Centre for International
Governance Innovation

CIGI Papers No. 264 — April 2022

The Digital Silk Road and China's Influence on Standard Setting

Alex He

Centre for International
Governance Innovation

CIGI Papers No. 264 — April 2022

The Digital Silk Road and China's Influence on Standard Setting

Alex He

About CIGI

À propos du CIGI

Credits

Managing Director of Digital Economy Robert Fay
Publications Editor Susan Bubak
Senior Publications Editor Jennifer Goyder
Graphic Designer Brooklynn Schwartz

For publications enquiries, please contact publications@cigionline.org.

Printed in Canada on Forest Stewardship Council® certified paper containing 100% post-consumer fibre.

67 Erb Street West
Waterloo, ON, Canada N2L 6C2
www.cigionline.org

Table of Contents

About the Author

Xingqiang (Alex) He is a CIGI research fellow. Alex is an expert on China and global economic governance, the Group of Twenty (G20), domestic politics in China and their role in China's foreign economic policy making, and Canada-China economic relations.

Prior to joining CIGI in 2014, Alex was a senior fellow and associate professor at the Institute of American Studies at the Chinese Academy of Social Sciences (CASS) and a visiting scholar at the Paul H. Nitze School of Advanced International Studies, Johns Hopkins University, in Washington, DC (2009–2010). Alex was also a guest research fellow at the Research Center for Development Strategies of Macau (2008–2009) and a visiting Ph.D. student at the Centre of American Studies at the University of Hong Kong (2004).

Alex is the author of *The Dragon's Footprints: China in the Global Economic Governance System under the G20 Framework*, published in English (CIGI Press, 2016) and Chinese editions, and co-author of *A History of China-U.S. Relations* (Chinese Social Sciences Press, 2009). He has published dozens of academic papers, book chapters, and newspaper and magazine articles. He has a Ph.D. in international politics from the Graduate School of CASS and previously taught at Yuxi Normal University in Yunnan Province, China. Alex is fluent in Chinese and English.

Acronyms and Abbreviations

3G	third generation
3GPP	3rd Generation Partnership Project
4G	fourth generation
5G	fifth generation
5G NR	5G New Radio
AC	alternating current
AI	artificial intelligence
BRF	Belt and Road Initiative Forum for International Cooperation
BRI	Belt and Road Initiative
BRICS	Brazil, Russia, India, China and South Africa
CIGRE	International Council on Large Electric Systems
DC	direct current
DSR	Digital Silk Road
eMBB	enhanced mobile broadband
EPO	European Patent Office
ICT	information and communications technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMT-2020	International Mobile Telecommunications-2020
IoT	Internet of Things
ISO	International Organization for Standardization
IT	information technology
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union Radiocommunication Sector
JTC	Joint Technical Committee
LDPC	low-density parity-check
LPWA	low-power wide-area
LTE-M	long term evolution for machine type communication
MIIT	Ministry of Industry and Information Technology
mMTC	massive machine-type communications
NB-IoT	Narrowband-Internet of Things
NDRC	National Development and Reform Commission
NITS	China National Information Technology Standardization Committee
PCT	Patent Cooperation Treaty
R&D	research and development
RIT	radio interface technology
SAC	Standardization Administration of China
SEPs	standard-essential patents
SG15	Study Group 15
SGCC	State Grid Corporation of China
SOEs	state-owned enterprises
TD-LTE	time division duplexing-long term evolution
TD-SCDMA	time division-synchronous code division multiple access
UHV	ultra-high voltage
URLLC	ultra-reliable and low-latency communications
USPTO	United States Patent and Trademark Office
WP1	Working Party 1
WP3	Working Party 3

Executive Summary

The Belt and Road Initiative (BRI), China's global investment plan to build a complex infrastructure network connecting the world, has extended to frontier areas such as fifth-generation (5G) mobile networks, the Internet of Things (IoT), artificial intelligence (AI), big data, smart cities, data centres and cloud computing in the digital economy era. The transition began with the Digital Silk Road (DSR), launched in 2017, which has evolved into a crucial part of the BRI.

