% female) confirms that women are descriptively under-represented. A logistic regression shows that organizations' size, industry, and geographical location are significant factors that are associated with representation by female standardizers. Standard-development for construction, mechanical and electrical engineering is especially male-dominated, while the east of Germany shows more female representation than the west. The presented empirical evidence of female under-representation suggests a need for standard-setting organizations to expand their focus from considering gender in standards documents to actively promoting female participation in their committees. It further adds to the debate on stakeholder representation in standardization and its legitimacy as a co-regulative system in the EU.

**Keywords:** standardization; legitimacy; gender gap; gender equality; sustainable development goals

## 1. Introduction

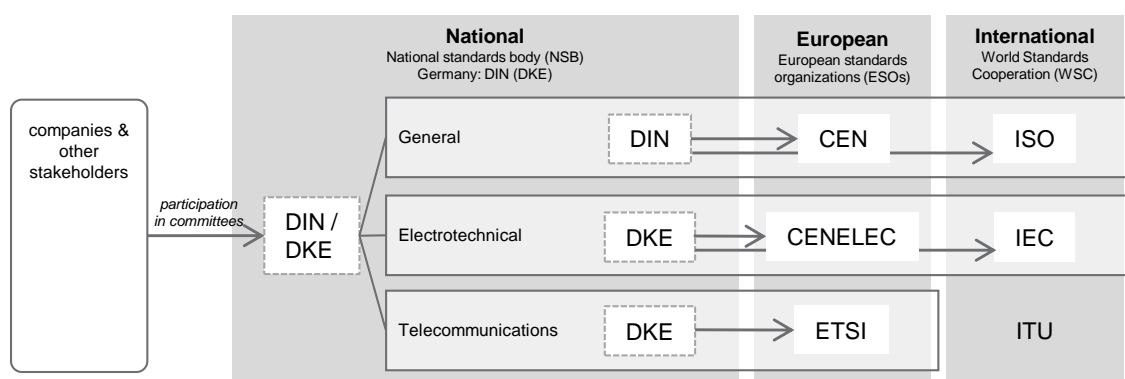
The creation of technical standards has traditionally been an area dominated by men. Early standard-setting was rooted in the need to react to the fast technological development of the 19th century and was motivated to develop a system of standards that would unify units of measurement and enable interoperability between new devices [1]. It was set in an era where women's movement towards representation in science, engineering and political decision-making was in its early infancy. The under-representation of women in areas that were most relevant to technical standardization was reflected in the composition of the first standard-setting committees, e.g., at the founding of the International Telecommunication Union (ITU) in 1865 [2] or the International Electrotechnical Commission (IEC) in 1908 [3], where all participants were men. In 1947, at the founding of the International Standards Organization (ISO), some of the delegates from the national standards bodies were women [4].

Today, standards are developed in an international ecosystem of organizations [5] that address a multitude of technological areas, often bring together different stakeholder groups [6,7] and operate upon different internal policies [8]. Modern standards not only have an impact on innovation, technological progress and economic growth [9–11], they can be tools to exert political influence [12,13], occupy a special position in (transnational) public governance [14] and shape social order [15]. This has sparked debates on prerequisites for the system's legal and political legitimacy [15–19].

Considering the advancements in women's rights and increasing representation in science and engineering since the Second World War [20], participation of women in these standard-setting

organizations and committees could be expected to have reached more balanced levels. This expectation is further underlined by the role of gender equality on agendas that affect the strategic orientation of standardization organizations. Internationally, gender equality, and specifically women's representation in political and economic leadership positions is recognized as a prerequisite for sustainable development. This is explicitly registered in the United Nations' Sustainable Development Goal 5 (SDG 5, [21]). As many standard-setting organizations claim to contribute to the achievement of the SDGs, increased expectations are raised for the role of women in these organizations.

Yet, more than 100 years after the foundations of an international standardization, the under-representation of women appears to be a persistent, and common characteristic of the system. This impression is reinforced when looking at gender statistics of international standard-setting organizations, e.g., those of committee managers at the International Electrotechnical Committee (IEC) and the International Standards Organization (ISO). In January 2020, 93% of all 220 committees at the IEC were chaired by men, while women mostly filled lower-ranked, administrative positions (Figure 4). At ISO, where committees work on a much broader, and often less technical range of topics, female numbers were slightly higher, while the distribution of women was similarly skewed towards lower-ranked positions. Interestingly, more women than men chaired committees at the ITU [22], which forms the World Standards Cooperation (WSC) with ISO and IEC, but which is, different to them, not a private organization, but an agency of the United Nations (Figure 1).



**Figure 1.** Regional levels and organizations in the system of formal standard-setting (German-European perspective, own illustration based on [23]).

This article aims to contribute to research on this gender gap in standardization in an initial approach to the topic. Focus is put on the development of formal standards (developed in consensus-driven processes in recognized standard-setting organizations.) in the EU, particularly that at the German national standards body (NSB) and by its delegations to the European standards organizations (ESOs) and international counterparts ISO and IEC (see Figure 1). The empirical investigation of the descriptive representation of women contributes to answering the following questions:

1. To what extent are women represented in standardization committees?
2. Why (if so) are women under-represented?

With limited literature on the representation of women (and the role of gender in general) in standardization, Section 2.1 first summarizes how the topic is currently addressed in relevant non-academic fora. Please note that this article refers to both women's or female representation and to gender. While this could be criticized as an incorrect or too narrow usage of the term gender, this is intentional to reproduce the United Nations Economic Commission for Europe's (UNECE) use of gender when talking about the consideration of women's interests in standards. The research questions and empirical sections refer to women, matching the NSB's gender binary data,

and following the focus on women in SDG 5-gender equality. Section 2.2 discusses possible perspectives on female representation in standardization and explores the potential relevance of a gender gap in standardization by giving a short review of literature on the role of gender in related fields, scientific publishing and patenting. It shows that the topic is not only relevant from the perspective of political legitimacy and gender equality, but possibly also when considering output-enhancing effects of gender diversity.

Investigating the second research question, Section 2.3 focuses on the (maybe most probable) theory that a possible gender gap in standardization can, at least in part, be explained by female under-representation in relevant positions in organizations that contribute to standards. Particularly industry affiliation and geographical location are hypothesized to be factors for gender gaps, both in the participating organizations and consequently in standardization (Section 2.4). The analysis of a unique data set of standardizing experts and organizations (Section 3.1) does indeed reveal a significant gender gap in standardization. Results from a regression model (Section 3.2) further confirm that organizations from industries and regions associated with a lower share of women in relevant positions also show a decreased probability of being represented by female experts in standardization (Section 4). The article closes with a discussion of the results, their implications and ideas for further research.

