China's Evolution in International Standardization: From Follower to Global Leader

John Jiong Gong and Vanessa Yanhua Zhang*

Abstract

This study explores China's evolution from a follower to one of the global leaders in international standardization. Following reforms to its standardization system, China has transitioned from a government-led model to a public-private partnership approach, achieving complete alignment with international practices. Supported by strong research and development (R&D) capabilities, market-oriented reforms, and regional and other international cooperation efforts, such as the Belt and Road Initiative (BRI), China has emerged as an increasingly prominent player in international standard-setting, with its influence growing rapidly. This study also features case studies highlighting China's significant contributions to international standard-setting in telecommunications, high-speed rail, and solar energy.

Keywords: standardization in China; regional cooperation; BRI

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China’s changing standardization landscape

China’s standardization landscape has undergone significant transformations over the past few decades. Initially, the country primarily adhered to international standards as a means to integrate into the global economy and enable domestic enterprises to engage in international trade and global value chains. This alignment with established global norms was crucial in laying the foundation for China's technological development and economic growth during the early years of reform and opening up despite China’s relatively limited technological capabilities at the time.

As China’s technological strength grew, its role evolved from merely adopting international standards to actively participating in the processes of international standard-setting. Today, Chinese stakeholders are increasingly influential in shaping global standards, particularly in emerging sectors. This shift illustrates a dynamic interplay rather than a one-sided “export” of Chinese standards; it reflects a co-evolution of international norms driven by enhancing global economic cooperation and China's increasing capacity for innovation. China's leadership in specific technical domains has further contributed to the evolution of international standards, solidifying its position as a key player in the global standardization landscape.

This section explores China’s development in the area of standards across three evolutionary stages: (1) adoption of international standards (1978–2000); (2) catching up with foreign standard-setters (2001–14); and (3) establishing leadership in global standardization (2015–present).

Evolutionary stages of the development of standards in China

1978–2000: Adoption of international standards

China’s recent standardization efforts had their start in translating and adopting Soviet standards. These standards were the foundational references for developing national, sectoral, and specialized standards in key industries. This laid the groundwork for rapidly building a national standard system in a relatively short period (SAC 2021a).

Following the economic reforms of 1978, China recognized the importance of a structured standardization system to support its economic and technological growth. The Chinese government actively promoted the development of standards by implementing a series of regulations that laid the foundation for rapid advancements in standardization research. A pivotal milestone in this process was enacting the Standardization Law of the People’s Republic of China in 1988, which established the nation’s first legal framework for standardization.

From 1978 to 2000, China primarily advanced its development of standards by aligning its practices with international standards. This approach not only enhanced domestic economic development and improved manufacturing quality but also facilitated the integration of Chinese firms into international markets. By 2001, China had formulated 19,744 national standards, of which 8,621 were developed by adopting international standards, suggesting an adoption rate of 43.7 percent (China Quality News Network 2011a) (refer to box 1). Moreover, China had converted 6,300 international standards that are applicable to China into national standards, indicating a conversion rate of 38 percent. These international standards were formulated by the International Organization for Standardization (ISO), one of the largest and most authoritative international standards organizations in the world, and the International Electrotechnical

Commission (IEC), the world's oldest international electrical standardization body, responsible for international standardization in the fields of electrical engineering and electronic engineering. China's engagement in global standardization organizations began with its entry into the IEC in 1957, followed by its participation in the ISO in 1978 (China Quality News Network 2011b) and the World Intellectual Property Organization (WIPO) in 1980.[1] These milestones marked China's early efforts to establish its influence in the international arena. Since then, China has steadily advanced its role in global standard-setting.

Box 1. Assessing the alignment of Chinese standards with international standards

The degree of alignment of Chinese standards with international standards is captured by three widely used statistical indicators, among others: the adoption rate of international standards, the conversion rate of international standards, and the degree of consistency between Chinese standards and international standards. The *adoption rate* represents the ratio of national standards that adopt international standards to the total number of national standards established in China. This indicator was more relevant during the initial stages of China's development in the area of standards. As the volume of national standards grew, this measure was quickly superseded by alternative metrics. The *conversion rate* is the ratio of the number of international standards that have been converted into Chinese standards to the number of international standards assessed as suitable for conversion in China. The *degree of consistency* involves the comparison of Chinese domestic standards with their international counterparts. If, after comparing the technical elements of the standard's technical requirements, a Chinese standard is found to be the same as or comparable to its international standard in the same field, it is considered consistent with the international standard.

In the early stages of China's standardization, the country faced a significant challenge: the number of independently formulated standards was relatively small, resulting in a considerable gap between its economic strength and technical capabilities compared to international standards. At that time, international standards represented the pinnacle of scientific and technological achievements, reflecting advances from around the world. For China, embracing these international standards was not only beneficial; it was a strategic necessity. By adopting these advanced benchmarks, China could enhance its own standardization efforts, thus facilitating the introduction of cutting-edge technologies and promoting export trade. This alignment with international norms also resonated with the interests of Chinese enterprises because it provided them with powerful incentives to innovate and compete globally.

2001–15: Catching up with foreign standard-setters

China's accession to the World Trade Organization (WTO) in 2001 marked a significant turning point, as China actively expanded its role in the global supply chain and technology markets. Along with the adoption of international standards, China also improved its standards management system and innovation level, in preparation for the development of China's indigenous standards (Yang, Gao, and Zhou 2023). This led to an increased demand for a more efficient standardization management system.

A significant step came in 2001 with establishing the Standardization Administration of China (SAC) and the Certification and Accreditation Administration (CNCA).[2] The SAC unified previously fragmented standard-setting bodies across international trade inspection, environmental protection, public security, and other government sectors, creating a centralized system with a robust legal framework and

enforcement authority.[3] To advance the integration of Chinese standards with international frameworks, the government introduced the Administrative Measures for Adopting International Standards. The measure establishes principles for adopting identical or modified international standards, defines requirements for drafting and approving national standards, and outlines best practices for their implementation.[4] The CNCA oversees standards compliance by screening and approving certification bodies responsible for evaluating products and business activities. As of August 2007, the CNCA had reviewed and approved 182 certification bodies across diverse industries, including railways, transportation, communications, chemicals, building materials, and textiles (Xinhua News Agency 2007).

In alignment with international norms, the certification process incorporates the ISO 9001 standards for quality management and the ISO 14001 standards for environmental management (Xinhua News Agency 2007). This approach also facilitates more effective participation in international trade for products produced by Chinese enterprises. As of 2015, the conversion rate of international standards in key consumer industries, such as household appliances, textiles, clothing, furniture, toys, and detergents, exceeded 80 percent in China (SAC 2016). A 2014 study revealed that 3,000 of the 3,800 domestic standards had either aligned with or exceeded their international counterparts when comparing the technical elements of the standards (SAC 2016).

Beyond aligning its standards with international benchmarks, the Chinese government has also actively promoted the global recognition and adoption of its standards. This proactive stance is reflected in key initiatives, such as the National Medium- and Long-Term Plan for the Development of Science and Technology (2006–2020) and the 11th and 12th Five-Year Development Plans for Standardization (Yang, Gao, and Zhou 2023). These plans underscore the critical role of technical standards in the country's economic modernization. The 2006 plan articulated the government's vision for the internationalization of standards, stating, "Encourage industry-academia-research collaboration in studying and developing major national technology standards, and associated priority adoption. Take an active part in international efforts for standards development, and strive to make our country's technology standards international standards."[5]

In parallel with these plans, China also significantly enhanced its involvement in international standardization bodies during this period (NSA 2016). In 2013, China became a member of the Technical Member Board of the ISO, which is responsible for the organization, coordination, strategic planning, and rules of procedure for the technical work of the ISO.[6]In 2015, Xiaogang Zhang made history by becoming the first Chinese president of ISO; he served a three-year term from 2015 to 2017 (NSA 2021). At this time, Chinese members also held more than 10 key positions—ranging from secretariat to president—across technical committees for key consumer industries in the ISO and IEC. Their active participation and proposal submissions have substantially increased China's contributions to these international bodies, evident in the marked increase in the number of international standards developed by China—from 13 before 2000 to 182 in 2015, according to ISO data—underscoring China's growing influence in the global standard-setting landscape (Phoenix News Media 2022).

2015 to present: A key setter of international standards and a leader in specific sectors

In 2015, China recognized the need to reform its process of developing standards to better align with a dynamic market economy and reduce government intervention (Sheehan and Feldgoise 2023). To shift the focus from state-led efforts to industry-driven initiatives, the government introduced the Scheme for Deepening the Reform of Standardization Work. This policy aimed to grant greater autonomy to research

organizations, private companies, and academic institutions, thereby fostering competition in innovative fields and advancing China's transition to a market-driven standard-setting system. The policy emphasized that the government should maintain only the "lowest threshold" for standards, allowing diverse entities to compete and drive innovation in standardization.[7]

The process has not been without its challenges. The main challenges stem from the gap between policy objectives and market realities, as well as the coordination barriers posed by different government departments' understandings of implementation details. A notable example is the phased rollout of the emission standards for heavy-duty diesel vehicles. Although the China IV emissions standard was scheduled for nationwide adoption starting in 2013, its rollout faced repeated delays due to divergent views between the Ministry of Ecology and Environment (MEE) and the Ministry of Industry and Information Technology (MIIT), particularly over the quality of domestic diesel fuel. As a result, the full implementation of China IV did not occur until January 2015. These experiences reflect the complexity of implementing standards in large-scale systems and the need for effective coordination among government regulators, industry stakeholders, and infrastructure providers to ensure standards are both technically feasible and practically enforceable (China Association of Automobile Manufacturers 2014).

China's vision for greater participation in global standardization was further solidified with the release of the National Standardization Development Outline in 2021, which outlines China's medium-term goals for standardization, with a target date of 2035. The outline highlights the government's strategic objective of establishing leadership in global technology standards. Specifically, it details efforts to strengthen standards research in emerging fields, including artificial intelligence (AI), quantum information, biotechnology, big data, blockchain, health care, new energy, and new materials (CEST 2021).[8]

To bolster these efforts, in mid-2024, China published the Guidelines for the Construction of a Comprehensive Standardization System for the National Artificial Intelligence Industry (Xinhua News Agency 2024a). These guidelines set goals to publish at least 50 national standards in AI and participate in the making of at least 20 international standards by 2026. Later in 2024, MIIT announced the formation of a 41-member committee tasked with establishing industry standards for large language models and assessing the risks associated with AI (Reuters 2024). This committee is pivotal in China's AI standardization efforts, linking domestic expertise with the ISO/IEC JTC 1[9]—one of the four major organizations involved in AI standard-setting.[10] Notably, China serves as the convenor for one of the five working groups under ISO/IEC JTC 1/SC 42 (ISO-IEC JTC 1 N17016 2024),[11] further solidifying its influence in global AI governance.[12]

In addition to AI, China has also emerged as a leader in developing standards for high-speed railways. In 2012, the country initiated the design of its first domestically produced high-speed railcar, culminating in the launch of the Fu Xing Hao in 2017. With a maximum speed of 350 km/h, it became one of the world's fastest high-speed trains (Jones 2023). Notably, 84 percent of the standards adopted in Fu Xing Hao were Chinese standards (Xinhua News Agency 2017). In 2022, the International Union of Railways (UIC)[13] published two international standards for the design of high-speed railway infrastructure and power supply, both of which were developed under China's leadership.[14] By 2024, China had led the development of all 13 system-level international standards for high-speed rail established by the UIC and contributed to 300 standard-setting projects in collaboration with the ISO, IEC, and UIC (Xinhua News Agency 2024b).

China has also contributed to regional technological development and standardization. China's landmark foreign policy initiative—the Belt and Road Initiative (BRI)—aspires to elevate the internationalization of

standards to a strategic priority. According to a 2024 interim progress report, China aims to "carry out exchanges on standardization with more countries and promote the integration of standardization work with more countries to jointly build the 'Belt and Road'" (SAMR 2024). In 2017, 81 bilateral standards agreements were signed between China and 47 countries, designed to facilitate international trade and reduce technical trade barriers. By the end of 2023, China had established 108 bilateral and multilateral standardization cooperation agreements with 65 national and regional standardization institutions and international organizations. This includes 57 agreements with the 47 countries participating in the BRI (SAMR 2023a).

China has also encouraged regional standardization cooperation through other efforts such as a conference with Southeast Asian countries in Guangxi, China, in 2019. The conference aimed to promote Chinese standards in agriculture, infrastructure, mechanical engineering, and information technology in countries such as Cambodia, Lao PDR, and Myanmar (China News 2019).

Notably, the evolution of China's standardization regime from a purely government-led model to a "government + market" approach reflects a well-founded economic and institutional strategy. First, this shift aligns with China's broader market-oriented reforms that began in the late 1970s. As state planning has transitioned to competitive markets, allowing enterprises and industry alliances to co-develop standards has become a logical extension of these reforms. Second, China's rapid industrial upgrading and deep involvement in global supply chains have created a practical need for faster and more specialized standards that align with international best practices and the latest technologies—something that industry stakeholders are uniquely equipped to provide. Third, the coexistence of state oversight and market initiative fits well within China's governance structure. In the case of standards, the government maintains a coordinating role to safeguard public interests such as safety, health, and environmental protection while leveraging private expertise to capture market signals and drive innovation. From an economic perspective, this hybrid model helps reduce information asymmetry, lowers transaction costs, and accelerates the diffusion of new technologies, ultimately enhancing overall competitiveness. Thus, the transition to a "government + market" parallel system is both a rational policy response to China's reform context and an effective mechanism for supporting sustained economic growth.

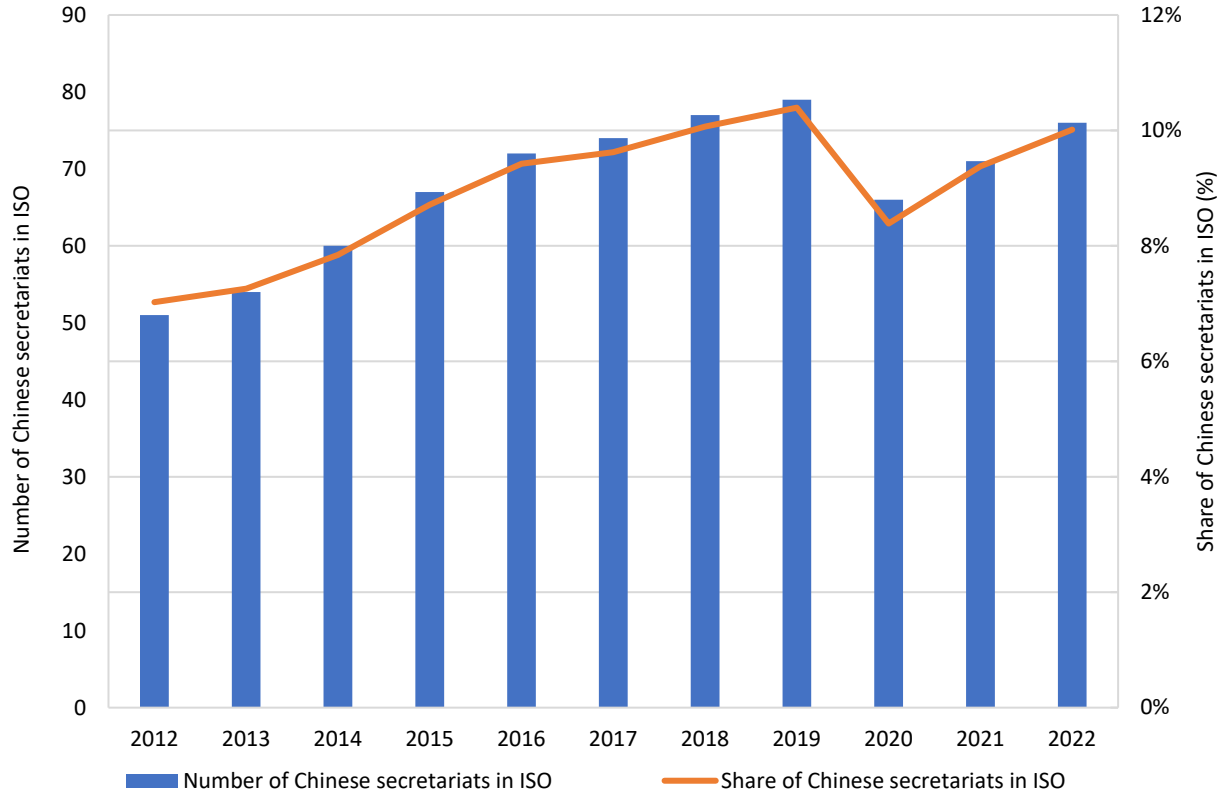
Significant expansion in international standardization organizations

China's transformation from a standard follower to a proactive leader in global standardization is underscored by various measurable indicators, each reflecting distinct dimensions of its evolving influence. These metrics collectively capture the nation's advancements in integration into global standardization governance frameworks, technological innovation, and regional technical cooperation.

