

Editorial:

Standardization in a Digital and Global World: State-of-the-Art and Future Perspectives

I. INTRODUCTION

A TECHNICAL standard is an established definition, norm, or rule that describes the characteristics of a product as well as its level of performance, safety, or quality. Standardization is the process for the development, adoption, and control of specifications based around the consensus of firms, users, interest groups, and governments.

Standardization has sometimes been considered an impediment to innovation, while at the same helping to facilitate the adoption and diffusion of innovation outcomes [1]. A widespread view in the management community is that the standardization is about uniformity, while innovation is about creativity and change [2]. In addition, some *de facto* standards can lead to monopoly power that favors the increasing returns or decreasing costs, while the conceived *de jure* standards may promote immature technologies [3]. Finally, standardization has contributed to the emergence of “essential patents,” which are indispensable for designing and manufacturing the products conforming to standards [4]. Ownership of such patents, along with the standardization, contributes to an increase in their price, acting as entry barriers and deterrent to innovation. Furthermore, when the patents are part of a standard THI helps to explain why some patents get licensed out, while others that are technologically similar do not [5].

However, the standardization is increasingly perceived as positive for the innovation, most notably by governmental institutions [6]. The purpose of a standard is to offer an innovation, which is accepted by most users or customers, in order to simplify the offer among many alternative and less efficient solutions [7]. In addition, the interoperability of the standards allows innovative solutions from different suppliers to work together and consequently foster the development of new products, services, and processes [8].

For instance, the European Union (EU) acknowledges that standards are the key for innovation and progress in the single market, and are essential to support European competitiveness, jobs, and growth [9]. Similarly, within China, there is a prevalent belief at the corporate and governmental levels that only companies that make the standards can be considered first-tier international technology-based companies. A popular Chinese saying states “third-tier companies make products; second-tier companies make technology; first-tier companies make standards” [10].

Standardization is now becoming central to the innovation strategy of companies and governments because of the advance of both digitalization and the globalization of innovation. Big data-driven digitalization is where the firms create and capture value using the seemingly infinite data from a current generation of four billion mobile device users engaged in digital interactions and transactions [11].

This digital vortex has already engulfed the industries, such as travel, music, retail, banking, and media, but now more traditional industries are also impacted, including energy, health care, agriculture, etc. [12]. By 2020, digitalization will have disrupted more than 80% of the industries at least in developed countries [13]. Meanwhile, the increased globalization of business in the last decades has had a disruptive effect on industries. There has been a multiplication of players and the apparition of successful competitors from various parts of the planet, and the demise of some traditional companies from the western world.

In the rest of this introductory article, we discuss how the standards emerge from an interaction between three main sources, the standards standard-setting organizations (SSOs), the competitive market forces, and the government. We present a framework (see Table I) that highlights how these sources differ and work together to shape the standardization in a digital and global context. Also, using this framework, we introduce the contribution of each article of this issue and their contribution to some of the major issues that the standardization is facing today in a digital and global world. We conclude with the suggestions of avenues for future research on this topic.

II. IMPACT OF DIGITALIZATION AND GLOBALIZATION ON STANDARDIZATION AND ITS ACTORS

A. Standard-Setting Organizations

An SSO is an entity that develops and adopts an industry standard. SSOs typically include two categories of organizations: standards development organizations (SDOs) and private sector-led consortia. SDOs gather representatives from several firms and other stakeholders to derive the technical rules of compatibility between various system components [14]. Consortia provide an institutional platform and mechanisms for faster and more flexible market-based technical coordination. This is a contrast to SDOs where reaching a consensus among the various participants can sometimes involve drawn-out technical discussions, time-consuming political negotiations, and lengthy

bureaucratic process steps [15]. Official SDOs endorse *de jure* standards, while consortia promote ad hoc standards.

The involvement in the development within SSOs facilitates the implementation of the standard and creates a competitive advantage compared with the firms not active in the standardization process [16]. The companies can also influence the upcoming standards in the standardization process in order to get the best position to diffuse their technologies; consequently, they can get a higher market share while raising the entry barriers for competitors.

In the information and communications technology (ICT) sector, some SDOs have been in place for a long time. The International Telegraph Union was created in 1865, the International Electrotechnical Commission (IEC) was inaugurated in 1906, and the International Organization for Standardization (ISO) was founded in 1947. However, besides these three major accredited SDOs, the swift development of digital technologies has generated an explosion of more than 250 private standards setting consortia working on the ICT standards development and sometimes challenging the traditional SDOs [17]. The resulting problem is that each consortium can have different coverage (both topical and geographical), intellectual property rights (IPR) rules, processes, voting procedures, or membership bases, for instance.