## 2. Literature and Theory

### 2.1. Initiatives on the Consideration of Gender in Standards

A number of economic and employment policy initiatives have addressed gender inequality in the job market and the gender pay gap in the past (e.g., [24]). In Europe, such policies date back least to at least 1957, when gender-equal pay was defined in Art. 119 of the Treaty of Rome (e.g., [25]), and has been tied to the EU's political identity since its creation [26]. Within the United Nations, gender equality has been a recurring topic at world conferences in 1975, 1980, 1985 and 1995 [27], and has resulted in the 1995 Beijing Declaration and Platform for Action (BPFA) [28] that was adopted by 189 UN member states. In the current 2030 Agenda for Sustainable Development [21], gender equality is goal 5 of the 17 Sustainable Development Goals, and has previously been part of the UN Millennium Development Goals [29]. The goal is composed of several sub-goals that target gender inequalities, discrimination and violence against women, and specifically, in sub-goal 5.5, "women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life." ([21], p. 22).

In the field of standardization, initiatives on gender equality are more recent. The 2016 United Nations Economic Commission for Europe's (UNECE) Gender Responsive Standards Initiative [30] aims at "enhancing the use of standards and technical regulations" as means for achieving gender equality. Similar to the EU soft-law approach to gender policy, it aims to "mainstream a gender perspective in the development and implementation [or enforcement] of standards [and technical regulations]" [31].

Major international standard-setting organizations (SSOs) and national standards bodies (NSBs) have signed the initiative's declaration [32,33]. According to a 2018 statement from the UNECE secretary of the Working Party on Regulatory Cooperation and Standardization Policies, before the signing of the UNECE declaration, "none of the major standard-setting bodies [had] adopted an official gender strategy for the organization and planning of their internal activities" [34]. This issue is certainly also related to new initiatives that connect standardization to the UN's SDGs and goal 5 in particular. In this context, support for female participation in standard-setting and highlighting of the contribution of standards to gender equality have started to be on some of the SSO's agendas (e.g., at ISO [35]).

The initiatives particularly emphasize the responsibility of standard-setters to create standards that promote gender equality. ISO, for instance, points as examples to the standards ISO 19867-1:2018 and ISO/TR 21276:2018 [36]. These standards define requirements for biomass cookstoves and are

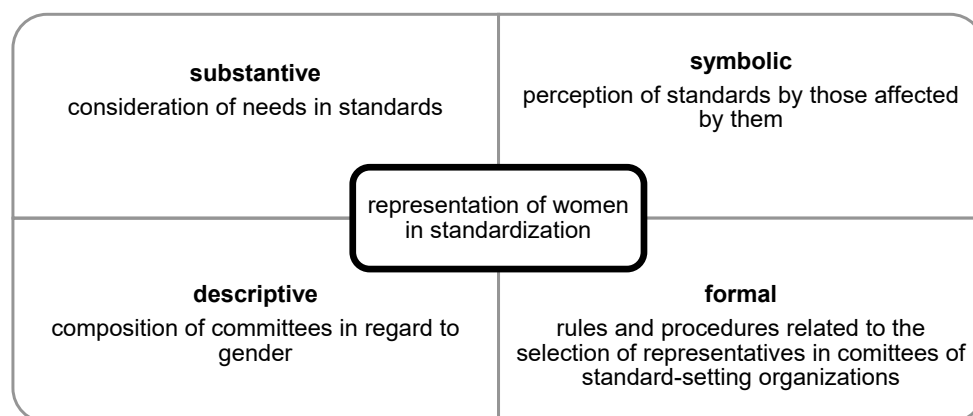
thought to have positive impacts on women, especially in developing countries. A participant in the UNECE initiative reports on code-of-conduct [37] and auditing standards [38], which were developed for an industry that is strongly affected by gender-biases [39]. Further reports point out that voluntary sustainability standards can be tools to increase gender equality in global value-chains [40].

UNECE acknowledges that while there is little literature on gender and standardization, anecdotal evidence indicates that

prevailing gender norms present barriers to women’s participation in the development of standards [and] dominance of male representation in standard-setting affects the way that standards are produced, with insufficient consideration of women specificities in the deliverables ([41], pp. 2–3).

## 2.2. Perspectives on Gender in Standardization

While the initiative puts its focus on the output of standardization—standards—the above quote reflects the duality of gender equality strategies in the UN [42], that could also be applied to standardization. From this point of view, the consideration of gender-related implications of standards would be only one part, the other one would be the equal representation of gender in decision-making in standardization committees and organizations in general. In analogy to a model of female political representation, e.g., discussed by [43], a more comprehensive view on female representation in standardization would consider its output as the aspect of substantive representation (Figure 2). Another aspect would be formal representation, i.e., the rules and processes in the standardization system and participants from industry, that have an impact on the selection of representatives to participate in its committees. This aspect has direct effects on descriptive representation, measuring the “compositional similarity between representatives and represented” ([43], p. 407), which is the focus of this article. All these aspects finally have an impact on the symbolic representation, which describes how much the represented perceive to be represented fairly and effectively. Translated to this model, the UNECE quote states that formal and descriptive under-representation in the standardization system is perceived to be a reason for the under-representation of women in standards.



**Figure 2.** Proposed dimensions when considering women’s representation in standardization, in analogy to [43,44].

An equal representation of women in the standardization system is certainly fundamentally desirable from the standpoint of fairness and gender equality. It is furthermore a prerequisite for the system’s political legitimacy. Its input legitimacy depends on the representation of relevant stakeholders in the standardization process [15,45], which, especially from a societal perspective, necessarily includes women. Admittedly, public political representation and representation in standardization are different—standard-development is a private activity, through which industry agrees on their own, generally voluntary, set of rules. Particularly in the EU, however, there is a close

relationship between standards developed by the private European standards organizations (ESOs), and public regulations and directives [18]. The European standardization system forms a co-regulative relationship with the legislative, as European laws can leave the concrete arrangement of abstract rules to private standard-setters, who set, e.g., limit values or define measurement procedures in standards. This concept enables the timely uptake of innovation and technological progress into legislation, but it also increases the need for a legitimized standardization system.