Growing participation in global standardization

A critical aspect of China's increasing influence is its leadership roles within international standardization organizations. For instance, as illustrated in figure 1, the number of ISO secretariats held by China—a critical indicator of administrative and strategic control over standard-setting processes—has increased, growing from 51 in 2012 to 76 in 2022 and boosting China's share of global ISO secretariats from 7 percent to 10 percent (CIRA 2022, 26). Additionally, the number of Chinese experts appointed as ISO convenors has increased, rising from 75 in 2012 to 226 in 2021, demonstrating a deepening of technical expertise and recognition as mediators in complex standardization discussions.

Figure 1. The rising share of Chinese secretariats in the International Organization for Standardization (ISO), 2012–22



Source: Compiled by Exovera's Center for Intelligence Research and Analysis (CIRA 2022, 6) from "ISO In Figures."
Note: Data for 2022 are as of July 2022.

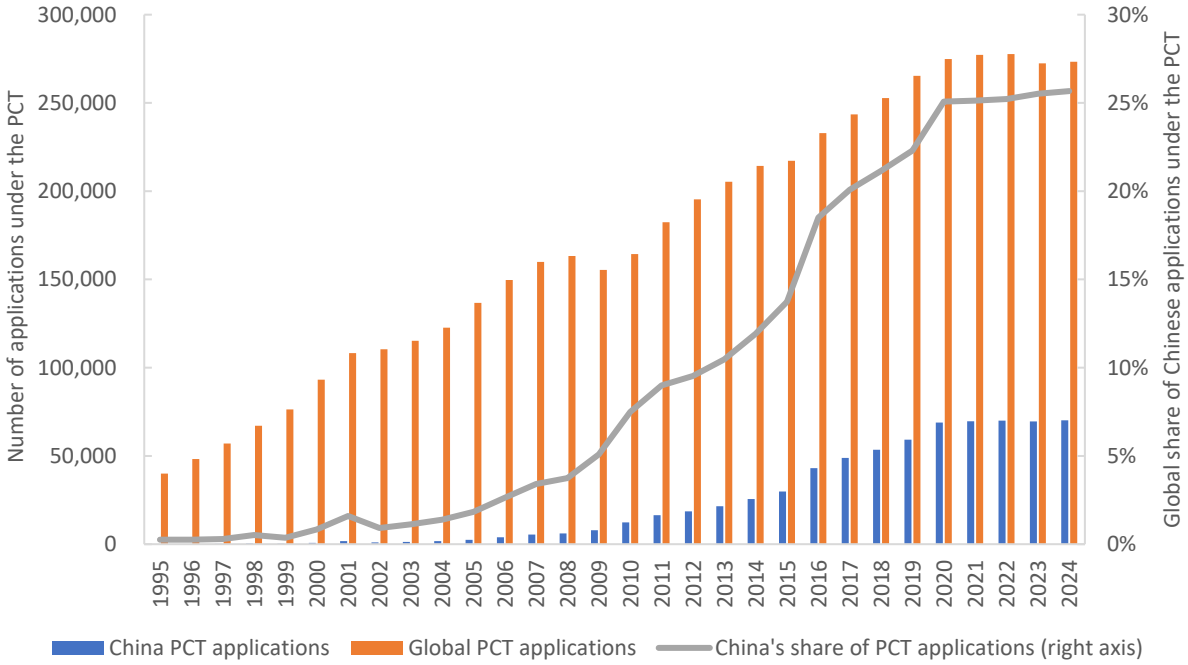
China's expanding participation in various technical committees and standard proposals of major international standard-setting organizations is also significant because it reflects China's capacity to shape norms rather than merely adopt them. Moreover, from 2012 to 2021, the number of IEC international standards proposed and published by China quintupled, rising from 62 to 368 (Yang 2022). By the end of 2022, China had submitted 1,337 proposals for ISO and IEC standards, making it one of the most active contributors to international standards (Globe Magazine 2023).

Such an increased participation in global standard-setting has significantly enhanced China's influence across various technology sectors, particularly in telecommunications. This increasing influence is evident in its increasing membership and representation in leadership positions within the International Telecommunication Union (ITU), the world's largest telecommunications organization.[15] The number of Chinese members in the ITU rose from 16 in 2013 to 106 in 2022 (CIRA 2022). Notably, Zhao Houlin became the first Chinese Secretary General of the ITU in 2014 and was re-elected in 2018 (Permanent Mission 2020). These significant involvements are enabling China to shape the future of wireless technology. A recent example of this influence occurred at the 2023 World Radiocommunication Conference, where China advocated for the reallocation of the 6425–7125MHz frequency band for the International Mobile Telecommunications (IMT) system, a crucial step in advancing next-generation communications, including 6G technology (MIIT 2024).

Rising innovation efforts

China's increasing significance in global standard-setting is closely tied to its robust research and development (R&D) initiatives and extensive technological innovation. This is particularly evident in the surge of patent filings. For instance, as illustrated in figure 2, China's applications under the Patent Cooperation Treaty (PCT) surged from 103 in 1995 to 70,153 in 2024, with their global share rising from 0.26 percent to 25.6 percent.[16] This exponential growth reflects China's shift from imitation to innovation.

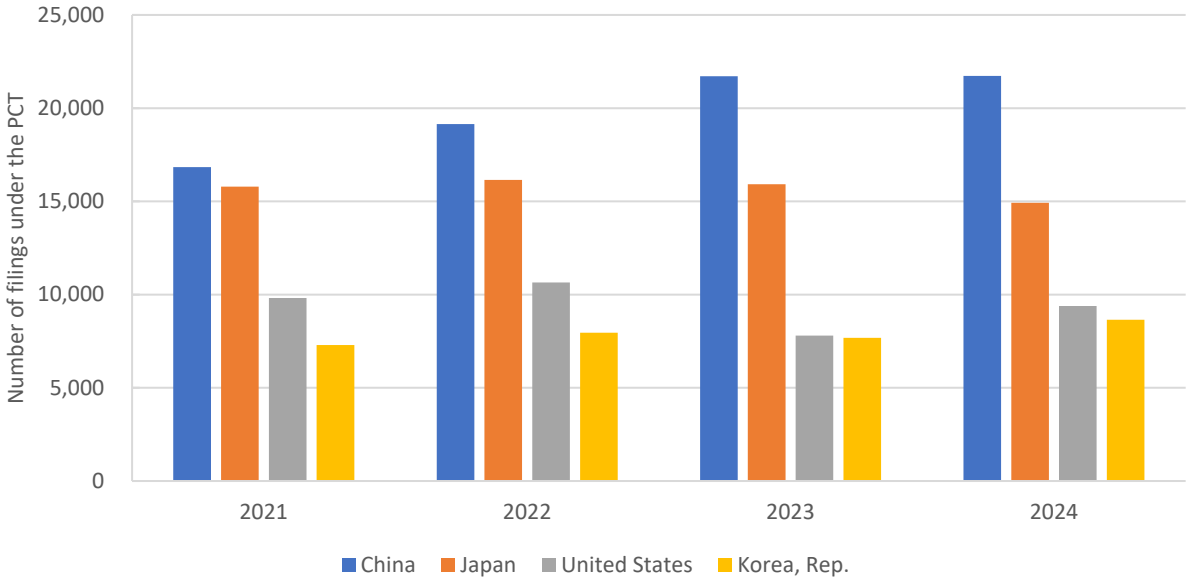
Figure 2. The upward trend in the number and global share of Chinese applications under the Patent Cooperation Treaty (PCT), 1995–2024



Source: World Intellectual Property Organization (WIPO) Statistics Database.
Note: Historical data are based on the latest disclosed statistics from WIPO for that year.

In particular, the number of PCT applications submitted by Chinese firms has consistently exceeded those of their international counterparts since 2021, as demonstrated by figure 3. In 2024, Huawei led the PCT rankings, filing 6,600 PCT applications—almost 1.5 times that of the second-ranked Samsung (4,640). Collectively, applications from Chinese firms in 2024 reached 21,730, nearly 50 percent more than those of companies from Japan (14,925), the second-ranked country (WIPO 2024). These innovative achievements by Chinese entities have provided solid support for their further participation in the global standardization process.

Figure 3. Consistent lead of Chinese firms in filings under the Patent Cooperation Treaty (PCT) among the top 50 global firms filing under PCT, 2021–24



Source: World Intellectual Property Organization (WIPO) Statistics Database.
Note: The figure presents the total number of filings under the PCT for Chinese firms, Japanese firms, US firms, and Korean firms based on WIPO's annually reported top 50 firms filing under PCT. Historical data are based on the latest disclosed statistics from WIPO for that year.

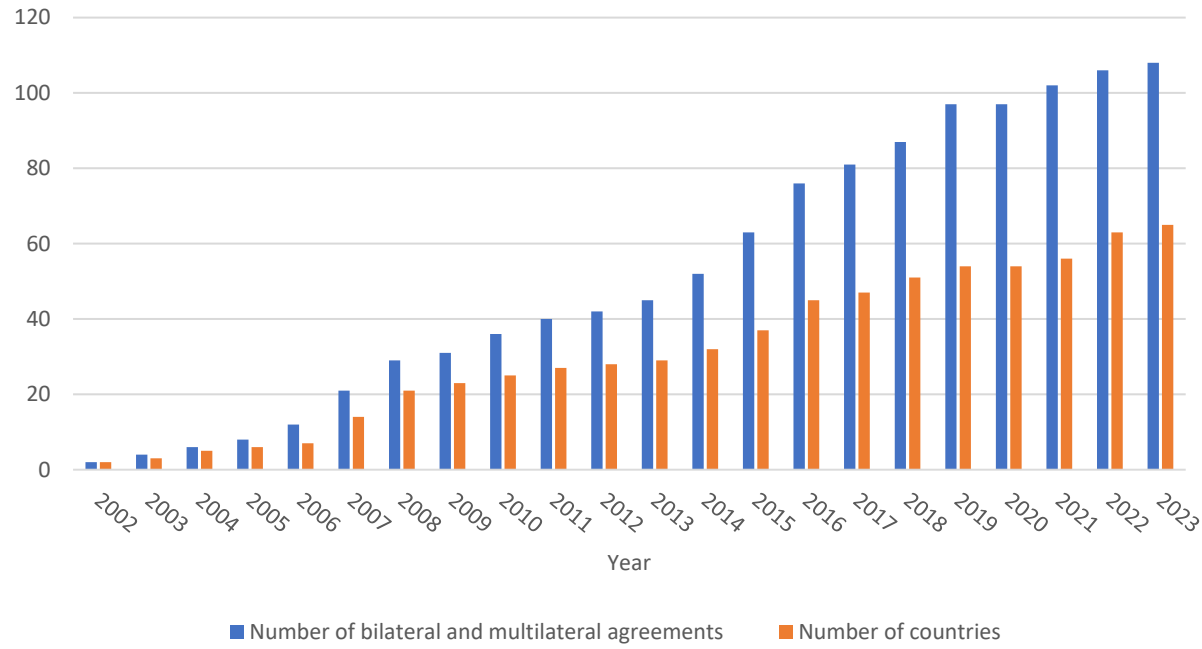
Moreover, China has established itself as the leading source of patent applications in several innovative fields, ranking first globally in areas such as 5G, blockchain, and AI (CAC 2021). Since the commercial rollout of 5G in 2019, China has been a leader in patent declarations, accounting for 42 percent of worldwide applications by 2024 (People's Daily 2024a). Notably, both Huawei and ZTE ranked among the top three globally in the declared 5G standard essential patents (SEPs) disclosed to the European Telecommunications Standards Institute (ETSI) (CAC 2021). By March 2024, Huawei had ranked first globally in 5G patent family ownership and continued to lead in technical contributions submitted to 3GPP, the organization responsible for developing 5G standards. With a commanding 12.42 percent of global 5G patents, Huawei is followed by ZTE (6.97 percent), Oppo (4.36 percent), and Da Tang (3.78 percent), underscoring China's strong presence in telecom innovation (CAICT 2024). These increases in the share of Chinese firms in the global SEP can serve as a close proxy for the growth in their licensing revenues, reflecting their economic success driven by technological advances.

Achievements in international standardization prompted by regional cooperation initiatives

China's contribution to the international standardization process has also been bolstered by its extensive regional cooperation. For example, since the BRI began, cooperation in standardization among China and the BRI countries has significantly strengthened. Between 2013 and 2023, Chinese applicants filed patent applications in 52 BRI partner countries and related organizations, resulting in a total of 70,000 filings and an average annual growth rate exceeding 20 percent, further solidifying China's position in the regional innovation landscape (CNIPA 2024a, 2).

A notable aspect of China's regional cooperation is the signing of 43 regional cooperation agreements on standardization with over 30 Belt and Road partner countries since 2014, highlighting its importance in fostering bilateral and multilateral relationships. The China National Standards Commission has also been active in this arena, having signed 108 documents on standardization cooperation with 65 national standardization bodies, regional organizations, and international entities. As illustrated in figure 4, the number of bilateral and multilateral international standardization cooperation agreements, as well as the number of participating countries, has been steadily growing (SAMER 2024).

Figure 4. A steady increase in the number of standardization cooperation agreements and participating countries, 2002–23



Sources: Standardization Administration of China (SAC); State Administration for Market Regulation (SAMR).

In support of these collaborative efforts, China has also hosted multiple forums to enhance standardization exchanges. Prominent events include the BRI Forum for International Cooperation,[17] the China-ASEAN Standardization Cooperation Forum with members of the Association of Southeast Asian Nations (ASEAN),[18] the China-South Asia Standardization Cooperation Working Meeting,[19] and the BRICS Ministerial Meeting on Standardization Cooperation.[20] These events have facilitated standardization exchanges with more countries and promoted the alignment of standardization efforts with BRI partner countries. Notably, the three BRI Forums for International Cooperation have included eight standardization achievements in their outcome lists (SAMR 2024).