In parallel, globalization is redefining the role of the SDOs. For instance, in the telecommunication industry, the development of the fifth-generation (5G) technology is expanding into new areas. TV, automotive, and many new IoT services now have to adhere to the global standards for 5G (e.g., [18]). Consequently, the 3rd Generation Partnership Project (3GPP), the SDO in charge of developing telecommunication standards at a worldwide level, such as the Global System for Mobile (GSM) communications and fourth-generation (4G) systems in the past, has now to incorporate more members of new industries and geographies.

B. Market Standards

The second source of the standards comes from the competitive battle of various companies seeking to benefit from a technology that becomes a *de facto* standard [19].

In fact, the most successful digital companies of today have a dominant market share, often driven by success at standardization. For instance, at a global level, Amazon is a leader in e-commerce with a 69% market share and an almost 35% share in the cloud services market [20]. Google, with Android, has more than 85% share of the mobile operating system market, more than 71% of the video platform market with YouTube, and with Chrome 65% of the web browsing market. It has a duopoly dominance of the digital advertising market with Facebook, which still owns more than 65% of the social media market.

Facebook, with WhatsApp, is also a leading player of the mobile messenger market with a 44% share. Microsoft has a dominant 77% share of the desktop operating system with Windows. Microsoft is also the second biggest company in the video games' consoles, with the Xbox having 41% of the market with its duopoly partner Sony, which has 57% with the PlayStation [21]. These are just a few of the many examples where one or two

digital companies use the platform standardization to achieve a "winner-takes-all" strategy [22].

Most digital companies, both in consumer and professional markets, use the *de facto* standards to build their own platform ecosystem of suppliers, customers, and other stakeholders (e.g., [23]). The standards allow such firms to maximize their network effect in order to scale up their customer base at a stratospheric speed and with a worldwide scope. Digital firms also use the standardization to reinforce their regulatory capture of the market in order to achieve dominant positions in their specific activity.

Furthermore, globalization has reinforced the battle for the *de facto* standards as new global champions emerge rapidly from different parts of the world, as illustrated by the recent rivalry between Alibaba and Amazon or between Samsung and Apple. Because of their size and market clout, Chinese firms have an increasing role in the definition of standards [24]. For instance, Alibaba is actively pushing the brand owners using its platform to adopt the international Global Standards One standards for barcode and global trade item number for the product identification as well as the global data synchronization network for the online exchange of information. Another large and powerful global smartphone maker, Huawei, is now developing and using its own operating software, Harmony, to replace Android. This innovation was triggered by Google's decision to suspend licensing Android to Huawei because the U.S. government banned Huawei from the American telecommunication infrastructure market. This new operating software could quickly become an alternative to Android.

C. Governments

Governments are a third source of standards. Governments can try to impose the standards or to influence the results of the committee-based standardization bodies for political reasons, such as controlling the social consequences of a technology (e.g., [25]) or defending long-term national interests for the security or economic development.

Governments may introduce powerful actors, such as government-controlled enterprises (GCEs) into the committee-based mode SSOs. Actually, GCEs have always played a leading role in standardization for information technology and communication in various countries. For example, in the U.K., the state-owned broadcaster British Broadcasting Corporation (BBC) controlled the setting of key U.K. tv standards, while in Japan, the government-controlled Association of Radio Industries organized the standardization for the second-generation (2G) systems [26]. Similarly, in Korea, a government affiliate, the Telecommunications Technology Association, headed the development of the wireless Internet platform for interoperability (WIPI), a wireless platform standard for the local market [27].

Governments can also set the agenda by identifying problems and selecting solutions. They then may build consensus among participants and ensure that different players work effectively together, even mediate in cases of conflict between the parties involved in the standardization process [28]. For example, coordination at the EU level on the complex cooperation process

among an array of the private and public actors was critical for the success of GSM in Europe [29].

In some cases, a government may contribute to the emergence of a new standard because it seeks advantages for its national firms in the international competition. Just recently, the Chinese government actively promoted the development of the technical standards to facilitate the development of innovation in China. In its five year plan for 2016–2020, the goal for innovation is to develop more than 200 international standards, through promoting the conversion of more than 1000 Chinese standards as reference for use in the foreign engineering construction or product manufacturing [30].