Aside from considerations of fairness and political legitimacy, how relevant is gender in standardization? Provocatively asked: are experts who develop standards not simply rational agents who are unaffected by personal characteristics, and who objectively represent the technological and political [12] agendas that were set by affiliated organizations? Are standards not merely results of technology-based, rational, well-prepared processes, and consensus-driven decisions within membership organizations? How much of the activity in standardization committees can be assumed to be affected by experts' subjective features? Furthermore, while studies find differences in preferences and decision-making between men and women, these findings do not necessarily apply to professional contexts, where such heterogeneity between gender groups appears to be less pronounced [46]. The assumption that women's participation in standardization necessarily has a different effect than that of men could, therefore, be criticized as too far-reaching and "gender-essentialistic".

At the time of writing this article, no literature on the effect of gender composition of committees on properties of their output was available. The scarcity of scientific literature on women in standardization is possibly connected to a lack of public data on the participation of individuals in standardization. Individual authors of standards documents are commonly not published. As standards are a product of collaborative development and a consensus-finding process of a larger number of parties, and as copyrights belong to the SSOs, the authorship is instead associated with the "organizational shell," the technical committee that is part of the structure of an SSO. In many cases, information on the individuals who participated in a committee's meetings, even their association with companies and other types of stakeholder organizations, is not made public and a disaggregation by gender is therefore unavailable.

Literature from adjacent fields of science, technology, and innovation (STI) research does, however, give indications of the relevance of gender [47,48]. In innovation research, women are subjects of study as authors of scientific publications, or as inventors and applicants of patents. In these contexts, data is often tied and retraceable to the level of individuals. Public databases such as PATSTAT, Web of Science, or Scopus serve as sources for a number of bibliometric studies that examine (or control for) gender in patenting or scientific publication behavior [49–52], or in both (e.g., [53]). In a comprehensive literature review, ref. [48] present evidence on the scientific, economic, societal, and environmental benefits of gender equality. They argue that, regarding science and innovation,

the presence of diversity balances biases, which thereby contributes to the generation of alternative perspectives and experiences for exploring new problems.

Based on results from [54–56], Bühner et al. [48] for instance point out that

[scientific] publications of mixed teams, i.e., with a high share of female authors, receive higher citation rates than homogeneous teams [and] women have higher citation rates than men.

Studies on the effect of gender are, however, not always conclusive. In the discussion around the effect of board diversity on the financial performance of firms, for example, a meta-study found that results did not consistently point to a positive association [57]. While the evidence of effects of gender in STI literature does not necessarily lead to the conclusion that gender-effects also exist in standardization, it gives a strong indication that considering such effects could be beneficial for research on standardization.

As elaborated in the preceding sections, the article is motivated by the proposition that female under-representation potentially creates the following inefficiencies in the standardization-system:

- general unfairness and gender inequality,
- lowered input-legitimacy,
- and, possibly, a suboptimal utilization of output-enhancing effects related to the diversity of standardization committees.

### 2.3. Causes of Female Under-Representation in Standardization

What are reasons for female under-representation? The under-representation of women in science, technology, engineering, and mathematics (STEM) education and workforce suggests that it is much less likely for women to reach positions in which they would be candidates for becoming an organization's representative in standardization committees. An often-used picture that describes the drain of women throughout the stages of education is that of a leaky pipeline [58]. While the ratio of women to men is mostly balanced in earlier stages of education, the ratio changes to the detriment of women further along the pipeline, as considerably fewer women than men complete master's degrees, Ph.D.s, and are appointed professors. In Germany, about 53% of high school graduates with qualifications for university entrance are female. This number drops below 50% for university degrees, 44% Ph.D.s, 29% habilitations and 33% professorships; data from 1999 to 2018 [59].

The education filter is amplified by a horizontal segregation into stereotypical "male" and "female" work areas. Such occupational segregation by gender is related to social and economic factors both on supply- and demand-side [60–63]. It is also clearly reflected in statistics on the selection of university subjects by gender. In 2017, 21% of engineering students, and only 18% of students in subjects at German universities related to information and communication (ICT) were female (Eurostat data [64]). Horizontal segregation in occupations and degrees is further an important factor in the gender pay gap [65], where

[men are] more heavily represented in [higher paid] engineering/technology and physical/mathematical sciences, whereas women had a much larger share of graduates in [lower paid] language studies and humanities, creative arts, and education ([65], p. 3).

In the German labor market, women are more often employed in jobs related to welfare, health-care and education, whereas jobs in construction and manufacturing are dominated by men [66]. While gender-segregating factors, such as cultural norms change, and the proportion of women graduating in STEM rises, specific fields still appear to have strong deterrent effects on women, especially the construction industry [55,67].

Already due to a lack of supply in the job market, filling certain technical positions with women might, therefore, not even be a realistic option for many organizations, especially in the construction industry or the electrical and mechanical engineering industry. In addition to the filter in early career stages, which is associated with the leaky pipeline in scientific education, and the horizontal segregation by university subjects and occupations, women further face vertical segregation in subsequent stages. Women often have to overcome more opposition to career advancement than men, especially in male-dominated work environments, and can be stopped by a glass ceiling [68] that prevents them from reaching leadership positions. Women in leadership positions (in German industries most relevant to standardization) are rarest in construction (7% women in top level), ICT (13%) and manufacturing (14%, data from 2014 [69]). The aspect that standardization experts are most often recruited from such a pool of experts in management and leadership positions in engineering industries [23,70], suggests even more limited chances for women in standardization than STEM student and job market figures might already imply.

The representation of women in the workforce and leadership positions, as well as the pay gap between women and men, is furthermore subject to (subnational) regional differences [69,71–75]. Particularly East Germany traditionally shows fewer disadvantages for women in the job market than the west [74], which can be attributed to historical and cultural developments, as well as to differing sectoral compositions. Ref. [76] highlights GDR women's obligation to participate in the

labour market, more university education and vocational training, and an extensive public child care system as particularly relevant differences to the West. While Germany has been re-united for 30 years, professional careers are still differently affected by such socioeconomic and political factors that are rooted in the Cold War era. The distinction between East and West Germany allows for controlling for such factors, and reflects the categorization in, e.g., the framework of [77], who classify countries according to women's labour market participation in engineering and propose two different categories for developed and never communist/socialist and former communist countries.