China’s proactive approach to promoting standardization cooperation with BRI partner countries extends across various fields. In road transportation, China has collaborated with BRI partner countries to develop 31 UIC standards for railways, with 18 of these standards already published. China has also supported the construction of 8 railway cooperation projects, including the China–Laos railway, the Mombasa–Nairobi railway in Kenya, and the Jakarta–Bandung high-speed railway in Indonesia. Additionally, 92 Chinese standards on the design, construction, and quality assessment of highways, bridges, and tunnels have been translated into English, French, and Russian, providing valuable experience for developing countries in road construction.

In energy infrastructure, China and BRI partner countries have engaged in international standardization cooperation in solar energy, nuclear power, ultra-high voltage (UHV) transmission, and smart grids through various initiatives and have successfully developed 88 international standards and prepared 19 technical reports for the International Commission on Large Electricity Grids (CIGRE).[21] All these accomplishments underscore the significance of regional cooperation initiatives, exemplified by the BRI, in achieving substantial advancements in regional standardization efforts.

China's model for developing standards

Since the reform of China's standardization system in 2015 and the enactment of the revised Standardization Law in November 8, 2017 (which went into effect January 1, 2018), significant advancements have been made in the country's development and management of standardization. The standardization development model has shifted from a predominantly government-led model to a more collaborative approach that engages various stakeholders from both the government and the market. Moreover, the Chinese legal system is enhancing the protection of intellectual property rights (IPR), offering equal protection to domestic and international IPR owners. This legal framework incentivizes technological development through innovation and supports the ongoing progress and internationalization of China's standardization efforts. These shifts and initiatives have significantly contributed to the swift advancement of standardization in China. China plays an increasingly significant role in developing standards worldwide, and is emerging as a setter of international standards and contributing notable beneficial influences to global technology and economic progress, particularly for some developing countries. The discussion that follows provides a detailed overview of the current standardization system and the framework for development of standards in China.

Overview of the standardization system in China

The revised Standardization Law, which came into force in 2018, delineates a hierarchical framework that includes three types of government-led standards (national standards, industry standards, and local standards),[22] as well as two types of market-driven standards (association standards and enterprise standards), which are developed by various market players. Association standards are formulated by social organizations, such as industry associations and technological alliances, while enterprise standards are developed either individually or collaboratively among enterprises.

These standards have different scopes of application. *National standards* are applicable nationwide, ensuring no other standards in the same field—sector standards, local standards, association standards, and enterprise standards—conflict with them. *Industry standards* are tailored to specific sectors, while *local standards* pertain to individual provinces and municipalities. Specifically, the local standards play a role in addressing needs specific to the region. In Lijiang City, for example, several local standards have been developed to align with the region's unique ecological and agricultural characteristics. One such standard, the Technical Regulations for the Propagation of Paeonia delavayi Seedlings, was tailored to the high-altitude environment of Lijiang. It provides a localized technical framework for improving seedling development, effectively addressing challenges such as prolonged nursery cycles and poor seedling quality. Given the diverse environmental and economic conditions across regions, the differentiation of local standards reflects a practical response to unique natural and industrial needs (China Quality News Network 2024).

Association standards are adopted voluntarily nationwide, while *enterprise standards* are applied exclusively within individual enterprises.[23] Notably, enterprise standards are akin to European technological specifications that are not recognized as formal standards due to the absence of consensus procedures. In China, however, enterprise standards play a crucial role in enhancing the technological capabilities and competitiveness of industries (Xu 2020).

The classification of standards also varies in terms of their binding nature. National standards can be categorized into two types: *mandatory standards*, which must be followed, and *recommended standards*, which are voluntarily adopted. In contrast, all other types of standards are adopted voluntarily by the market participants. Indeed, the standardization reform has led to the elimination of most mandatory standards. In 2019, the mandatory national standards were drastically reduced to 2111 items, which is about 41 percent less than before the reform. For example, the State Administration for Market Regulation (SAMR) has consolidated 22 mandatory national standards for lamp safety requirements into a single standard (SAMR 2019). As a result, recommended standards—chosen voluntarily by market participants—have become the predominant focus.

These voluntary standards can deliver several benefits. They raise information transparency by giving regulators, buyers, and consumers clear performance benchmarks beyond the legal minimum. They can also intensify competition because firms can signal superior quality or innovative features by conforming to a higher-level voluntary standard rather than merely meeting a mandatory baseline. Minimizing the scope of mandatory standards likewise strengthens the market-oriented dynamic of China's new "government + market" model. When only a narrow safety-oriented baseline is mandatory, competing voluntary standards can compete on technical merit, cost-efficiency, and user acceptance. This standard competition curbs the risk that any single specification gains undue regulatory protection, thereby limiting monopoly rents and preventing technology lock-in. Firms are incentivized to innovate and differentiate, while adopters can shift to superior standards as technologies evolve. The result is a more contestable, transparent, and adaptive standards ecosystem—one that aligns with industrial economics theory by fostering dynamic efficiency and ensuring that market signals, rather than regulatory fiat, determine which technical solutions ultimately prevail.

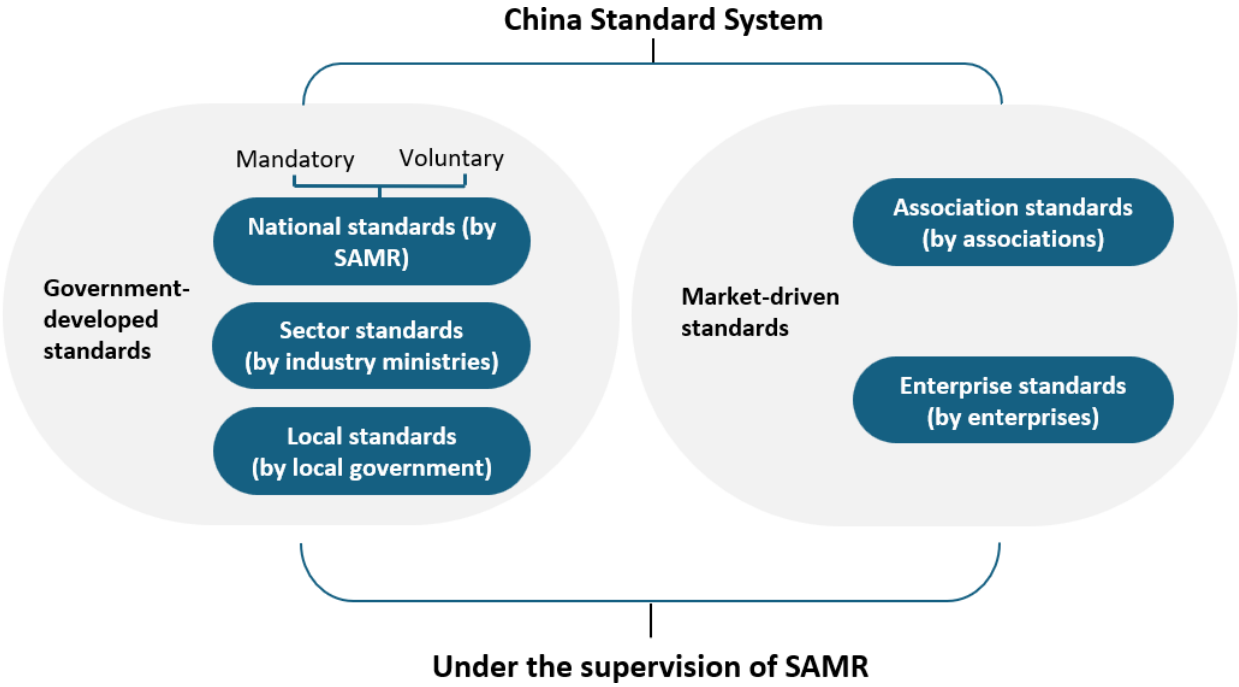
Specific critical industries—primarily in the areas of public safety and medical equipment—still have some mandatory standards. These standards aim to protect people's health and the security of their lives and property, safeguard national and eco-environmental security, and fulfill the basic requirements of economic and social management.[24] In essence, these mandatory national standards act as technical regulations and set out the minimum technical requirements; voluntary standards are required to surpass the technical requirements set by relevant mandatory national standards.[25]

China has studied and taken inspiration from the European Union's "New Legislative Framework" and its focus on essential requirements, but there are some differences in implementation (Gommel et al. 2022; Xu 2020). More specifically, in the European Union (EU), regulations define essential requirements, such as safety or environmental protection, while harmonized standards offer one way to demonstrate compliance, granting products a presumption of conformity without being mandatory (presumption of conformity). China does not have technical regulations similar to those of the EU. Instead, China's mandatory standards serve a dual role as both technical specifications and regulatory instruments, and full compliance is legally required.

Consider the standardization of China's automobile sector as an example. Recent data indicate that mandatory national standards account for the smallest share among all automobile standards and are primarily focused on safety-related technical requirements. There were 1,556 automotive national and industry standards as of March 2025, according to statistics compiled by the China Automotive Technology and Research Center (CATARC) and the National Technical Committee of Auto Standardization (NTCAS). Only 119, accounting for just 7.6 percent, were mandatory standards. They span a wide range of safety concerns, including comprehensive safety, general safety, active and passive safety, as well as energy conservation and environmental protection. Among the remainder, 55.3 percent (861) were industry standards and another 37.0 (576) percent were recommended national standards

Figure 5 provides an overview of the current development and management system of standards in China. In recent years, the proportion of standards driven by the government has gradually declined, while market-driven association standards and enterprise standards have been gaining prominence. Data from the *Annual Report on Standardization Development in China* document this trend. Specifically, from 2018 to 2023, national standards decreased from 25.54 percent to 16.53 percent, industry standards fell from 42.75 percent to 30.02 percent, and local standards kept from 25.62 percent to 25.89 percent (SAC 2020, 2021b, 2023, 2024).

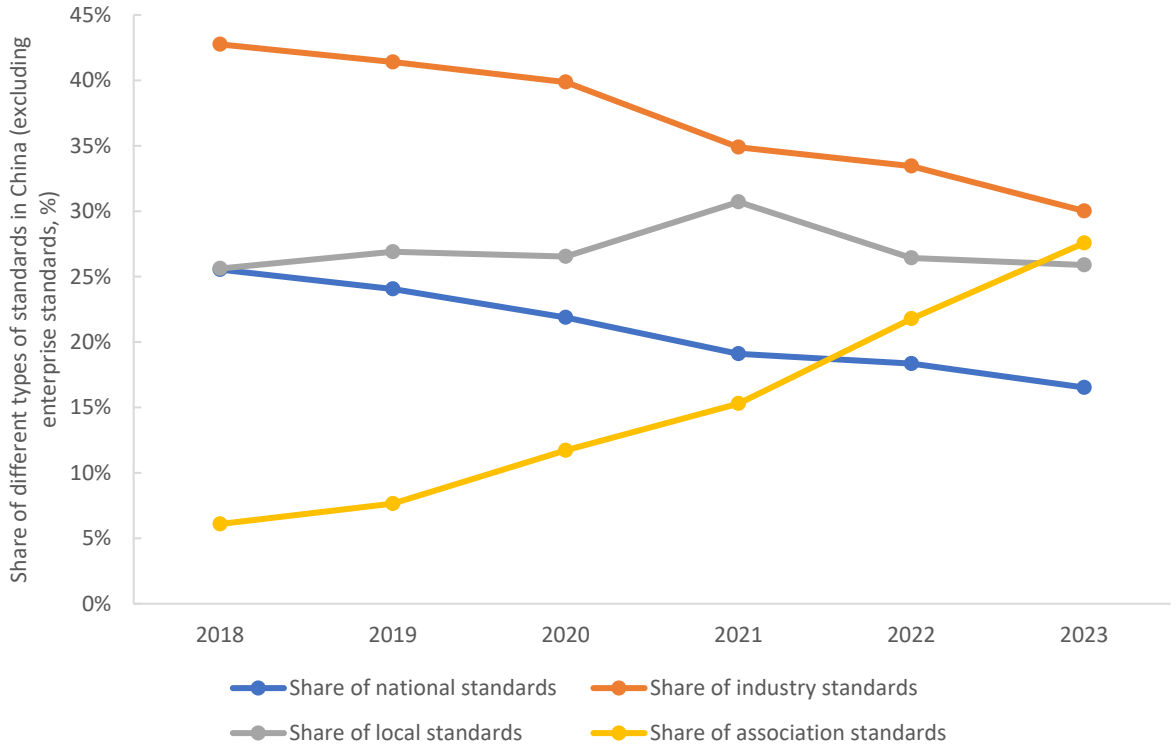
Figure 5. Overview of the Chinese standard framework



Source: The Standardization Law of P.R.C. (2017, effective 2018).
Note: SAMR = State Administration for Market Regulation.

In contrast, the share of market-driven standards has significantly increased, as illustrated in figure 6. The share of association standards has risen, going from 6.09 percent in 2018 to 27.57 percent in 2023 (SAC 2024), making them the third-largest category among different standards. This trend highlights the essential contributions of diverse enterprises and social organizations to standardization development and signifies a significant shift from government-led standards to those jointly powered by the government and the market.

Figure 6. The rising share of market-driven association standards compared to three types of government-led standards in China, 2018–23



Sources: Standardization Administration of China (SAC); State Administration for Market Regulation (SAMR).
Note: To present the results more clearly, calculations excluded the number of enterprise standards from the share of association standards as well as from the three government-led standards.

China's model of developing standards: partial convergence to the Western model

China's model in the area of standards has transitioned from a largely government-led approach to a more collaborative framework that actively involves a diverse array of public and private stakeholders, including, increasingly, international ones. This growing involvement of market players, particularly concerning the prominence of association standards, indicates that China's standard-setting paradigm is shifting toward the Western model to some extent. A reformed model, fueled by *enhanced* innovation inputs and bolstered by a robust intellectual property system, has enabled China to achieve significant advancements in its development of standards, aligning them with international technological standards. Moreover, the ongoing promotion of regional policies has further facilitated China's ability to export its technical standards internationally, positioning the country as a leader in various areas of global standardization.

Shift from government-led to market-oriented multistakeholder engagement

This transition has been characterized by market-oriented mechanisms and enhanced participation from industry associations, scientific research institutes, and universities, as well as numerous state-owned and private enterprises. These entities collectively drive the accelerated advancement of standardization in China through substantial innovative research and development investments and extensive collaborative efforts. In particular, the shift in the formulation model of standards in China exhibits the following characteristics.

Public-private cooperation under government coordination

The government of China leads the formulation and promulgation of standards across three categories: national, sectoral, and local. Central to this process are the Standardization Technical Committees (STCs) and Technical Working Groups (TWGs) led by the State Council administrative departments for standardization in China, with involvement from a wide range of public and private parties.[26] Typically, they comprise government agencies, state-owned research institutions, and private enterprises, all collaboratively working to advance standardization initiatives and promote technological innovation.