III. CONTRIBUTION OF EACH ARTICLE OF THIS ISSUE AND THEIR CONTRIBUTION TO SOME OF THE MAJOR ISSUES

The first article we introduce from this special issue is titled “A system dynamics model of standards competition.” It provides a fascinating model that helps understand why some digital platforms outsmart their competitors to become the dominant standard, as in the case of the Facebook, Apple, Amazon, Alphabet/Google, and Microsoft (FAAM), for instance. Additionally, the article explores under which conditions the competition outcomes could have been different. Thus, it offers interesting and original insights about how a standard could have been reversed, giving way to another one. At a time where the dominant position of the FAAM has become an element of discussion not only economic but also political [31], the article casts a new light on what could be the future for some platforms and other digital technologies if their “de facto” dominance was broken by the law.

As the standardization is a definitive way to achieve a strong competitive advantage, the second article focuses more on the potential benefit of SSOs. It is titled “Drivers for companies entry into SSOs” and it studies the reasons for the innovative technology companies to join the technical committees at SSO. One prominent reason is the introduction of new products or services in the market as well as the protection of innovations by patents. The company’s size is also a significant driver: growing medium-size companies enjoy a clear benefit from participating in SSOs, while very large players will engage less since they already have the necessary market power to make their innovative products successful. Interestingly, the “absorptive capacity” of a company to take in, implement, and apply the knowledge discussed in SSOs is shown as not having a significant positive influence to join a standardization committee.

The third article considers the role of government vis-à-vis the SSOs. It is titled “Government-controlled enterprises in standardization in the catching-up Context: Case of TD-SCDMA in China.” It offers a detailed analysis of the implication and the role of the Chinese government in the development and diffusion of the 3G of mobile systems in China, time division synchronous code division multiple access (TD-SCDMA), that not only dominated the Chinese market but also was accepted as an international standard. Additionally, the TD-SCDMA standardization is not only the starting point of China’s success of the indigenous innovation but it also establishes the

foundation for the 4G system standardization and even the incoming 5G.

The article casts a new light on the role of GCEs or organizations in the standardization process. The author shows how, in China, the government fostered GCEs to take the lead in the standardization process and to defend the Chinese government’s interests. For instance, the government pushed for the time-division synchronous code division multiple access standard against the opinion of some GCEs, which wanted to move with another standard, wideband code division multiple access, which looked more appealing to the market. But the authors clearly show that the government had the national security considerations in mind and wanted to have full control of the 3G technology in China. Finally, this absorbing article illustrates how a latecomer country can create its own path-breaking standard for the digital technology infrastructure with the strong backing of the government. The article concludes that GCEs are not always mandatory once a country has achieved enough experience in setting up a new digital standard. Actually, the private Chinese telecom hardware and service vendors were the forces behind the building of the 4G standard and they are now leading in the standardization of the incoming technology 5G.

The emerging standards have been tested by the designers and developers for many years. Information technology (IT) standardization organizations, such as the world wide web consortium (W3C) or the Internet engineering task force, have been using the agile test-driven standardization methodologies for the early stage of a 5G development to demonstrate the feasibility of technologies and to test the possibilities of meeting the standards’ requirements defined by the 3GPP and the International Telecommunication Union. But recent developments in digital innovations, such as the Internet of Things and smart systems, demand faster and more responsive approaches for the standardization. Two of them are analyzed in the following articles.

The first research focuses on the building of standards for the Industrial Internet of Things (IIoT), i.e., a system of interrelated computing devices, mechanical and digital machines that can communicate and transfer data over the Internet without the human interference, applied to industrial businesses. The article is entitled “Towards agile standardization: Testbeds in support of standardization for the IIoT.” The testbeds are test and experimentation platforms. The article analyzes how a testbed plays an important role in the standardization of innovation for the emerging IIoT, sometimes called smart manufacturing. IIoT implies the combination of multiple devices, machines, and applications across value chains, domains, and countries.

The standards are needed to guarantee that this interoperability will function smoothly and reliably. However, IIoT presents numerous challenges to the traditional standardization due to the complexity, dynamics, and accelerating speed of technological progress. Consequently, traditional engineering disciplines, automation, and IT cannot be considered separately. Instead, they have to be integrated, as must meet their standards. Thus, the standardization of the IIoT requires cross-sectoral systems reasoning, and multidisciplinary and inclusive processes as well as new tools. Among those new tools are the testbeds. They are made in the spatially confined environments outside the

real production environment for experimentation, prototyping, and testing new applications, processes, products, services, and business models to ascertain their usefulness and viability before taking them to the market.