#### 2.4. Hypotheses

In a first attempt to describe and explain female under-representation in standardization, focus in this article is put on the theory that input into the standardization system is restricted by a lack of female supply, as it sits at the end of a leaky pipeline that disadvantages women's careers. According to the data and literature discussed in the previous paragraphs, gender-related disadvantages in areas that shape the supply of standardization experts have been shown to primarily vary with industry and region. Concentrating on these factors, the analysis will disregard any further discriminating effect that could be inherent to the standardization system itself, and assume that organizations choose equally among suitable experts to delegate to standardization committees, regardless of their gender.

The following sections will, therefore, be dedicated to testing the following hypotheses:

**Hypothesis 1.** *The extent of descriptive female representation in standardization is associated with industry—organizations that are primarily active in male-dominated industries (construction, mechanical, electrical engineering) are less likely to be represented by women than those active in, e.g., education, textiles, food etc.*

**Hypothesis 2.** *The extent of descriptive female representation in standardization is associated with regional differences between delegating organizations—in the case of Germany, organizations located in the eastern states are more likely to be represented by women than those in the west.*

### 3. Materials and Methods

#### 3.1. Data

Open data on the activity of individuals in standard-setting organizations are mostly unavailable. This article makes use of a non-public data set on organizations' activities in technical committees which was provided by the German NSB (DIN) and contains information from 2016 to 2018 on: (a) the affiliation of seats in technical committees with organizations (companies, associations, public institutions, etc.) and (b) a list of standardization experts representing each organization, including gender (m/f) and academic title. After removing duplicates, consolidating entries where, e.g., different departments of the same organization were registered, dropping organizations that were not active in any committees, as well as individuals without affiliation (private participants) and standardization organizations themselves, 14,376 organizations remained.

All organizations were assigned to industries following the WZ 2008 classification [78]. Certain classes were grouped to avoid sparsity, which reduced their number from 21 to 17. The number of employees per organization was provided in 8590 cases. This information was most often missing for public organizations (87.0% missing), organizations active in science and education (75.1% missing), and associations (73.5%). The fraction of missing data in other industries lay between 20.0% (metal production) and 36.1% (energy, water, oil). In 11,129 cases, geographical data were available in the form of zip-codes (German organizations only), which were mapped to the German federal states and the area of the former GDR and West Germany.

An investigation of cases with missing data could not confirm any other missing data bias than that of industry-related availability of employee counts. Results from subsequent analyses are, unless stated

otherwise, based on all cases where both data on the number of employees and geographical location was available ( $n = 8134$  organizations located in Germany).

In total, 28,715 individual experts were affiliated with these organizations. Information on gender (“female” or “male”) was available in almost all cases; in some cases, I inferred it from the first name. A minority of 3106 (10.5%) experts were female, the rest (89.5%) male.

The organizations held 316,569 seats in committees in various standard-setting organizations, including German DIN and DKE, European CEN and CENELEC, ISO and IEC, as well as other associated bodies such as ASD-STAN (aerospace) or ECISS (iron and steel). While the list of seats at DIN and DKE can be assumed to give a near-complete picture, the sample is incomplete for organizations such as CEN or ISO, as it only includes German delegates and is missing those from other countries. For each seat, the data set included the respective function in the committee and the affiliation with an organization. Affiliation on an individual level was not provided, which made a direct statistic of gender/function or gender/SSO analogous to Figure 4a unavailable. The link between gender- and seat-data can, however, be established under the assumption that the number of seats given to women  $seats_f$  out of all available  $seats_t$  organization that sends  $N_f$  female and  $N_m$  male experts to committees are distributed hypergeometrically, so that

$$E(seats_f) = seats_t \frac{N_f}{N_f + N_m} \quad (1)$$

I decided against integrating the variable  $seats$  into the regression models in order to avoid increasing the number of model assumptions and creating a false impression of measurement accuracy. Sample statistics are nonetheless reported.

### 3.2. Models

Multivariate logit analysis investigates the properties of organizations that are represented by women in standardization and of those that are not. The logistic regression model is defined as:

$$women_i = \alpha_0 + \alpha_1 \log(size_i) + \alpha_2 industry_i + \alpha_3 region_i + \alpha_4 involvement_i + \epsilon_i \quad (2)$$

The dichotomous dependent variable  $women_i$  is equal to one if at least one woman is affiliated with organization  $i$ , otherwise zero.  $\epsilon_i$  denotes unobserved or unobservable organization characteristics, such as a company culture, diversity policies, etc. The coefficients  $\alpha_j$  are estimated by a maximum likelihood procedure. I considered using a continuous model with the fraction of female experts as dependent variable, however, decided to focus on this binary representation, considering that the by far largest share of organizations sends no women at all, and the variation in the group of organizations sending at least one woman was not ideal for most standard models (fraction of two right-skewed discrete distributions). To check the robustness of the binary approach, I also provide results of a fractional logit model estimated by quasi-maximum likelihood [79]. In this model, the dependent variable  $fracw_i \in [0, 1]$  is the fraction of female experts affiliated with organization  $i$ , with the same independent and control variables as in (2).

## 4. Results

### 4.1. Regional Differences

Table 1 shows the percentage of organizations sending women by sample demographics size (number of employees), sector, industry, and region (east/west). Most organizations were located in the urban regions around the industrial centers of the west (Figure A1a,b). In comparison, female participation was generally more pronounced in the east and high in the city-states of the west (Figure A1c). Most organizations were located in the states of North Rhine-Westphalia (27.0%), Baden-Wurttemberg (17.7%), and Bavaria (15.2%). Far fewer organizations were located



in Mecklenburg-Vorpommern (0.7%), Saarland (0.7%) and Bremen (1.0%). In total, 8.0% of all organizations had their headquarters in the east of Germany (former GDR, not counting East Berlin), most of them in Saxony (3.3%). Female participation was strongest in Saxony-Anhalt (20.0% experts female) and Berlin (18.3%), while it lay around 9% in the most-represented western states (NRW: 8.9%, Baden-Wuerttemberg: 9.1%, Bavaria: 8.7%).