Specifically, industry stakeholders in China are encouraged to participate in developing national standards, both mandatory and voluntary. To promote their effective engagement in the formulation and revision of mandatory national standards, SAMR issued the Administrative Measures for Mandatory National Standards in 2020.[27] This regulation provides mechanisms for industry stakeholders at various stages of the standardization process, including project proposal, approval, public consultation, international notification, and implementation oversight. Stakeholders include enterprises, public institutions, social organizations, consumer associations, research and educational institutions, and individual citizens. For instance, during the project proposal stage, any of these parties may submit suggestions for new mandatory national standards to the competent authority under the State Council or provide feedback to relevant administrative departments. Similarly, during the project approval stage, stakeholders may offer comments during the public announcement period. This inclusive approach enhances transparency and ensures that mandatory standards reflect diverse societal needs.[28]

This collaborative model, which encourages engagement between the public and private sectors under the leadership of the relevant government, has significantly contributed to the advancement of standardization in the country. For example, as a working group to promote the advancement of 5G technology in China, in February 2013, MIIT, the National Development and Reform Commission (NDRC), and the Ministry of Science and Technology (MOST) jointly established the IMT-2020 (5G) Working Group, with members comprising the three major domestic telecom operators; industry players such as Huawei; and universities and research institutes such as Tsinghua University. Some six years later, in June 2019, MIIT further promoted the establishment of the IMT-2030 (6G) Working Group, with members including not only China's major operators, manufacturers, universities, and research institutes but also multinational firms such as Apple and Samsung, signifying greater diversity.[29]

In addition to its role in standard-setting, the Chinese government provides substantial guidance and support to social organizations and enterprises in their formulations of standards. The government also encourages participation by Chinese enterprises in standard-setting by implementing various preferential policies. These policies include tax exemptions and reductions, financial support for scientific research initiatives, and recognition awards for enterprises and individuals who demonstrate exceptional contributions to the standard-setting endeavor. This collaborative approach facilitates a more responsive adaptation to dynamic market demands.

Market-driven development

The revisions to the Standardization Law in 2017 established the legal status of association standards for the first time. This law encourages social organizations—such as societies, associations, chambers of commerce, federations, and industry technology alliances—to actively collaborate with various market stakeholders to formulate market-driven association standards. By doing so, China aims to better align with the evolving demands of the marketplace and technological advancements.[30] Association standards, developed independently by market players, can be freely chosen and voluntarily adopted by market

participants. This introduces a competitive landscape where association standards vie for acceptance, harnessing the mechanisms of market competition to identify those that best meet consumer needs.[31]

Although both recommended national standards and association standards are, in principle, applicable nationwide, there are certain differences in practice. Recommended national standards are developed under government leadership and follow a formalized process involving project approval, public consultation, technical review, and so on, and are then made available for voluntary adoption across the country. In contrast, association standards are formulated by social organizations such as academic societies, industry associations, chambers of commerce, federations, or industrial technology alliances. These standards do not require government approval and are typically adopted by the members of the organization that issued the standard through mutual agreement and are offered for voluntary adoption nationwide.[32] As a result, while association standards are theoretically available for national use, they are not necessarily adopted by all relevant industry participants across the country. Nevertheless, association standards remain a vital channel for market-driven participation in the broader national standardization process.

The collaborative efforts of these social groups can include state-owned research institutes, universities, and both state and private enterprises across the industrial chain. Such cooperation enhances the efficiency of developing standards, allowing for more responsive alignment with market demand. It effectively guides research initiatives through the lens of market participants' needs and facilitates the industrial application of technology advancements. A notable example of this collaboration is the China Communications Standards Association (CCSA). As indigenous telecommunications companies gained prominence, the CCSA was established in 2002. Unlike the top-down governance that used to prevail in China, the CCSA was composed of internet service providers (such as China Unicom); technology companies (such as Huawei and ZTE); manufacturers (such as BOE Technology Group and Nokia Shanghai Bell Co.); universities (such as Peking University); and research institutions (such as the Institute of Computing Technology) (Suttmeier, Yao, and Tan 2024). This marked a shift in standardization, where the government was no longer the sole driving force; instead, market dynamics brought private sector leaders to the forefront of standard-setting efforts and led to China emerging as an active player in international standards setting. In 2004, the CCSA became an organizational partner of the 3rd Generation Partnership Project (3GPP). By 2014, its members had submitted more than 10,000 contributions to ITU, 3GPP, 3GPP2, and other international and regional standards bodies. Securing a seat at the table allowed Chinese enterprises to help shape international standards, reflecting China's growing influence in the global economy (Zhao 2018).

Similarly, the China Automotive Engineering Association established the Electric Vehicle Industry Technology Innovation Strategy Alliance, involving enterprises, research institutions, and universities. This alliance has made significant strides in developing standards in the electric vehicle (EV) sector. As of March 2025, its official website has recorded the release of 59 association standards, covering areas such as EV vehicle control, battery testing, fire safety, brake energy recovery, heat pump air conditioning technology, and wireless charging, among others.[33] These efforts have provided significant impetus for developing technical standards and industrialized applications in the rapidly growing electric vehicle sector.

In addition to association standards, technical standards developed independently or jointly by enterprises are also an important part of the market-driven standards in China. The Chinese government consistently encourages enterprises to conduct innovative research and development, incorporating their innovations into standard-setting work. This approach enables the development of high-quality products and services

with high-level standards, ultimately facilitating the internationalization of its technologies and products (SAMR 2023b). With policies such as special funds for developing enterprise standards and provision of credit support for enterprises with high standardization levels, Chinese enterprises have achieved a leap in R&D investment and innovation achievements in recent years. These have supported the rapid development of enterprise standards, enhancing the technical capabilities of Chinese companies to compete with international standards of the highest caliber and facilitating their involvement in formulating international standards.

The share of R&D investment in the overall economy rose from 2.36 percent in 2020 to 2.68 percent in 2024, according to statistics from China's National Bureau of Statistics (NBS),[34] reflecting a gradually narrowing gap with the United States, where this indicator stood at 3 percent in 2024. More specifically, the number of Chinese companies in the top 2,500 global R&D spenders grew from 199 in 2013 to 679 in 2022.China has surpassed Japan and the European Union, securing second place worldwide regarding the number of companies with high R&D investment. This robust R&D investment has also resulted in a steady increase in patent applications submitted by Chinese enterprises. In 2024, the top 500 Chinese enterprises filed 2,029,700 patents, marking a 7.66 percent yearly increase. Notably, 899,600 were invention patents, reflecting a 19.67 percent rise over the prior year (China Economic Net 2024).

These innovations have significantly contributed to developing enterprise standards and encouraged Chinese enterprises to actively create and draft international standards. In 2024, the top 500 Chinese enterprises announced their participation in formulating 5,267 international standards, an increase of 275 compared to the prior year (China Economic Net 2024).

Notably, these market-developed standards can influence the development of national and industry standards from the bottom up. If market-driven standards achieve sufficient recognition and are proven to have application value, they may transition into national, industry, and local standards or be referenced in government policies and regulations (Xu 2020). In other words, the impact of these market-developed standards can extend beyond the association and enterprise standards themselves to the entire standardization system in China.

Aligned with international best practices

To mitigate technical barriers to trade and respond to the demands of global commerce, the Chinese model of developing standards has made internationalization one of the focuses of reform and has fostered the convergence of Chinese standards with international best practices through various aspects.

First, China has developed many standards based on international benchmarks set by organizations such as the ISO, IEC, and ITU. These Chinese standards either directly adopt the content of international standards or incorporate suitable modifications to better reflect the practical context of the country. The conversion rate of international standards in China has steadily increased, rising from 75 percent in 2021 to 82 percent in 2023, according to the *Annual Report on Standardization Development in China*.[35] Notably, in key sectors such as equipment manufacturing—including construction machinery, the chemical industry, and ferroalloys—and new-generation information technology channels such as the Internet of Things and artificial intelligence, the conversion rate of China's international standards has surpassed 90 percent (SAC 2024). In addition to converting international standards, China also continuously promotes the mutual recognition of existing domestic standards with international standards to reduce the cost of repeated certification for enterprises. It has facilitated enterprises' exports by signing agreements on mutual

recognition of standards with several countries (SAC 2024). Such alignment efforts enable many products produced by Chinese enterprises to achieve compatibility and interchangeability with international products, facilitating the development of China's international trade.

Second, China has made significant strides in enhancing its international connections as it develops and formulates its own standards. The country actively promotes global cooperation in its standardization process to facilitate this goal by inviting international participation. The Standardization Technical Committees play a crucial role in this effort, as they increasingly integrate international parties into their activities. Recent data from SAMR indicate that representatives from foreign-invested enterprises have emerged as an important segment of the newly appointed members of China's technical committees. In 2023 alone, 400 new members from foreign-invested enterprises joined China's technical committees, representing 5.4 percent of the new members that year (SAC 2024).

The National Technical Committee for Information Security Standardization (TC-260) illustrates this inclusivity. This committee boasts participation from diverse stakeholders, including state-owned research institutions such as the Chinese Academy of Sciences, private companies such as Huawei and ZTE, and leading foreign corporations such as Intel, IBM, and Siemens. This diverse representation underscores China's commitment to aligning its standardization efforts with international standards and practices.[36]

Third, China has significantly enhanced its involvement in establishing international standards, aligning its initiatives with global technological advancements. By the end of 2022, the country had led the development of 1,337 international standards under ISO and IEC frameworks, supported by a network of more than 12,000 registered experts, positioning China as one of the most active contributors to international standardization (Science and Technology Daily 2023). Moreover, many Chinese standards have attained recognition by international standard-setting organizations, elevating them to global status. An example is the standard "Microwave Transmission Method for Determining Latex Moisture" (T/CIS 17002-2018) published by the Chinese Instrument and Control Society. In 2024, it was integrated into the American Society for Testing and Materials (ASTM) standard "Standard Specification for Rubber—Concentrated, Ammonia Stabilized, Creamed, and Centrifuged Natural Latex" (D1076-23) in recognition of its status as a key method (CIS 2024).

In specific sectors, Chinese standards have effectively become de facto international standards. In the railway sector, for example, the China International Railway Union (CIRU) has formulated all 13 system-level international standards under the guidance of China Railway. As of November 25, 2022, China has emerged as the world's leading source of railroad technology, with approximately 70 percent of global railroad patent applications attributable to Chinese innovations. These patents encompass diverse areas, including high-speed railway design, construction, equipment manufacturing, and coach production (Qianji Investment Bank 2024).

Moreover, the domestic standards for China's high-speed railways have gained significant international recognition, mainly due to initiatives such as the Belt and Road Initiative. This initiative has played a crucial role in promoting the widespread adoption of these standards in various countries. Indeed, the internationalization of Chinese standards is thus closely intertwined with regional policies—a process further examined in the next subsection.

Increased protection of intellectual property rights for Chinese and international companies

Another convergence with Western models of developing standards can be traced to China's progressive efforts to protect intellectual property rights (IPR).

In recent years, China has experienced a dramatic increase in the number of intellectual property (IP) cases heard by Chinese courts involving Chinese and global patentees. Between 2013 and 2023, the number of first-instance IP cases escalated from fewer than 100,000 to more than 450,000—a 450 percent increase. Furthermore, the Chinese legal system has become a preferred avenue for international multinational enterprises to settle IP disputes. In 2022, the volume of newly accepted IP cases involving foreign parties increased from 1,697 in 2013 to 5,241, representing a rise of more than 300 percent (CNIPA 2024b). The Intellectual Property Court of the Supreme People's Court (SPC) has made significant strides in protecting the patents of foreign enterprises, adjudicating various cases related to invention patent licensing, and establishing jurisdiction over global licensing conditions for SEPs. This legal framework serves as a cornerstone for fostering continuous innovation among market participants and advancing efforts to standardize practices (Zijing Magazine 2024).

Notably, China is one of many jurisdictions where intellectual property (IP) cases can be adjudicated, and its judicial achievements reflect a commitment to fair protection for both domestic and international IP rights owners, rather than any interference from the government in the IP licensing process. For instance, in disputes involving standard essential patents (SEPs), the Chinese judiciary has neither imposed nor suggested any intention to control fair, reasonable, and non-discriminatory (FRAND) royalty rates. Like their counterparts in other countries, Chinese companies license SEPs under FRAND commitments. Disputes over licensing terms are handled through normal market mechanisms—bilateral negotiations, mediation, and, when necessary, litigation or arbitration in leading jurisdictions such as the United Kingdom and other international forums. Chinese firms fully comply with decisions rendered by these courts and tribunals.

Beyond national borders, China promotes IPR protection globally, fostering exchanges and cooperation with international organizations such as the World Intellectual Property Organization (WIPO) and IP institutions across various countries and regions (CNIPA 2025). These international initiatives not only enhance global IPR governance but also support the international development of China's standardization efforts.

Development of international standards powered by regional cooperation initiatives

China's role in the development of regional standards is part of a broader drive to internationalize its efforts in the area of standards. Both the government and the business community share a common interest in seeing indigenously developed technologies become international standards or part of the international standards.

A good example is the coal-fired power generation technology. This technology was invented in the West but refined by China. There are many such power plants built across China over the last three decades. Most of the equipment involved can be sourced in China. Chinese companies also have a very reliable and mature set of practices, standards, rules, and norms in terms of building, running, and managing this type of power plant. In the early days of the Belt and Road Initiative, this technology was exported to some

developing countries until China committed to stopping building any new coal-fired power plants. As part of Pakistan's CPEC (China-Pakistan Economic Corridor) program, the Port Qasim power plant project was built using this line of technologies based on standards that were almost exclusively Chinese standards. The project was completed on time and on budget, and it started to generate economic benefits quickly.

Railways are another example where China has seen successful adoption of its standards, but that not only generates benefits for the project per se, but also benefits in a broader sense as well in terms of regional economic integration. The China–Laos railway is a case in point. This railway is a 100 percent Chinese solution with Chinese standards. As a matter of fact, it can be argued that barring the Laos language apparent in the railway system, some Chinese passengers on the train have claimed that it is even hard to distinguish the ride experience from railway trips within China! However, its contribution to the Lao economy is noticeable, enabling Lao PDR, a landlocked country, to have relatively easy access to major seaports in China. According to research statistics from the National University of Laos, this railway partly led to Lao PDR's GDP growth of 4.5 percent in 2023. The project itself achieves an estimated internal rate of return (EIRR) at about 18.5 percent, indicating high expected economic returns (China Daily 2024).

Thailand is also now investing in a major railway project, the Northeastern high-speed rail line, using Chinese technologies with Chinese standards. This railway is supposed to eventually connect to Vientiane, and be part of the grand vision of the Kunming–Singapore railway central line. Malaysia's East Coast Rail Link is also currently under construction using Chinese technologies with Chinese standards. Yet another China-built high-speed railway in Southeast Asia, the Jakarta–Bandung railway, has been completed and is currently in operation.

Lastly, for some industries, standards are developed jointly with other countries. An example is in the automobile industry where standards are usually country-specific. The relevant automobile standard-setting body in China, the China Automotive Technology and Research Center Co., Ltd, has been actively engaging in bilateral exchanges with many developing countries to help or jointly develop new automobile standards in these countries.

Standards cooperation of this sort appears to be partly motivated by the likely benefits associated with the promotion of Chinese technologies. The promotion of a country's technologies and standards is inherently intertwined and may well happen concomitantly; it is hard to distinguish which comes first. For example, in railway projects, it is hard to imagine that Chinese standards, practices, and norms would take a back seat during the contract negotiation stage. The promotion of a country's technologies and standards also inevitably leads to better prospects for more of its exports and investments. However, this is not just a one-way street; these efforts also contribute to the development of a country's related industries. For example, Thailand, a major sourcing country for automobile parts in the ASEAN market, benefits from the timely development of EV-related standards, as the auto industry is rapidly moving toward electrification.