The article also analyzes how the testbeds can play a key role in the standardization process for IIoT for different reasons. First, the insights gained from the testbeds can contribute to defining requirements for a technology standard. Second, the testbeds can help to identify and address the issues early on and validate the proposals swiftly, to meet the challenges of fast changing and complex systems. Third, many stakeholders in the testbeds are also members of relevant SDOs and consortia and use their testbed activities to directly benefit from them in the work of the technical committees. The article concludes that the testbeds can contribute to accelerating the standardization and technology diffusion processes.

The next article is titled “Standards development for smart systems—A potential way forward.” Smart systems are born from the integration of ICT and cognitive application areas, such as sensing, actuation, data communication, or energy management. They include intelligent transport systems, smart manufacturing, smart buildings, and smart cities. The multidisciplinary nature of smart systems requires the cooperation between the standardization entities (and individuals) with very different cultures and from equally different backgrounds. The author notices that multidisciplinary is not an entirely a new phenomenon in the ICT domain since ICT itself is the result of the fusion of the IT and telecommunication sector.

But the multitude of SSOs for digital technologies has often led to the domain-specific solutions with few considerations for the cross-domain interoperability. It happens to be a real challenge for the development of the standards for smart systems where the interoperability is essential. The article offers some possible solutions based notably on the study of the case of the geospatial data, which are crucial for a number of smart applications, such as smart cities and intelligent transport systems.

For this article, the spatial data on the web working group is a successful example of the multidisciplinary cooperation between the geospatial domain, whose focus is on the standards for geospatial data and services, and the web domain (W3C), which works on the standards for the world wide web. The article details the lessons from that fruitful collaboration that could be applied to other domains. It also suggests another solution, which is the creation of a dedicated smart system SSO runs according to some functioning principles and process, which have been successfully implemented for developing semantic web technologies standards.

At the core of digital technologies are the data, which can be created, manipulated, transferred, and applied. Consequently, data security is of the primary importance especially because the growing connectivity contributes to security breaches. This is the context for the last article in the special issue that we introduce. It considers how the standardization can contribute to help organizations in protecting their information and is titled “Exploring the adoption data creation of the International Information Security Management Standard ISO/IEC 27001: A web mining-based analysis.” More specifically, it examines why the ISO/IEC 27001 has not been as successful as the

other reference standards even if it has been accepted by many ICT companies and backed by the EU. The article offers fascinating insights about the adoption of the ISO/IEC 27001, which is actually a metastandard, i.e., a management system standard.

The article shows that the moderate attraction for this standard is due to the direct competition with other standards, usually more specialized, as well as the indirect competition of certified partners or IT certified personal. Another barrier to adoption is the cost of certification, especially for small and medium-sized enterprises (SMEs). Finally, the certification for ISO/IEC 27001 is voluntary, contrary to the other standards where legal forces make their adoption practically mandatory. Thus, many companies have no reason to embrace it. However, this attitude could change soon at least in Europe because of the latest EU cybersecurity act adopted in June 2019.

Table I summarizes the key points of the framework regarding the various sources of standardization as well as the contributions of all the articles in the special issue.

IV. AVENUES FOR FUTURE RESEARCH

We believe that the articles in this special issue collectively highlight and individually examine different issues concerning the significance of standardization in a digital and global world. They actualize a number of theoretical frameworks to handle and understand the increasing complexity of the role of the standards in the innovation process and success. They also stimulate the discussion and thinking about the future of standardization from a multicountry and multilevel perspective, and this opens a number of interesting avenues for more research in the future.

For instance, in the case of the SSOs, researchers could examine if digitalization and globalization drive more homogeneity or heterogeneity in the politics of standards’ committees, especially with the rise of the Chinese companies in the last few years. Other interesting research questions relate to the fact that digitalization and globalization are increasing market uncertainty. Does this imply that the institutional regulation always leads to a lower innovation efficiency, while the committee standards have the opposite result, as it is the case in Germany [6]? Could it be different in other jurisdictions with different regulations and innovation policies?

Regarding the market standards, the open-source software is now a major approach in the context of digitalization (e.g., [32]). Consider, for example, how Android or Linux among others has used this approach to become global standards. More research could help to better understand the impact of globalization on such digital open standards.