**Table 1.** Model variables and summary statistics.

	Variable		Women = 1 (%)	Obs.	Mean	Std. Dev.
dependent	women	Logistic regression model. Equal to 1 if an organization is represented by at least one female expert, otherwise 0	16.7	8134		
dependent	fracw	Fractional logit model. Fraction of female experts affiliated with organization				
independent	industry	Cert., Test. Labs	42.0	317		
		Public	39.0	136		
		Food	35.5	62		
		Associations	32.6	221		
		Science, Edu.	31.1	325		
		Chem., Pharma.	24.2	541		
		Energy, Water, Oil	21.9	269		
		Logistics, Mobility	21.6	125		
		Automotive Eng.	20.7	309		
		Medical Eng.	19.6	560		
		Clothing, Textiles	18.9	334		
		Service	11.4	1827		
		Mechanical Eng.	11.2	1326		
		Metal Prod.	11.0	619		
		Electrical Eng.	10.8	753		
		Trade	10.5	229		
		Construction	7.5	361		
	sector	Primary	14.3	888		
		Secondary	15.2	4246		
		Tertiary	19.4	3180		
	region	Berlin	31.4	388		
		East Germany	20.7	666		
		West Germany	15.6	7260		
	size	Number of employees		8134	2649	21,771
		Micro: <10	10.9	1364		
		Small: 10–49	12.8	1718		
		Medium: 50–249	14.7	2345		
		Large: 250–999	18.3	1605		
		Larger: ≥1000	30.2	1282		
control	involvement	Total number of experts affiliated with organization (experts = employees active in standardization)		8134	3.5	8.5

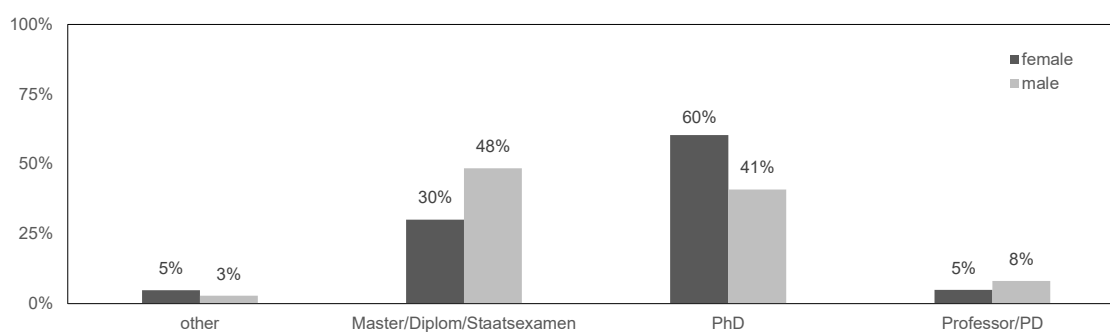
#### 4.2. Size

The sample included organizations from a range of micro (less than 10 employees, often one employee) to large corporations with more than 100,000 employees, e.g., active in automotive or electrical engineering. The group sizes of micro, small, medium, large, and “larger” organizations in Table 1 show that no size was under-represented and that the share of organizations sending women grew with organization size (correlation  $\log(\text{size})$  and  $\text{women}$ :  $rs = 0.15$ ,  $p < 0.001$ ).

Organizations were on average represented by  $M = 3.5$  experts ( $SD = 8.5$ ), ranging from 1 (33.9% of all organizations) to a maximum of 472. Of all 2819 organizations with only one representative, 6.9% were represented by a woman, while this number rose to 48.3% for organizations with at least five experts. Organizations that were represented by at least one woman ( $n = 1392$ ) were on average represented by more experts ( $M = 8.6$ ;  $SD = 19.3$ ) than those only represented by men ( $M = 2.4$ ;  $SD = 2.2$ ),  $t(8312) = 25.9$ ,  $p < 0.01$ .

### 4.3. Education

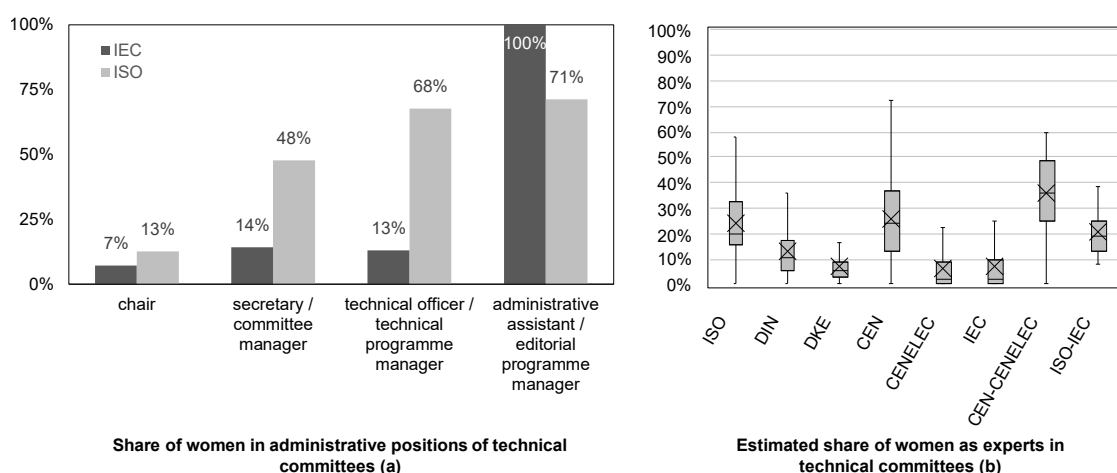
Some ( $n = 5996$ ) of the experts in the sample stated their academic or job title (e.g., B.Sc., Dipl.-Ing., Meister, Prof., etc.). A manual assignment to the four education-levels “Professor,” “Ph.D.,” “Master’s degree,” “other/lower” showed that significantly more women (60% vs. 41% men) had a Ph.D. and significantly more men held a Master’s degree or equivalent (48% vs. 30% women; most common: “Diplom Ingenieur”), see Figure 3. However, in 79.1% cases, data were missing, which could either mean that individuals had no degree, or that they did not state their degree.



**Figure 3.** Academic titles of men and women in standardization.  $n = 5996$  experts, rest (22,719; 79.1%) did not state titles.