In short, it is not surprising to see that China, as one of the world's major technology powerhouses, is actively promoting its technologies and standards internationally. These efforts bring benefits not only to China—inevitably, but also contribute in many instances to the industries and the economy of the host country. One prominent aspect of benefits manifests in stronger regional economic integration, particularly in the area of railways.

China's standardization reform offers several lessons for other developing economies. First, it is built on an explicit partnership between the government and market participants: the government sets a

safety-oriented baseline with mandatory standards and provides coordination, and enterprises, industry alliances, and academic bodies actively participate in the formulation of standards. Second, the Chinese system draws a clear line between mandatory and voluntary instruments. By minimizing the scope of mandatory standards, China encourages competing voluntary and association standards to flourish, which can help curb monopoly rents and mitigate technology lock-in. Third, China pursues vigorous two-way alignment with the global system: it reduces purely "China-specific" specifications by adopting ISO/IEC or other international norms wherever feasible, and it actively internationalizes domestic best-practice standards in fields such as high-speed rail, 5G, and photovoltaics. This bidirectional integration keeps the framework open from the outset and ensures that the evolution of standards is driven by technological progress rather than regulatory insulation. Together, these features demonstrate how a mixed governance model, a restrained use of mandatory requirements and other forms of compulsion, and proactive global engagement can deliver a dynamic, innovation-friendly standardization ecosystem.

Case studies on China's achievements in developing standards

Benefiting from ongoing policy reforms and an increasingly robust development system driven by both government initiatives and market forces, China has achieved rapid and significant progress in standardization across various industries. In particular, the wireless communications sector, which was once dominated by European and US entities, has seen China transition from a follower to one of the key leaders in the development of global technical standards. Similarly, China has taken the lead in global standard-setting in the emerging high-speed rail sector through comprehensive technological innovation. This proactive approach is also evident in China's solar energy standardization efforts, which have substantially contributed to global green economic development. To illustrate China's evolving role in the global standard-setting arena, this section presents case studies of these three industries.

Communications technology industry

China's mobile communications technology has leapfrogged quickly through stages of standardization. China has evolved from accepting international common standards in the third-generation (3G) and fourth-generation (4G) eras to achieving global leadership in the fifth-generation (5G) era, and continuing to make breakthroughs in international rule-making in the field of even more cutting-edge 6G communications technology.

3G/4G era: Following international standards

During the 3G era, China primarily was a follower of international communication standards. China introduced the TD-SCDMA technology standard, which diverged from the WCDMA standard led by Europe and the CDMA2000 standard spearheaded by the United States. However, TD-SCDMA was licensed five to ten years after its Western counterparts. Its limited performance ultimately hindered network construction and widespread adoption by users, preventing it from becoming an internationally adopted standard.

With the advent of the 4G era, China took a more proactive stance by leading the development of the TD-LTE technology standard. This standard served as a complementary standard to FDD-LTE, which was widely adopted not only in Europe and the United States but also in China. Nevertheless, outside China, the

application of the TD-LTE technology standard remained limited, as most global operators have chosen the more mature and widely supported FDD-LTE technology.

5G Era: Leading international standards

On June 14, 2018, the Third Generation Partnership Program (3GPP)[37] approved the independent networking function for the 5G standard, marking the official global rollout of 5G technology. 5G began to be commercially deployed globally in 2019. In the 5G era, China transitioned from being a follower of standards to a leading force in global mobile communication technology.

China's participation and influence in international standard-setting organizations have increased significantly. Comparing the 2001–04 period with the 2017–20 period reveals a significant shift in the representation of various countries in the ITU's Telecommunication Standardization Sector (ITU-T)[38] Study Groups (SGs) and Working Parties (WPs).[39] In the earlier period, US entities dominated, holding 22 chairs and vice-chairs (including SGs and WPs) along with 60 rapporteurs, while China had a single vice-chair and 3 rapporteurs. In stark contrast, from 2017 to 2020, Chinese representatives secured 25 chair and vice-chair seats and 89 rapporteur positions among multiple SGs and WPs. Chinese companies and research institutes have established themselves as influential players. Notably, within SGs, both Huawei and the China Institute of Information and Communications Research (CIICR) have secured chairs throughout this period, with various Chinese entities occupying 10 vice-chair positions and holding 29 percent of the rapporteur seats. In contrast, US entities secured only 5 chairs and vice-chairs, with the number of rapporteurs decreasing to 16. As for WPs, the Chinese representatives held 9 chairs and 6 vice-chairs, again positioning them as the leading contributors on a global scale (DiploFoundation 2021).

More recently, China's influence within the ITU-T has been further enhanced. At the 2022 World Telecommunication Standardization Assembly (WTSA-22), 13 experts from the Chinese industry were elected as chairmen or vice-chairmen of various ITU-T SGs for the Study Period 2022–2024 (MIIT 2023). Furthermore, all 11 Chinese experts recommended by the delegation were elected as chairs or vice-chairs of the various SGs for the Study Period 2025–2028 at the 2024 World Telecommunication Standardization Assembly (WTSA-24) (MIIT 2024).

In addition to its growing representation, Chinese entities have made significant technical contributions in shaping global 5G standards (CAICT 2024). The continuous R&D and innovation of Chinese enterprises have not only contributed a large number of 5G standard essential patents (SEPs) in the field of 5G technology but also submitted a significant number of technical proposals, playing a pivotal role in advancing 5G technology globally In 2022, there were more than 210,000 global 5G declared SEPs, involving 47,000 patent families, according to statistics from the China National Intellectual Property Administration; among these, China declared 18,000 patent families, ranking first in the world with a share of nearly 40 percent (People's Daily 2022). This momentum has continued in recent years. As of December 2024, China ranked first in the number of ETSI-disclosed 5G SEP families, accounting for 40.8 percent of all ETSI-disclosed 5G SEP families worldwide, according to the 2025 World's Leading 5G Patent Owners Report (Patently 2025).

In the context of such progress in patent innovation, various entities are advancing 5G standardization by submitting proposals to the 3GPP. As of March 31, 2024, Chinese companies accounted for 29.69 percent of the top 10 contributors to global 5G SEPs and standard proposals. Notably, Huawei led the way with a 16.92 percent share, followed by ZTE at 6.03 percent, Datang at 3.8 percent, China Mobile at 2.8 percent,

and VIVO at 2.96 percent (CAICT 2024).

Moreover, the adoption of proposals at 3GPP meetings is a crucial indicator of how effectively the technical solutions proposed by participants are integrated into standards. As of March 31, 2024, Chinese companies accounted for 33.96 percent of the proposals successfully adopted by the top ten contributing entities in this global ranking. Breaking this down further, Huawei again led the pack with an adoption rate of 20.76 percent, followed by ZTE at 5.25 percent, Datang at 2.84 percent, China Mobile at 3.3 percent, and VIVO at 1.81 percent (CAICT 2024).

Looking ahead to 6G: China's aspirations

Looking to the future, China is poised to take a leading position in developing 6G standards. In September 2024, 3GPP approved the first 6G standard project—the 6G Use Cases and Requirements Study Project—led by China Mobile. This initiative marks a significant milestone in 6G standardization efforts. China also led the first 6G security project at the ITU—"Security Considerations for IMT-2030 (6G) Networks," positioning itself at the forefront of developing 6G security standards (Xinhua News Agency 2024c). Experts anticipate that 6G will enter commercial use between 2028 and 2030, with China likely to be among the first countries to deploy 6G networks and promote its standards.

Huawei–The global leader in the 5G and the 6G era

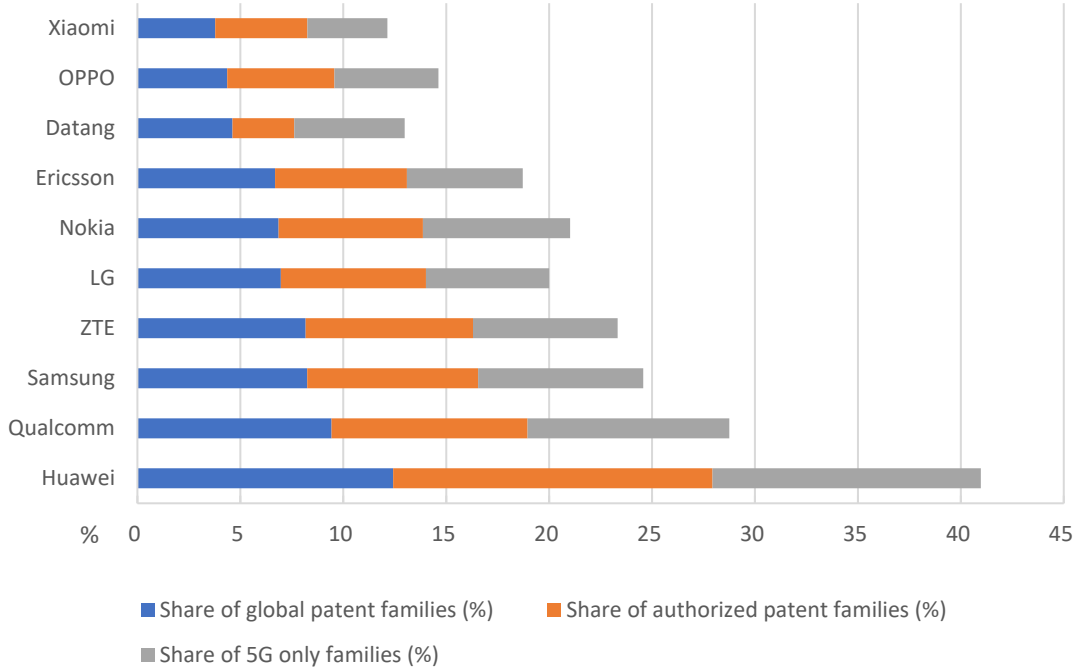
As a leader in the communications technology industry, Huawei has consistently ranked among the top in terms of patent applications and grants in major countries and regions, including China, the United States, and the European Union. The Huawei Innovation and Intellectual Property White Paper (2020) reveals that starting with its first international patent in 1999, Huawei's patent applications increased to approximately 17,000 in 2013, ranking it first in the world. Since 2018, Huawei has joined more than 140 standards organizations, holding more than 250 key positions within various boards and committees, including those at 3GPP, ITU, CCSA,[40] ETSI,[41] IEEE (Institute of Electrical and Electronics Engineers),[42] WFA (Wi-Fi Alliance),[43] and WWRF (Wireless World Research Forum).[44] Huawei submitted more than 5,000 proposals to various international standardization organizations in 2018, bringing the company's cumulative total to nearly 60,000 proposals submitted throughout its history. By the end of 2018, Huawei had been granted a total of 87,805 patents, including 11,152 patents in the United States and more than 6,600 in Europe (Huawei 2019). By the end of 2020, Huawei held more than 40,000 validly licensed patent families worldwide (Huawei 2020). These patent applications encompass various standards spanning 3G to 5G, reflecting Huawei's ongoing innovation in communications technology.

Spotlighting the 5G field, Huawei stands out as a leading force in China's 5G standardization efforts, having actively contributed to shaping global 5G standards. As of March 31, 2024, Huawei's declared 5G SEPs accounted for 12.42 percent of the global patent family, 15.52 percent of the licensed patent family, and 13.03 percent of the 5G-only patent family (CAICT 2024). It is projected that by early 2025, Huawei's declared 5G SEPs will reach 8,400, accounting for approximately 15 percent of the global 5G SEP family (Patently 2025).

The global landscape of wireless communication patents also reveals Huawei's patent strength. At the very start of the 5G era in 2018, Huawei ranked first globally with 7,760 patents (from January 1, 2018 to December 31, 2018) (IPRdaily 2020) (refer to figure 7). Fast forwarding to the period from June 1, 2021, to May 31, 2023, Qualcomm ranked first in the world with 26,944 invention patents, while Huawei secured second with 20,136 invention patents (IPRdaily 2020). Reports published by the China Academy of

Information and Communications Technology (CAICT) from 2022 to 2024 have consistently shown that Huawei maintains a leading position in global 5G SEPs and licensed patents (refer to figure 8). [45]

Figure 7. Huawei's first-place ranking in 5G patents worldwide, 2024

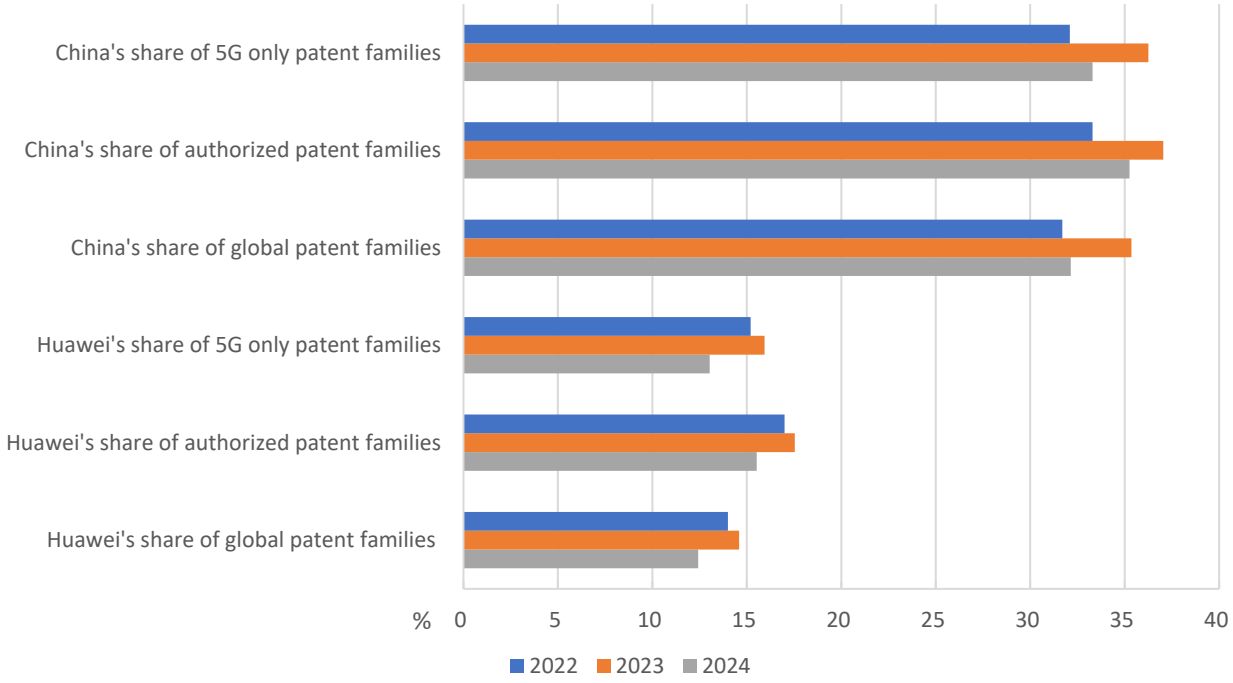


Source: China Academy of Information and Communications Technology (CAICT) 2024.
Note: Data are as of March 31, 2024.