Concerning the role and place of the governments, future research could examine if digitalization and globalization are pushing for a convergence between the national and multinational standards or, conversely, is this proliferation of national standards moving to a fragmentation and a reduction of international standards. Another interesting area for research would be to examine if and how the increasing contribution of the emergent countries contributes to an intensification of the number of national standards.

TABLE I
MAPPING OF THE VARIOUS SOURCES OF GLOBAL AND DIGITAL STANDARDS

Sources of standardisation	Definition and key characteristics	Examples in digital and the global world	Special issue article focus and contributions
<p>Standard Setting Organizations (SSOs):</p> <ul style="list-style-type: none"> - Standards Development Organizations (SDOs) - Private Sector Consortia 	<p>- SDOs gather representatives from several firms and other stakeholders to derive the technical rules of compatibility between various system components. SDOs usually imply long technical discussions, time consuming political negotiations, and lengthy bureaucratic process. Official SDOs endorse de jure standards</p> <p>- Consortia provide an institutional platform and mechanisms for faster and more flexible market based technical Consortia promote ad hoc standards</p>	<p>- SDOs have long existed. The International Telegraph Union (ITU) was created in 1865, the International Electrotechnical Commission (IEC) was inaugurated in 1906, and the International Organization for Standardisation (ISO) was founded in 1947. A more recently established SDO includes the 3rd Generation Partnership Project (3GPP).</p> <p>Today there are more than 250 private standards setting consortia working on ICT standards development such as W3C (the World Wide Web Consortium), OASIS (the Organization for the Advancement of Structured Information Standards), or OMG (the Object Management Group).</p>	<p>- Paper from Lorenz et al. studies the reasons for innovative technology companies to join technical committees at standard-setting organization (SSO). Prominent reasons are the introduction of new products or services in the market as well as the protection of innovations by patents</p> <p>-Paper from Koch analyses how testbeds can play a key role in the standardisation process for IIoT for different reasons, mainly new insights, fastest process, and use in the work of the SDOs technical committees</p> <p>- Paper from Jacobs examines how the multi-disciplinary nature of Smart Systems require co-operation between standardisation entities with very different cultures and from equally different backgrounds.</p> <p>-Paper from Mirstch et al. explores some limitations of the SSOs with the study of the relative failure of ISO/IEC 27001, a standard designed to protect data.</p>
Market standards	Companies with a dominant market share that use <i>de facto</i> standards to build their own platform ecosystem of suppliers, customers, and other stakeholder.	Examples include the US FAAMG (Facebook, Apple, Amazon, and Google/Alphabet) and the Chinese BATHX (Baidu, Alibaba, Tencent, Huawei, and Xiaomi)	<p>- Paper from Papachristos analyses how some digital platforms outsmart their competitors to become the dominant standard. A model explores how competition outcomes could have been different and reversed an existing a standard.</p> <p>- Paper from Koch examines how testbed play, an important role in the standardisation of innovation for the multi-disciplinarity industrial IIoT (smart manufacturing). Standards are needed to guarantee a smooth and reliable interoperability between multiple devices, machines, and applications across value chains, domains and countries.</p>

TABLE I
CONTINUED

Governments	Government controlled associations or affiliates that try to influence or impose standards for controlling the social consequences of a technology or defending national interests for security or economic development.	<ul style="list-style-type: none"> - In the UK, the BBC controlled the setting of key TV standards. - In Japan, the Association of Radio Industries organized 2G systems standardisation. - In Korea, the Telecommunications Technology Association, headed the development of WIPI, a wireless platform standard. - In Europe, the EU commission drove the cooperation among private and public actors to promote the GSM standard. <p>The Chinese five year plan for 2016-2020 on innovation planned to develop more than 200 international standards</p>	- Paper from Gao et al. provides a detailed analysis of the implication and the role of the Chinese government in the development and international diffusion of the third generation (3G) of mobile systems in China, TD-SCDMA.
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The current coronavirus crisis is just illustrating the power of standardization, digitalization, and globalization. The World Health Organization (WHO) secretariat reviewed and published a list of guidance documents to be adopted by the WHO expert committee on biological standardization. The listing explains how WHO written standards can guide the development, production, and evaluation of candidate COVID-19 vaccines [33]. Furthermore, with the billions of people confined at home all over the globe, the digitalization and accompanying standards govern the online social communication and teleworking. S. Nadella, the current CEO of Microsoft, has estimated that with the coronavirus two years' worth of digital transformation occurred in two months [34]. All the major global digital companies see their revenues growing in 2020. We can safely predict that the global digital world is going to be a new reality for many and standardization will have a fundamental role in it.

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