### 4.4. SSOs

The 8314 organizations sent delegates to 7155 committees (aggregated to technical committee + working group level, in case of DIN: Normenausschüsse (NA) + sublevel (“Fachbereiche” etc.); including mirror-committees.) Of those, 6572 were hosted at the standard-setting organizations DIN, DKE, CEN, CENELEC, ISO, IEC and as joint committees between ISO/IEC and CEN/CENELEC. The estimation of the number of seats given to women in each committee according to (1) showed that the organizations specialized in electrotechnical standard-setting (DKE, CENELEC, IEC) were more likely to host committees with a low female percentage (Figure 4). The international organizations ISO and CEN, with a broader spectrum of standard-setting topics, were more likely to host committees with a higher share of seats estimated to be taken by women. The percentage of committees where no participating organization from the sample was represented by any woman was highest at IEC (47.7%,  $n = 1353$ ) and CENELEC (44.7%,  $n = 347$ ). The other SSOs had lower shares: DIN (11.0%,  $n = 681$ ), DKE (9.2%,  $n = 195$ ), CEN (3.1%,  $n = 1811$ ), CEN-CENELEC (2.2%,  $n = 46$ ), ISO (1.1%, 2104), ISO-IEC (0%,  $n = 35$ ). Note that the sample of CEN-CENELEC and ISO-IEC was small and that the estimation solely relied on German seat-data and, therefore, only represents the share of seats given to German organizations (active at DIN).



**Figure 4.** Percentage of administrative positions (a) and seats in technical committees (b) filled by women. (a) IEC ( $n = 220$ ) and ISO ( $n = 248$ ), data scraped from IEC and ISO websites [80,81], January 2020. (b) Boxplot of estimated shares of seats taken by female (German) delegates in committees at SSOs. Estimation according to (1).  $N = 6572$  committees.

#### 4.5. Regression

Table 2 reports the average marginal effects of *size*, *sector* or *industry* and *region* on (a) whether organizations are represented by women ( $women = 1$ , logistic regression, models 1–4), and (b) the fraction of female experts ( $fracw$ ) representing an organization (fractional logit, model 5). The nested models 1–3 are used to test the effects of including horizontal (sectoral) and regional differences. Likelihood-ratio tests confirmed that including *sector*, *region*, and *industry* improved model fit.

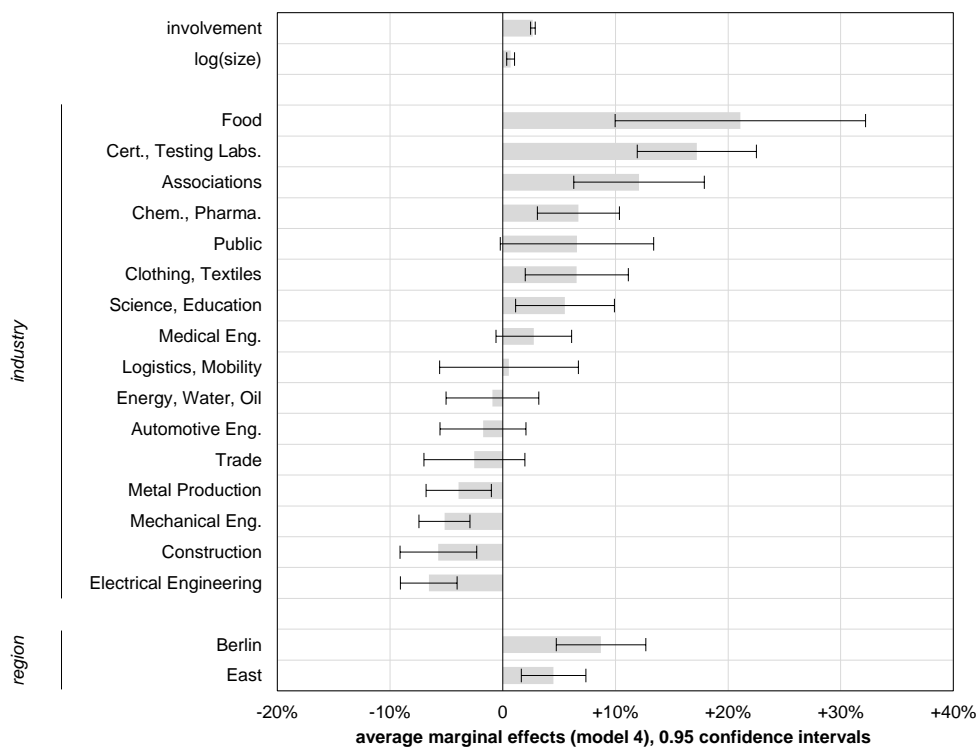
The coefficients estimated for models 1–4 indicate that *size*, *sector/industry*, and geographical *region* are factors that are significantly associated with the representation of organizations by women in standardization. Model 5 further confirms this for the extent of female representation measured on a continuous scale. The number of experts affiliated with an organization, representing the extent of *involvement* in standardization, is significantly positive in all models—the more experts an organization sends, the more likely it is that there is a woman among them. This relationship is non-linear and particularly dependent on the industry. At around 20 to 30 experts, the average probability of at least one delegated woman nears 100%.

Even controlling for the number of delegated experts, the size of organizations is significantly ( $p < 0.01$ ) positively associated with the delegation of women (Figure 5). However, the marginal effect (even for the log-transformed number of employees), is on average much smaller than that of industry and region. A difference in one unit of size (e.g., moving from 10 to 100 employees) increases the probability of at least one female representative by about  $0.7\% \pm 0.4$  (95% CI) on average, growing linearly with the log. Belonging to the food industry, versus belonging to the service industry (which is most frequent in the sample) raises the probability by 21.1% ( $\pm 11.2$ ) on average. Other industries with significantly positive average marginal effects ( $p < 0.01$ ) are certification, testing laboratories (such as e.g., TÜV,  $+17.2\% \pm 5.3$ ); associations ( $+12.1\% \pm 5.9$ ); chemical, pharmaceutical ( $+6.7\% \pm 3.7$ ); clothing, textiles ( $+6.6\% \pm 4.5$ ); and science and education ( $+5.5\% \pm 4.3$ ). Negative effects are estimated for the “male-dominated” industries electrical engineering ( $-6.6\% \pm 2.5$ ), construction ( $-5.7\% \pm 3.3$ ), mechanical engineering ( $-5.2\% \pm 2.4$ ) and metal production ( $-3.9\% \pm 2.9$ ). Combined (model 3), organizations in the tertiary sector had an average of 6.4% ( $\pm 2.4$ ) higher probability of being represented by women than those in the primary sector. The difference for the secondary sector was, on average, not significant on a 0.95 confidence level. Geographical location also played an important role. Organizations in the former East German states (model 4) had an average  $+4.5\% (\pm 2.9)$  higher probability of delegating women, surpassed by Berlin ( $+8.7\% \pm 3.9$ ).