In recent years, Huawei has made significant contributions to the development of 6G, the upcoming generation of telecommunications technology. The company has initiated numerous in-depth research initiatives focused on 6G, obtaining significant achievements in patents. Huawei ranked second in the world in October 2023, with 3,435 6G-related patent applications, according to statistics released by the Intellectual Property Development and Research Center of China National Intellectual Property Administration (IPDRC-CNIPA 2023).

Moreover, Huawei has also made a deep commitment to the development plans of international standards-setting organizations for 6G. The ITU-R is currently developing telecommunications technology for 2030 and beyond, with a focus at this stage on establishing the 6G framework as a first step toward globally consistent 6G standards. To support the ITU-R in developing a comprehensive global 6G vision, Huawei has actively contributed to drafting technical proposals and hosted discussions on 6G capabilities during the ITU meeting. Notably, Huawei introduced two pioneering scenarios for 6G: communication sensing integration and communication AI integration. In addition to its extensive involvement with the ITU-R, Huawei collaborates closely with various organizations, including 3GPP and the IEEE, as well as global operators, industry stakeholders, and academic institutions. Looking forward, Huawei is poised to continue its intensive collaboration with all relevant parties in the realm of 6G research, consistently promoting the standardization of 6G technology (Huawei 2023).

Figure 8. Notable global presence of Huawei and Chinese 5G patents, 2022–24



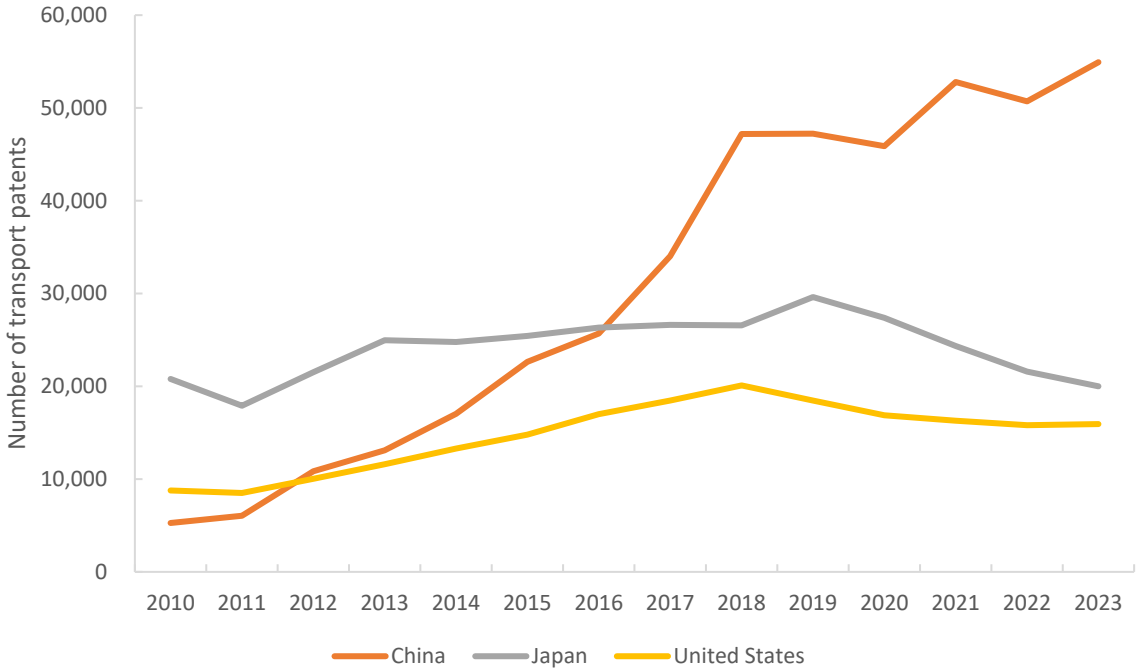
Source: CAICT 2022, 2023, 2024.

High-speed rail industry

China has gone from being a follower to a leader in standardization development in the transport sector. According to WIPO, China issued 5,269 transport patents in 2010, accounting for 7.59 percent of the world's total transport patents. At that time, Japan was at the forefront, issuing 20,784 patents. However, China's transport patent issuance has surged over the years, reaching 54,927 patents by 2023. This progress has secured China's position as the leading country, accounting for 39.35 percent of the world's total transport patents—2.7 times that of Japan, which ranks second, and 3.4 times more than the United States in third place, as illustrated in figure 9.

In the face of increasing global competition in railway technology, China's railway industry has made significant strides, emerging as a leader in setting global standards and filing patent applications. As of August 1, 2023, China has become the world's most prolific country, with 143,681 granted patents and 62,726 pending applications (Cat Vitale 2023). In recent years, China has become one of the most active and influential countries in the ISO's Technical Committee on Railway Applications (ISO/TC 269).[46] Chinese experts have assumed the chair of the Sub-Technical Committee on Rolling Stock (ISO/TC 269/SC2) and the rotating secretariat of the Sub-Technical Committee on Infrastructure (ISO/TC 269/SC1), a position that rotates every three years. As of March 2024, ISO/TC 269 had developed 35 international standards, of which China chaired discussions about 6 (accounting for 17 percent) and participated in preparing the remaining 29 standards. As of April 2024, work on 28 international standards was underway, with China chairing discussions about 7, accounting for 25 percent, and contributing to developing the remaining 21 standards (CNRA 2024).

Figure 9. Surge of Chinese transport patents compared to Japan and the United States, 2010–23



Source: World Intellectual Property Organization (WIPO) Statistics Database.

China's leadership is particularly evident in the field of high-speed rail. By 2024, China's railway industry has participated in and contributed to more than 300 projects of the UIC, ISO, and IEC to develop and revise international standards (Xinhua News Agency 2024b). Notably, China has formulated all 12 system-level international standards established by the International Union of Railways (UIC) for high-speed railways, encompassing high-speed railway design, construction, operation, equipment, and infrastructure—all of which reflect China's substantial influence in the global high-speed railway industry.

China's leadership in global standard-setting for high-speed railway technology correlates directly with its robust patent portfolio in this sector. As of 2023, China accounted for 70 percent of all global high-speed railway patent applications, significantly ahead of other major countries and regions, including the United States, Europe, Japan, India, and the Republic of Korea. This achievement marks China's pivotal role in the innovation and development of high-speed rail technology (Qianji Investment Bank 2024).

Moreover, China's high-speed rail initiatives are enhancing domestic transport and driving international standardization efforts. For example, Chinese high-speed rail standards have facilitated the establishment of a unified railway technical system in East African countries. All locomotives operating on the Mombasa–Nairobi Railway are powered by Chinese models, effectively connecting Kenya, Uganda, Rwanda, and other East African countries. In Angola, the Benguela Railway stands as the longest, fastest, and most significant modern railway project in the country's history, designed and constructed entirely using Chinese railway standards. China's high-speed rail standards have also been adopted by ASEAN countries through the Belt and Road Initiative. For instance, the China–Thailand High-Speed Rail, funded by Thailand, adheres to Chinese standards. The Malaysia–Thailand East Coast Rail Link exemplifies the export of Chinese high-speed rail technology and service standards (International Business Daily 2023).

Through international cooperation, China not only disseminates its technology but also brings substantial economic benefits to developing countries. Indonesia's Jakarta–Bandung High-Speed Rail project, the first high-speed rail in Indonesia and Southeast Asia, has adopted Chinese high-speed rail technical standards, including track design, signaling systems, and train manufacturing. This railway has significantly boosted the development of small and medium enterprises along the route, creating a new community economic ecosystem. For example, the travel time from Halim Station to Karawang Station is only about 15 minutes, forming a key pillar of Indonesia's industrial development (People's Daily 2024b).

Additionally, China has provided comprehensive training for Kenyan railway operators, equipping them with the skills necessary to operate and maintain high-speed rail. The railway has directly and indirectly created more than 74,000 jobs in Kenya and trained more than 2,800 high-quality railway professionals and management talents. Since its opening to traffic, passenger travel on the Mombasa–Nairobi Railway has increased annually, from 700,000 passengers in 2017 to 2.73 million in 2023. Experts have estimated that the project contributes more than 2 percent to Kenya's GDP, driving industrial development through railway construction and providing sustainable operational support for the railway (UPSC 2024).

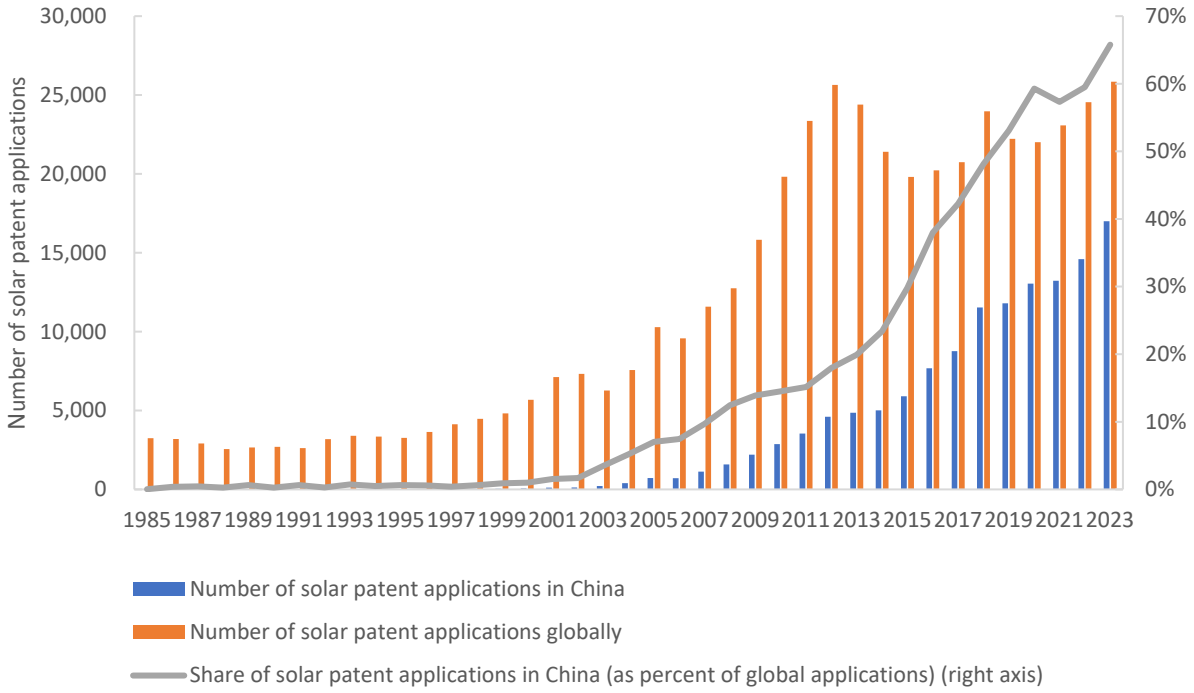
Solar energy industry

In recent years, China has made significant achievements in solar energy technology innovation and is playing an increasingly important role in developing international standards for solar energy.

As a key member of the ISO's Technical Committee on Solar Energy (ISO/TC 180), one of the earliest and most prominent committees in this field, China holds significant technical leadership roles within its subcommittees and working groups. As of January 2023, ISO/TC 180 has developed and published 20 international standards for solar thermal utilization, with China leading the development of four of these standards while actively promoting research and development on two additional ones (CNIS 2024). Notably, in collaboration with Denmark, China has led the development of ISO 24194:2022, which is crucial for evaluating the performance of solar collector fields and providing technical support for solar heating and various applications (CNIS 2023).

China is emerging as a leading source of solar cell technology globally. Figure 10 illustrates the rapid advancement of China's solar patenting strength. China's solar patent applications increased from 123 in 2002 to approximately 17,000 in 2023, with the global share rising from 2 percent to 66 percent, contributing significantly to global solar standardization.[47]

Figure 10. The rising number and global share of solar patent applications in China, 1999–2023



Source: World Intellectual Property Organization (WIPO) Statistics Database.

In particular, China has made significant contributions to photovoltaic (PV) technology—the primary method of solar energy utilization, recognized for its efficiency and flexibility and its increased participation in the standardization efforts of international organizations in this sector. For instance, in 2020, the China Electronics Standardization Institute (CESI) submitted nine proposals to the IEC standards, of which seven were successfully approved. In 2021, the China Photovoltaic Industry Association's Standardization Technical Committee proposed eight association standards in cutting-edge areas, including PV cells and PV support brackets, which were successfully approved as IEC standards (CESI 2022). These standards encompass areas such as PV direct-drive appliance controllers, light-induced degradation testing methods for crystalline silicon PV cells, and online electroluminescence measurement of PV arrays. At the 2024 IEC/TC 82 meeting, China advanced six projects, including "Accelerated Stress Test Sequence for PV Modules and Materials" (IEC/TS 63556), and proposed 12 new projects, such as "Product Category Rules for Carbon Footprint of PV Products: PV Modules," "Testing Methods for Perovskite PV Cells for R&D," and "Test Procedures for PV Module Materials: Acid Content Testing for Encapsulation Materials" (CESI 2024).

Moreover, advancements in China's photovoltaic industry have significantly spurred the regional economy and technology development by promoting standardization processes in numerous developing countries, particularly those involved in the Belt and Road Initiative. Benefiting from strong supply and external demand, Chinese PV products have been exported to more than 200 countries and regions. This outreach has significantly enhanced access to clean energy technologies in developing nations and reduced global costs for green technologies. For example, since 2021, China has exported approximately $4.1 billion worth of PV products to Pakistan, enabling the country to provide solar power capabilities for residential, industrial, commercial, and government sectors. Additionally, the Chinese solar technology company

LONGi Green Energy Technology Co., Ltd. has collaborated with a Brazilian nonprofit organization to provide PV technology to Rio de Janeiro's *favelas*, thereby reducing electricity costs through the use of solar energy (China Daily 2025).

Conclusion

Over the past few decades, China has shifted from relying on international standards to establishing itself as one of the global leaders in standard innovations. Reforms to the standardization system since 2015 have fostered increased collaboration among government, industry, and academia, enabling rapid technological advances. China's active engagement with international standard-setting organizations, as well as its participation in various international initiatives, has augmented its influence on the global stage. These efforts have not only enhanced China's technological competitiveness but have also bolstered regional economic development in many developing countries, as evident, for example, in China's contributions to the development of telecommunications, high-speed rail, and solar energy standards. Nowadays, China has emerged as a powerful force in global standardization. Moving forward, the country's drive for innovation seems poised to make increasingly significant contributions to advancing global standards and technologies, shaping the future of various industries worldwide.