Table 2. Regression results for dependent variables *women* and *fracw*.

Models		Logistic Regression				Fract. Logit (5)
		(1)	(2)	(3)	(4)	
<i>involvement</i>		0.028 *** (0.001)	0.028 *** (0.001)	0.028 *** (0.001)	0.027 *** (0.001)	0.000 ** (0.000)
log( <i>size</i> )		0.005 ** (0.002)	0.007 *** (0.002)	0.007 *** (0.002)	0.007 *** (0.002)	0.003 ** (0.001)
<i>sector</i> baseline Primary	Secondary		0.015 (0.011)	0.016 (0.011)		
	Tertiary		0.071 *** (0.012)	0.064 *** (0.012)		
<i>region</i> baseline west	Berlin			0.099 *** (0.021)	0.087 *** (0.020)	0.044 *** (0.013)
	East			0.054 *** (0.015)	0.045 ** (0.015)	0.029 ** (0.010)
<i>industry</i> baseline Service	Associations				0.121 *** (0.030)	0.077 *** (0.019)
	Automotive Eng.				−0.017 (0.019)	−0.017 (0.011)
	Chem., Pharma.				0.067 *** (0.019)	0.050 *** (0.014)
	Clothing, Textiles				0.066 ** (0.023)	0.051 ** (0.018)
	Construction				−0.057 *** (0.017)	−0.037 *** (0.011)
	Electrical Eng.				−0.066 *** (0.013)	−0.036 *** (0.008)
	Energy, Water, Oil				−0.009 (0.021)	0.000 (0.014)
	Food				0.211 *** (0.057)	0.180 *** (0.048)
	Logistics, Mobility				0.006 (0.031)	0.023 (0.023)
	Mechanical Eng.				−0.052 *** (0.012)	−0.036 *** (0.007)
	Medical Eng.				0.028 (0.017)	0.011 (0.011)
	Metal Production				−0.039 ** (0.015)	−0.025 ** (0.009)
	Public				0.066 (0.035)	0.062 ** (0.022)
	Cert., Testing Labs.				0.172 *** (0.027)	0.120 *** (0.019)
Science, Education				0.055 * (0.022)	0.041 ** (0.015)	
Trade				−0.025 (0.023)	−0.014 (0.016)	
Const		−2.744 *** (0.081)	−3.195 *** (0.138)	−3.267 *** (0.139)	−2.952 *** (0.099)	−2.782 *** (0.104)
Observations		8314	8314	8314	8314	8314
Pseudo $R^2$		0.159	0.167	0.172	0.200	0.047
AIC		6322	6270	6233	6053	4515

Table shows average marginal effects with robust standard errors in parentheses. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .



**Figure 5.** Effect of organizations' characteristics on probability to be represented by female standardization expert(s). Baseline: average-sized West German organization in service industry. (Model 4, average marginal effects, 0.95 confidence intervals).

## 5. Discussion

The regression results confirm the Hypotheses 1 and 2, and the impressions created by the sample statistics. Organization size is a significant, albeit smaller factor than expected. The German east–west gap is significant, even when controlling for differences in industry-composition. Female representation differs significantly between most industries, putting especially engineering and construction at a disadvantage, irrespective of average organization size or their extent of involvement in standardization. This is consistent with the estimated lower fractions of seats given to women in electrical engineering committees (DKE, IEC, CENELEC, Figure 4).

On average, women in the sample were better educated than men. A cautious interpretation (considering the high amount of missing data and its ambiguous interpretation) could be that women face a higher “entry-barrier” than men, meaning that they have to have a higher education to reach the same position. Another simple explanation could be that industries that are more related to scientific activities (like certification, testing laboratories, chemical, and pharmaceutical industry) sent a higher percentage of women to standardization than, e.g., construction or mechanical engineering. In such industries, a master’s degree (or “Dipl.-Ing.”) might be more prevalent.

These results underline that women are indeed descriptively under-represented in standardization and show that general factors related to industry, size, and region (east/west) can be seen as at least one part of an explanation. This is in line with the idea that standardization is at the end of a leaky pipeline, where the standardizing organizations might be facing the problem of simply not having enough available female staff to send to committees.

The results do however do not give any indication on whether low female participation is only determined by filters that affect career entry and advancements on career ladders in industry and science, or if the number of women reaching standardization committees is further (positively or negatively) influenced by properties of the standardization system itself. Further research should, therefore, investigate if the gender gap in standardization can be sufficiently explained by a “leaky

pipeline effect”, what other external effects could play a role, and if there are additional effects inherent to standardization. This could include controlling for “pre-standardization filters” with suitable variables, such as industry-region specific statistics on women in positions relevant for standardization (CEO, R&D/QM departments, etc.).

The definition of representation in this article is purely descriptive—it measures the percentage of female delegates of standard-developing organizations. It does not consider how this does or does not lead to the representation of female interests through standardization. Further research could therefore aim at creating a more “integrated model” of the gender gap in standardization [43], as descriptive representation is not necessarily equal to substantive representation. While theoretically, completely male teams could sufficiently represent female interests, it appears evident that the representation would benefit from the participation of women. In fact, as [82] show, political representation is only achieved at a certain critical mass, and a whole team’s general openness towards diversity has an impact on its performance [83]. Another object of research in this context could be how work is split up among participants in the standardization system. Ref. [70] discuss managers, engineers, generalists, specialists, and developers as a possible taxonomy of participant roles. An analysis of such different roles and their relationship to gender would further help to gain a deeper understanding of female participation. Finally, interview- or questionnaire-based research could investigate the perception of female (symbolic) representation in standardization and standards by women active in standardization and/or affected by standards.

While gender equality can be considered an essential aspect of the legitimacy of standards and the standardization-system, the under-representation of women in standardization remains an under-researched topic. This is undoubtedly due to an unavailability of data, but possibly also due to an inclination to locate the problem not in the standardization system itself, but in the under-representation of women in standardizing industries in general. In a first approach to the topic, this article examines the properties of German organizations that are, or are not, represented by women in standardization. The results show that women are indeed under-represented in standardization and that the degree of representation is significantly associated with industry, organization size, and geographical region. This leads to the conclusion that female under-representation in standardization can indeed, at least in part, be attributed to female under-representation in organizations that participate in standard-development.