Notes

[1] WIPO, "The Country Profile of China" (https://www.wipo.int/directory/en/details.jsp?country_code=CN).
[2] In March 2018, their responsibilities were officially transferred to the State Administration for Market Regulation (SAMR), with the brands SAC and CNCA retained externally (https://www.sac.gov.cn/zzjg/ and https://www.cnca.gov.cn/jggk/index.html).
[3] SAC (Standardization Administration of the People's Republic of China), "What We Do" (https://www.sac.gov.cn/AboutSAC/Whatwedo/index.html).
[4] SAMR, Administrative Regulation for Adopting International Standards (effective December 4, 2001) (https://www.gov.cn/zhengce/2021-06/25/content_5723647.htm).
[5] International Telecommunication Union (ITU), Section VIII.4 of "The National Medium-and Long-Term Program for Science and Technology Development," (2006–2020) (https://www.itu.int/en/ITU-D/Cybersecurity/Documents/National_Strategies_Repository/China_2006.pdf).
[6] ISO/TMB Technical Management Board (https://www.iso.org/committee/4882545.html).
[7] State Council on the Issuance of the Deepening Standardization Work Reform Program, published March 26, 2015 (https://www.gov.cn/zhengce/content/2015-03/26/content_9557.htm).
[8] See Section II of "National Standardization Development Outline." CEST, November 8, 2021. https://cset.georgetown.edu/wp-content/uploads/t0406_standardization_outline_EN.pdf).f
[9] ISO/IEC JTC 1 is a technical committee jointly established by ISO and IEC, primarily responsible for standardization in the field of information technology.
[10] The Big Four include ISO/IEC JTC 1, ISO, IEC and ITU (refer to He 2022, 15).
[11] ISO/IEC JTC 1/SC 42 (hereinafter referred to as "SC 42") is a subcommittee under JTC1 of ISO and IEC. It is an international technical organization responsible for developing standards in the field of AI, primarily focusing on establishing international standards in areas such as AI management systems, data, trustworthiness, use cases and applications, computational methods, system characteristics, and testing of AI systems.
[12] See Executive Summary and Summary 3 of Current SC 42 Officers, JTC 1/SC 42 Business Plan–2024 (https://assets.iec.ch/further_informations/21538/ISO-IEC%20JTC%201_N17016_JTC%201-SC%2042%20Business%20Plan%20-%202024.pdf).
[13] The International Union of Railways (UIC) was founded in Paris on the recommendation of the International Economic

Conference held in Genoa in December 1922, with the participation of 46 railway bodies in 27 countries at that time, and a total of 68 railway bodies and 15 organizations related to railways participating in the body in January 1983. By January 1983, 68 railway bodies and 15 railway-related organizations were participating. UIC aims to improve and standardize railway development and construction conditions for the benefit of international traffic. UIC has published more than 600 loose-leaf documents setting international standards and norms for all aspects of railway activity.

[14] China hosted the development of the UIC standard "High-speed Railway Design Infrastructure," which was officially released and implemented (https://www.gov.cn/xinwen/2022-07/01/content_5698761.htm). Refer also to https://global.chinadaily.com.cn/a/202207/19/WS62d6bd39a310fd2b29e6d3db.html.

[15] ITU holds a Council every year; a World Radiocommunication Conference every two years; and a Plenipotentiary Conference, a World Telecommunication Standards Conference, a World Telecommunication Development Conference every four years. .

[16] WIPO, "IP Facts and Figures" (https://www.wipo.int/en/ipfactsandfigures/patents).

[17] The Belt and Road Summit Forum for International Cooperation is the highest international event under the framework of the Belt and Road, a high-level and large-scale multilateral diplomatic activity initiated and hosted by China, and an important international cooperation platform for all parties to discuss and build the Belt and Road and share the fruits of mutually beneficial cooperation.

[18] The China-ASEAN Standardization Cooperation Forum aims to promote exchanges and cooperation between China and ASEAN countries in the field of standardization, with the goal of fostering mutual recognition and coordination of standards. The Forum addresses standardization issues in trade, industry, technology, and other fields, offering technical support for enhancing economic and trade cooperation between the two sides.

[19] The China-South Asia Standardization Cooperation Working Meeting establishes a cooperation platform for China and South Asian countries in the field of standardization, promoting standard docking and technical exchanges. The meeting focuses on discussing key industry standards cooperation to promote regional economic integration and trade facilitation.

[20] The BRICS Ministerial Meeting on Standardization Cooperation aims to strengthen cooperation in standardization, promote mutual recognition of standards, and enhance the competitiveness of products and services in the international market. The meeting focuses on technical standards, certification and accreditation, and metrology and testing, promoting the synergistic development of the standard systems of BRICS member countries (Brazil, Russian Federation, India, China, and South Africa, the Arab Republic of Egypt, Ethiopia, Indonesia, the Islamic Republic of Iran, and the United Arab Emirates)

[21] The International Council on Large Electric Systems (CIGRE) is a biennial conference held in Paris. Its purpose is to promote the international exchange of scientific and technological knowledge and information on power generation, high-voltage transmission and large power grids, including the electrical parts of power plants; substations, substation equipment and their construction and operation; the structure, insulation and operation of high-voltage lines; and the interconnection of systems and the operation and protection of interconnected systems (refer to SAMR 2024).

[22] The State Administration for Market Regulation (SAMR) plays a key role in the development of national standards in China. While SAMR is responsible for national standards, industry ministries under the State Council, such as MIIT, are tasked with developing industry-specific standards. Additionally, local administrative bodies, such as local market regulation authorities, are responsible for creating local standards. SAMR also coordinates, guides, and supervises the formulation of both industry and local standards. Before SAMR was established in 2018, SAC managed the standardization responsibilities SAMR now handles.

[23]In broad terms, the standards by SAC plus association standards in China can be considered market standards and might be regarded as comparable to the American National Standards Institute's (ANSI) assessments of standards (Xu 2024).

[24] Standardization Law of the People's Republic of China (effective January 1, 2018), Article 10 (https://www.sac.gov.cn/zt/xxddbzhfzsbb/dt/art/2018/art_e8d4158256f24b768946ff7bea4d7b4a.html).

[25] Standardization Law of the People's Republic of China (effective January 1, 2018), Article 10 (https://www.sac.gov.cn/zt/xxddbzhfzsbb/dt/art/2018/art_e8d4158256f24b768946ff7bea4d7b4a.html).

[26] Refer to SAMR, Measures for the Management of National Professional Standardization Technical Committees (effective January 1, 2018) (https://www.samr.gov.cn/zw/zfxxgk/fdzdgknr/fgs/art/2023/art_15fee27b38e643e9b2933ee57ef47c88.html). Following the State Council's institutional reforms in 2018, SAMR was established as an organization directly under the State Council, responsible for comprehensive market supervision and regulation, as well as related standardization work. SAMR is responsible for drafting laws and regulations related to market supervision and management, as well as leading standardization work, including the coordination and management of STCs and TWGs (https://www.samr.gov.cn/index.html). In addition, the provincial standardization authorities can establish local standardization technical committees to develop local standards.

[27] Refer to SAMR, Measures for the Administration of Mandatory National Standards (effective January 6, 2020) (https://www.samr.gov.cn/cms_files/filemanager/samr/www/samrnew/samrgkml/nsjg/fgs/202001/W020211127352278016690.pdf#:~:text=).

[28] SAMR, Interpretation of the Measures for the Administration of Mandatory National Standards, January 17, 2020

(https://www.samr.gov.cn/zw/zfxxgk/fdzdgknr/xwxcs/art/2023/art_41f9e74ec1184f799186a77bfb768031.html).
[29] See IMT-2030 (6G) Working Group Profile, Members (https://www.imt2030.org.cn/html/default/zhongwen/tuijinzujianjie/chengyuandanwei/index.html?index=1).
[30] Standardization Law of the People's Republic of China (effective January 1, 2018), Article 18 (https://www.sac.gov.cn/zt/xxddbzhfzsbb/dt/art/2018/art_e8d4158256f24b768946ff7bea4d7b4a.html).
[31] Industrial Standards Department, Notice on the General Administration of Quality Supervision, Inspectionand Quarantine and the Standardization Administration of China on Issuing the Guiding Options on Cultivating Association Standards. March 10, 2016 (https://www.sac.gov.cn/zt/ydylzt/zccs/art/2016/art_2492df4207504b46bcd33a677386f047.html).
[32] Zhonghong website, "Mandatory National Standards Reduced to 2,111," September 11, 2019 (http://hn.zhonghongwang.com/show-140-14569-1.html).
[33] China Industry Technology Innovation Strategic Alliance for Electric Vehicle Association standard (http://www.caev.org.cn/c49).
[34] China's National Bureau of Statistics (NBS), Statistical Bulletin on National R&D Investment (https://www.stats.gov.cn/sj/tjgb/rdpcgb/qgkjjftrtjgb/).
[35] The international standards to be converted are those that the National Standardization Technical Committee has assessed to be suitable for conversion into Chinese standards.
[36] Name list of SAC/TC260 members (https://www.tc260.org.cn/front/tiaozhuan.html?page=/front/gywm/%2Fwymd_Detail_nr).
[37] 3GPP (3rd Generation Partnership Project) was created in 1998 to develop 3G mobile standards for WCDMA and TD-SCDMA accesses and their core networks. The original scope of 3GPP (1998) was to produce Technical Specifications and Technical Reports for a 3G Mobile System based on evolved GSM core networks and the radio access technologies that they support (i.e., Universal Terrestrial Radio Access (UTRA) both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes). The scope was subsequently amended to include the maintenance and development of the Technical Specifications and Technical Reports for evolved 3GPP technologies, beyond 3G. See (https://www.3gpp.org/about-us/introducing-3gpp).
[38] ITU is one of the 15 specialized agencies of the United Nations, but is not legally a subsidiary body of the United Nations; its resolutions and activities are not subject to approval by the United Nations but it is required to report annually on its work to the United Nations. The ITU's organizational structure is divided into the Telecommunication Standardization Sector (ITU-T), the Radiocommunication Sector (ITU-R), and the Telecommunication Development Sector (ITU-D).
[39] ITU-T, at the heart of the ITU's standardization efforts, is responsible for the development of key standards in the global information and communication technology (ICT) infrastructure, known as ITU-T Recommendations. The department carries out its work to develop standards through the establishment of Technical Study Groups (SGs), which bring together telecommunications standardization experts from around the world. In the standardization process, the SGs are driven by research questions. Each research question focuses on technical research in a specific area of telecommunications standardization. In order to work more efficiently, each research group establishes Working Parties (WPs) as needed.
[40] The China Communications Standards Association (CCSA) is a voluntary, joint organization of domestic enterprises and public institutions that conducts standardization activities in the field of information and communication technology nationwide, with approval from the relevant department and registration with the national association registration authority. CCSA is a nonprofit legal person social organization that carries out standardization activities in the field of information and communication technology nationwide.
[41] The European Telecommunications Standards Institute (ETSI) is a nonprofit organization that standardizes telecommunications technologies, approved by the European Commission in 1988. ETSI's standardization area primarily focuses on the telecommunications industry, but also encompasses the fields of information and broadcasting technology, working in cooperation with other organizations. ETSI is recognized by CEN (the European Committee for Standardization) and CEPT (the Conference of European Postal and Telecommunications Administrations) as a telecommunications standards institute. Its recommended standards are often adopted by the European Community as the technical basis for European regulations and are required to be implemented.
[42] The Institute of Electrical and Electronics Engineers (IEEE) is an international association of engineers in electronics and information sciences and the world's largest nonprofit professional and technical society. IEEE publishes nearly one-third of all technical literature in the fields of electrical and electronic engineering, computing, and other related technologies, including 200 journals and magazines published annually, as well as the IEEE Xplore digital library containing more than 5 million documents. In conjunction with scholarly communication activities in all specialized technical fields, IEEE also publishes a range of publications, including journals, technical newsletters, and conference proceedings.
[43] The Wi-Fi Alliance (full name: Wi-Fi Alliance Organization, abbreviated as WFA) is a commercial alliance whose primary purpose is to implement globally compatible certification of Wi-Fi products and to develop the IEEE 802.11 standard wireless LAN technology. The alliance comprises more than 200 member units, with 42 percent originating from the Asia-Pacific region,

and includes five members based in China.

[44] The WWRF (Wireless World Research Forum) is an international academic organization dedicated to the research and development of mobile communication technology, founded in 2001 by world-renowned telecom equipment manufacturers and operators, including Siemens, Nokia, Ericsson, Alcatel, Motorola, France Telecom, IBM, Intel, and Vodafone. It is an international academic organization dedicated to the research and development of mobile communication technology. Its members include most of the telecommunication equipment manufacturers, telecommunication operators, and scientists engaged in mobile communication technology research in Europe, the United States, and Asia. The goal of WWRF is to plan the future research direction of wireless field in the industry and academia, to put forward and establish the research direction of the development of mobile and wireless system technology, and to provide constructive help for the research of wireless communication technology in the world.

[45] According to the *Global 5G Patent Activity Report 2022* (CAICT 2022), the *Study on Global 5G Standard Essential Patents and Standard Proposals 2023* (CAICT 2023), and the *Study Report on Global 5G SEPs and Standard Proposals 2024* (CAICT 2024), Huawei's declared 5G SEPs share, licensed patent family share, and 5G-only family share have been maintained at the top of the global rankings.

[46] The International Organization for Standardization Technical Committee on Railway Applications (ISO/TC269) is the only technical committee established by ISO in the field of rail transportation.

[47] WIPO Statistics Database (https://www3.wipo.int/ipstats/ips-search/patent).

References

CAC (Cyberspace Administration of China. 2021. *Digital China Development Report 2020.* July 2, 2021. https://www.cac.gov.cn/2021-06/28/c_1626464503226700.htm.

CAICT (China Academy of Information and Communications Technology). 2022. *Global 5G Patent Activity Report*. http://www.caict.ac.cn/kxyj/qwfb/ztbg/202204/P020220422375972363387.pdf.

CAICT (China Academy of Information and Communications Technology). 2023. *Study on Global 5G Standard Essential Patents and Standard Proposals*. http://www.caict.ac.cn/kxyj/qwfb/ztbg/202304/P020230421528385442774.pdf.

CAICT (China Academy of Information and Communications Technology). 2024. *Study Report on Global 5G Standard Essential Patents and Standard Proposals*. http://www.caict.ac.cn/kxyj/qwfb/ztbg/202409/P020240926566555589029.pdf.

Cat Vitale. 2023. "Patents Signal: China Remains Most Powerful Region across Transport Sector." *Railway Technology*, August 1, 2023. https://www.railway-technology.com/news/china-most-powerful-region-transportation-sector/?utm_source=&utm_medium=13-106149&utm_campaign=&cf-view.

CESI (China Electronics Standardization Institute). 2022. "China Photovoltaic Industry Association Standardization Technical Committee 2021 Annual Working Conference Held," January 4, 2022. http://www.cesi.cn/202201/8191.html.

CESI (China Electronics Standardization Institute). 2024. "IEC/TC82 2024 Conference Successfully Held in Xi'an, China," October 31, 2024. https://www.cesi.cn/202410/10635.html.

CEST (Center of Security and Emerging Technology). 2021. "National Standardization Development Outline." November 8, 2021. https://cset.georgetown.edu/wp-content/uploads/t0406_standardization_outline_EN.pdf.

China Association of Automobile Manufacturers. 2014. "National IV Emission Standards Will Be Implemented Early Next Year, Foreign Investors Have Long Been Laid Out in Advance," April 24, 2014). http://www.caam.org.cn/chn/1/cate_2/con_5118934.html.

China Daily. 2024. "The China-Laos Railway is a 'Debt Trap'? Some of Them are Red-eyed," February 22, 2024. https://cn.chinadaily.com.cn/a/202402/22/WS65d7450ba3109f7860dd299c.html.

China Daily. 2025. "China's renewable energy boosts global transition," January 13, 2025. https://china.chinadaily.com.cn/a/202501/13/WS6784d4f0a310b59111dad90f.html#:~:text=.

China Economic Net. 2024. "2024 China's Top 500 Enterprises List Released–Steady Growth in Scale and Improved Development Quality." September 12, 2024. https://www.gov.cn/yaowen/liebiao/202409/content_6974003.htm.

China News. 2019. "China-ASEAN Strengthens International Standardization Cooperation and Releases the Nanning Initiative," September 23, 2019. https://m.chinanews.com/wap/detail/chs/zw/8963515.shtml.

China Quality News Network. 2011a. "What Stages Has the Development of China's Certification and Accreditation Business Gone Through?" March 9, 2011. https://www.cqn.com.cn/zj/content/2011-03/09/content_1171464.htm.

China Quality News Network. 2011b. "Chronicle of Standardization in China." March 9, 2011. https://m.cqn.com.cn/zj/content/2006-01/16/content_560044.htm.

China Quality News Network. 2024. "Yunnan Province Lijiang City Market Supervision Bureau Releases Typical Cases of Local Standard Implementation," October 15, 2024. https://www.cqn.com.cn/zj/content/2024-10/15/content_9072123.htm.

CNIS (China National Institution of Standardization). 2023. "China Jointly Led the Development of the ISO International Standard 'Solar Collector Field Performance Testing' and Officially Released It,"

January 6, 2023. https://www.cnis.ac.cn/bydt/zhxw/202301/t20230106_54507.html.
CNIS (China National Institution of Standardization). 2024. "CNIS Researchers in Charge of 8 Solar Energy International Standards in ISO 24871 Series." October 29, 2024. https://www.cnis.ac.cn/ynbm/zhfy/zhxw/202411/t20241105_58998.html.
CIRA (Center for Intelligence Research and Analysis). 2022. "A New 'Great Game?': China's Role in International Standards for Emerging Technologies." August 2022. https://cira.exovera.com/wp-content/uploads/2022/08/NIST-Final-Report.pdf.
CIS (China Instrument and Control Society). 2024. "The Standards by the CIS Have Been Published and Implemented as ASTM International Standards," January 26, 2024. http://www.cis.org.cn/post/detail/116/6417.
CNIPA (China National Intellectual Property Administration). 2024a. *Patent Landscape: China and Belt and Road Partner Countries (2013–2023).* July 2024. https://english.cnipa.gov.cn/module/download/downfile.jsp?classid=0&filename=fbd6219df7de4ef8a817581c038eb211.pdf.
CNIPA (China National Intellectual Property Administration). 2024b. "White Paper on the Status of Intellectual Property Protection in China (2023) Officially Released," April 30, 2024. https://www.cnipa.gov.cn/art/2024/4/30/art_53_192127.html#:~:text=.
CNIPA (China National Intellectual Property Administration). 2025. "Work Report of Shen Changyu, Director General of the China National Intellectual Property Administration" (excerpt). January 8, 2025. https://www.cnipa.gov.cn/art/2025/1/8/art_53_197077.html.
CNRA (China National Railroad Administration). 2024. "One ISO International Standard for Railroads Hosted by China Officially Released and Implemented." April 28, 2024. https://www.nra.gov.cn/xwzx/xwxx/xwlb/202404/t20240428_345150.shtml.
DiploFoundation. 2021. *The Geopolitics of Digital Standards: China's Role in Standard-Setting Organizations.* December 14, 2021. https://www.diplomacy.edu/wp-content/uploads/2021/12/Geopolitics-of-digital-standards-Dec-2021.pdf.
Globe Magazine. 2023. "How Can the 'Chinese Voice' Be More 'Standard'?" December 14, 2023. http://www.news.cn/globe/2023-12/14/c_1310754874.htm.
Gommel, Mattias, Joachim Freimuth, Siglinde Kaiser, and Monika Schädler. 2022. "Standardization in India and China from a Corporate Perspective." In *Standardization Strategies in China and India. Professional Practice in Governance and Public Organizations,* edited by J. Freimuth, S. Kaiser, and M. Schädler, 433–43. Wiesbaden, Germany: Springer. https://doi.org/10.1007/978-3-658-45583-5_10.
He, Alex. 2022. "The Digital Silk Road and China's Influence on Standard Setting." CIGI Paper No. 264, Centre for International Governance Innovation. https://www.cigionline.org/static/documents/no.264.pdf.
Huawei. 2019. "Huawei Innovation and Intellectual Property White Paper 20219." https://www.huawei.com/-/media/CORPORATE/PDF/white%20paper/2019/Huawei_White_Paper_on_Innovation_and_Intellectual_Property_cn.pdf.
Huawei. 2020. "Huawei Innovation and Intellectual Property White Paper 2020." https://www-file.huawei.com/-/media/CORP2020/pdf/download/Huawei_IPR_White_paper_2020_cn.pdf.
Huawei. 2023. "ITU-R WP5D Completion of the IMT-2030 (Global 6G Vision) Framework Proposal." June 2023, https://www.huawei.com/cn/huaweitech/future-technologies/itu-r-wp5d-completed-recommendation-framework-imt-2030.
International Business Daily. 2023. "China-ASEAN: One Belt One Road on High-Speed Railway," September 11, 2023.

https://epa.comnews.cn/padphone/content/202309/11/content_10172.html.
IPDRC-CNIPA (Intellectual Property Development and Research Center of China National Intellectual Property Administration). 2023. "6G is in a Critical Window of Patent Layout before Standard Formation," October 13, 2023. https://cnipa-ipdrc.org.cn/news_copy.aspx?newsId=298.
IPRdaily. 2020. "Top 100 Global Wireless Communication Network Technology Invention Patents in 2020 (TOP 100)," November 19, 2020. http://iprdaily.cn/news_26345.html.
ISO-IEC JTC 1 N17016. 2024. "JTC 1-SC 42 Business Plan–2024." November 10, 2024, https://assets.iec.ch/further_informations/21538/ISO-IEC%20JTC%201_N17016_JTC%201-SC%2042%20Business%20Plan%20-%202024.pdf.
Jones, Ben. 2023. "Flying Without Wings: The World's Fastest Trains." CNN, June 26, 2023. https://www.cnn.com/travel/article/worlds-fastest-trains-cmd/index.html.
MIIT (Ministry of Industry and Information Technology). 2023. "World Telecommunication Standardization Plenary Meeting Closes Chinese Delegation Achieves Positive Results," March 11, 2023. https://www.miit.gov.cn/jgsj/kjs/gzdt/art/2022/art_a8b30902101d4a8c8b0bc002628a6367.html.
MIIT (Ministry of Industry and Information Technology). 2024. "World Telecommunication Standardization Plenary Meeting Closes Chinese Delegation Successfully Completes Participation," October 25, 2024. https://www.miit.gov.cn/jgsj/kjs/gzdt/art/2024/art_103d7ba836ff4f62845059cbef781dda.html.
MIIT (Ministry of Industry and Information Technology). 2024. "WRC-23 Insight: Where the Industry is Going—Global Rule Base Established for 6GHz Band Segmentation for 5G/6G," January 8, 2024. https://www.miit.gov.cn/ztzl/rdzt/sjwxdtxdh/ywkb/art/2024/art_b07e57c923be4038805fcf79907a081c.html.
NSA (National Standardization Agency). 2016. "189 Chinese Standards Become World Standards," September 20, 2016. https://www.sac.gov.cn/xw/bzhdt/art/2016/art_93052518a5ad4050963d83485b469e3a.html.
NSA (National Standardization Agency). 2021. "National Technical Standard Innovation Base: Standardizing to Help High-Tech Innovation and Promoting High-Level Development," November 30, 2021. https://www.sac.gov.cn/jdbnhbz/bzgs/art/2021/art_ffff51986742456d942f9820ad9d9cfc.html.
Patently. 2025. *2025 World's Leading 5G Patent Owners Report.* https://app.patently.com/Patently-100-5G-2025.pdf.
Permanent Mission of the People's Republic of China to the United Nations Office at Geneva and Other International Organizations in Switzerland. 2020. "International Telecommunication Union, ITU." July 27, 2020.
People's Daily. 2022. "China Declares 18,000 5G SEPs, Tops in World," June 8, 2022. https://www.chinanews.com.cn/cj/2022/06-10/9776844.shtml.
People's Daily. 2024a. "China's 5G Development Showcases the Booming Growth of Science and Technology, as Well as the Solid Progress in Building a Strong Country in This Field." September 23, 2024. https://www.gov.cn/yaowen/liebiao/202409/content_6975879.htm.
People's Daily. 2024b. "Yavan High-Speed Rail to Benefit the "Land of a Thousand Islands," October 29, 2024. https://www.yidaiyilu.gov.cn/p/0702NRCA.html.
Phoenix News Media. 2022. "Innovators: How 'Chinese Standards' Become 'International Standards.'" Carnegie Endowment for International Peace, August 16, 2022. https://finance.ifeng.com/c/8IV0d80VxuV.
Qianji Investment Bank. 2024. *China High-Speed Rail Industry Research Report (2024).* January 29, 2024. https://www.qianzhan.com/analyst/detail/220/240112-c7f5254f.html.

Reuters. 2024. “China Sets Up AI Standards Committee as Global Tech Race Intensifies,” December 13, 2024. https://www.reuters.com/technology/china-sets-up-ai-standards-committee-global-tech-race-intensifies-2024-12-13/.

SAC (National Standardization Administration). 2016. “The Conversion Rate of International Standards in Major Industries such as Home Appliances and Textiles in China is Largely Over 80%.” August 26, 2016. https://www.gov.cn/xinwen/2016-08/26/content_5102577.htm.

SAC (National Standardization Administration). 2020. *Annual Report on Standardization Development in China 2019*. September 2020. https://www.samr.gov.cn/cms_files/filemanager/samr/www/samrnew/bzcxs/sjdt/gzdt/202009/P020200910331877427036.pdf#:~:text=.

SAC (National Standardization Administration). 2021a. “National Technical Standard Innovation Base: Standardization Helps High Technological Innovation, Promotes High Level of Openness, and Leads High Quality Development.”

SAC (National Standardization Administration). 2021b. *Annual Report on Standardization Development in China 2020.* November 5, 2021. https://www.samr.gov.cn/xw/zj/art/2023/art_739a7debf4224ead9007afb2f89ded53.html.

SAC (National Standardization Administration). 2023. *Annual Report on Standardization Development in China 2022*. April 25, 2023. https://www.sac.gov.cn/xw/bzhdt/art/2023/art_af1d9fd607e14496b216587fee4ec4c0.html.

SAC (National Standardization Administration). 2024. *Annual Report on Standardization Development in China 2023*. March 28, 2024. https://www.sac.gov.cn/xw/bzhdt/art/2024/art_ed9fa13f542c4b9aa40188eb0e8349f7.html.

SAMR (State Administration for Market Regulation). 2019. “Consolidation and Streamlining of Mandatory Standards Completed,” September 11, 2019. https://www.thepaper.cn/newsDetail_forward_4394085.

SAMR (State Administration for Market Regulation). 2023a. *Annual Report on Standardization Development in China 2023.* https://www.sohu.com/a/770057845_121117464#:~:text=.

SAMR (State Administration for Market Regulation). 2023b. “The Department of Standards and Innovation of the General Administration of Market Supervision Replied to a Reporter's Question,” September 9, 2023. https://www.samr.gov.cn/zw/zfxxgk/fdzdgknr/xwxcs/art/2023/art_0bf1f6dd1ef64f77a3cc727a96fef3db.html.

SAMR (State Administration for Market Regulation). 2024. *Report on Standardization Achievements at the 10th Anniversary of the Belt and Road*. December 2024. https://oss.yidaiyilu.gov.cn/ice/2025/01/06/116326d3c0db4ddeb1bab2f83b71ca89.pdf.

Science and Technology Daily. 2023. “Standardization Helps Chinese Innovation Go Global,” October 13, 2023. https://www.news.cn/fortune/2023-10/13/c_1129913666.htm.

Sheehan, Matt, and Jacob Feldgoise. 2023. “What Washington Gets Wrong about China and Technical Standards.” Carnegie Endowment for International Peace, February 27, 2023. https://carnegieendowment.org/research/2023/02/what-washington-gets-wrong-about-china-and-technical-standards?lang=en.

Suttmeier, Richard, Xiangkui Yao, and Alex Zixiang Tan. 2024. “Standards of Power? Technology, Institutions, and Politics in the Development of China’s National Standards Strategy.” National Research of Asian Research, Seattle, WA. http://www.sitedoconsumidor.gov.br/qualidade/comites/CBN_paises/china.pdf.

UPSC (Urban Planning Society of China). 2024. “The Path to Benefit the People, the Road to Prosperity—The Seven-Year Operation of the Mombasa-Nairobi Railway.” July 17, 2024.

https://en.planning.org.cn/belt/view?id=1481.
WIPO (World Intellectual Property Organization). 2024. Annex 1-2 in "WIPO's Global IP Registries for Patents, Trademarks and Designs Grew in 2024." https://www.wipo.int/export/sites/www/pressroom/en/documents/pr-services2025-annexes.pdf#page=3.
Xinhua News Agency. 2007. "Approved by the Commission at Present, China Has a Total of 182 Various Types of Certification Bodies," August 8, 2007. https://www.gov.cn/jrzg/2007-08/08/content_710493.htm.
Xinhua News Agency. 2017. "'Fuxing' Departs to Let the World Witness the Power of 'Chinese Standards'," September 20, 2017. http://www.xinhuanet.com/politics/2017-09/20/c_1121691707.htm.
Xinhua News Agency. 2024a. "Four Departments Issued a Document: China's Artificial Intelligence Industry Will Formulate More than 50 New National Standards and Industry Standards," July 2, 2024. https://www.gov.cn/lianbo/bumen/202407/content_6960709.htm.
Xinhua News Agency. 2024b. "China's Railroads Have Been Instrumental in the Formulation of 13 System-level International Standards in the Field of High-Speed Railways." November 15, 2024. https://www.gov.cn/yaowen/liebiao/202411/content_6987274.htm.
Xinhua News Agency. 2024c. "From Technology Research to Standards Research 6G is Becoming the Focus of Global Science and Technology Innovation," November 21, 2024. http://www.ciia.org.cn/news/26182.cshtml.
Xu, Betty. 2024. "A Comparison of the Standardization Systems in the EU and in China and the Role of SESEC." In *Standardization Strategies in China and India. Professional Practice in Governance and Public Organizations*, edited by Joachim Freimuth, Siglinde Kaiser, and Monika Schädler. Wiesbaden, Germany: Springer. https://doi.org/10.1007/978-3-658-45583-5_10.
Yang, Yang. 2022. "IEC Chairman Shu Yinbiao: China Deepens International Standards Cooperation and Promotes Dual-Carbon Standards System." *ThePaper*, August 20, 2022. https://m.thepaper.cn/newsDetail_forward_19541021.
Yang, You-hong, Ping Gao, and Haimei Zhou. 2023. "Understanding the Evolution of China's Standardization Policy System." *Telecommunications Policy* 47 (2, March): 102478.
Zhao, Shizhuo. 2018. "China Communication Standards Association." International Telcommunications Union (ITU). September 10, 2018. https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/ConformityandInteroperability2018/Session%201-4.pdf.
Zijing Magazine. 2024. "SPC: China Increasingly Becoming One of the Preferred Locations for International Intellectual Property Litigation," April 24, 2024. https://www.chinacourt.org/article/detail/2024/02/id/7814440.shtml.