Future research could further focus on whether the standardization-system acts as an additional filter that in- or decreases female participation. A more detailed analysis should investigate if certain roles in the system are associated with gender. More information on subjective perceptions of female representation in standardization should be gathered in interviews and surveys. Most importantly, there is a strong need for additional evidence from other countries and organizations. Standard-setting organizations could contribute to this research by providing more data.

## 6. Conclusions

This article shows that women are significantly under-represented in the development of German standards, as well as European and international standards with German contribution. This is a fundamental issue that exists across industries, small and large organizations and across Germany. Statistics from international standards organizations suggest that female under-representation in standardization is not restricted to Germany, but potentially exists on a global scale. In the case of Germany, under-representation is most strongly pronounced in construction, electrical engineering, mechanical engineering and metal production, in smaller organizations and in the western states. This pattern of variation is similar to that of women in leadership positions in the respective industries and regions, which implies that the standardization system suffers from a lack of women in positions that generate standardization experts.

The under-representation of women can be considered an aspect that challenges the standardization system’s legitimacy. It could certainly be argued that private standard-setting does not

necessarily have to match the level of accountability for adequate representation of society as that of a public legislator. This position is however weakened by the potentially wide-ranging impacts of certain standards on the public, and their close relationship to laws. Especially in the case of harmonized European standards that are referred to by EU directives and regulations, legitimacy as rule-makers is a prominent issue for the standardization system and its participants. Through the inclusion of societal stakeholder organizations, that represent consumers, workers and environmental interests, the standards organizations acknowledge the need for political legitimacy.

Recently, standards organizations have recognized the issue of gender in standards and standardization, and have pledged to pursue the sustainable development goal of gender equality. While initiatives mainly focus on the consideration of gender in standards, this article addresses the “upstream” issue of descriptive under-representation in standardization committees. It can be argued that adequate consideration of gender aspects in standards can not exist without a better representation of women in standardization, and that organizations might need to adapt their rules and processes to promote female participation. Examples like the high rate of female committee chairs at the ITU show that this is possible.

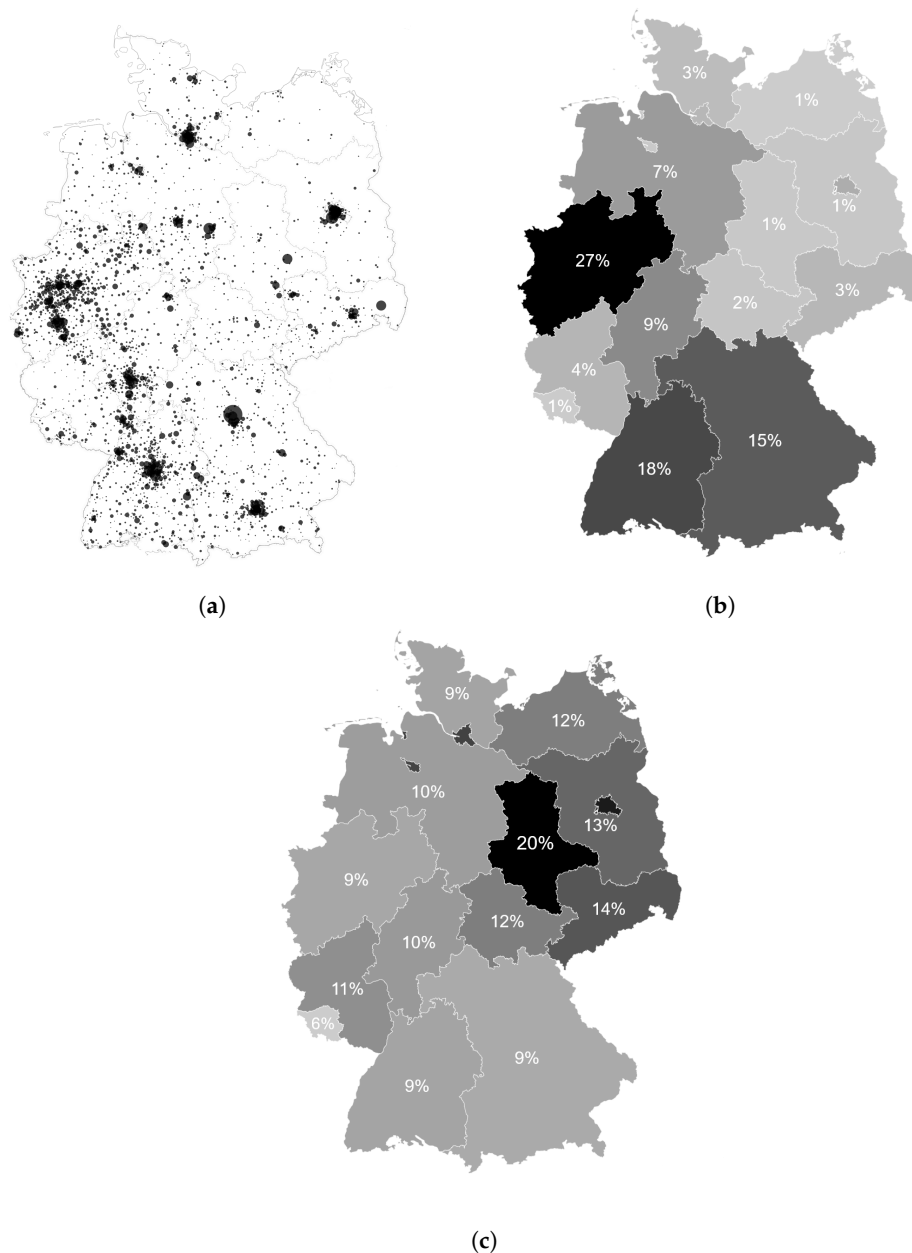
While this article finds and quantifies descriptive female under-representation in standardization and associates it with industries’ and regional particularities, its scope is limited. In order to better understand the phenomenon, future research needs to further explore the causal relationships that determine female participation. A lack of availability of female standardizers on the supply side appears to be a central factor, while it remains unclear whether the standardization system itself discriminates against or exerts deterring effects on women on the demand side. As argued in the article, analyses of female representation should include more integrated than purely descriptive concepts of representation. Further focus should be put on the effect of female participation on the system’s output, and whether diversity effects similar to those found in innovation research can be observed in the standardization system.

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## Appendix A



**Figure A1.** Geographical distributions. (a) Locations of organizations active in standardization and affiliated number of experts (bubble size). (b) State-level distribution of organizations that are active in standardization. (c) Share of female (vs male) standardization experts in each state.

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