Standard connectivity is an important component of the BRI and the DSR. As the DSR moves ahead, Chinese private companies, not state-owned enterprises (SOEs), have become the main drivers fuelling the rise of China in technology progress and shaping standards in both domestic and global markets. Chinese companies' overseas investments covered a variety of fields in the digital economy, including 5G and IoT, big data and smart cities, data centres and cloud computing, AI and AI-based facial recognition and surveillance, and submarine and territorial cables.

Geopolitical and economic security concerns unavoidably played an important role in global competition for standardization to seize strategic heights in frontier technologies. Under China's political and economic conditions, companies cooperate with the government in pushing for China's grand initiatives such as the BRI and the DSR. Many private big technology companies and promising tech start-ups have closely cooperated with the Chinese government in forging national innovation platforms to promote technological innovation and create national standards. In the 5G era, the Chinese government has relied more on Huawei and ZTE's influence on 5G and IoT standard setting. With their increasing investment and market expansion in digital technologies and related standards application among BRI countries, Chinese enterprises are expected to complement the Chinese government's goal to have more influence in international standard-setting organizations.

China's ambitions in standard setting are embodied in strategies such as China Standards 2035, standardization practices via overseas investment initiatives such as the BRI and the DSR, and more assertive participation and rising influence in international standard-setting bodies. Concerns over the link between standards and values associated with the application of technologies and standards are reasonable. Among them, Huawei's advantages in patents and standardization of 5G and IoT and Chinese companies' leading roles in AI-based facial recognition and video surveillance stand out. Exporting these technologies in many non-democratic regimes within the BRI further reinforces the concern over China's increasing influence in standard setting and the potential that China may capture the data associated with their use to boost its AI industries.

However, there are great challenges facing China's realization of its ambitions in international standard setting. Gaps between China's ambitions and technological capacity in international standard setting and between its policy goals and policy implementation, the inconsistency between government goals and enterprises' commercial interests, as well as the fierce global competition over standards and technologies could hold China's progress in international standard setting in check. These developments are something to watch but not worry about at this point.

Chinese companies' leading position in technologies and market share in AI-based facial recognition and surveillance have not translated into more influence at major standard-setting organizations. China's representation and influence in international standard-setting organizations are still outweighed by the traditional powers of the European Union and the United States, with the exception of China's increasing influence on 5G and IoT at the 3rd Generation Partnership Project (3GPP) and the International Telecommunication Union (ITU).

The European Union and the United States dominate global standardization competition in key areas such as AI, biometrics, data centres and cloud computing, and optical fibres and cables, although China has been actively participating in the relevant international standard-setting bodies in recent years. China is facing formidable competitors in the European Union and the United States when promoting its standards. In the areas of 5G and IoT, where Chinese companies have certain advantages, enterprises from the European Union, South Korea and the United States each have an equivalent or even greater influence on patents and standardization.

Chinese companies, in particular private enterprises' investment behaviour in frontier technologies, are mainly driven by market-oriented strategies for larger market share and profit maximization. The enterprises' commercial calculation can be inconsistent with and undermine the implementation of the Chinese government's strategies and policy goals in standard promotion along the DSR. Indeed, China is gaining more influence in market share and standard setting in some frontier technologies through Chinese companies' expansion in BRI countries, but this narrative may overstate the geopolitical reasons for the adoption of different technologies and standards. In many cases, the advance of technology itself, including the availability of technological requirements, and the supply chains behind it, as well as commercial interests are the primary reasons for adopting different technologies and standards.

Introduction: When Standards Meet the DSR

Standardization in vehicles, measures, currency and so forth helped the Qin Empire successfully transform China into a united middle kingdom. Fast-forward 2,000 years, and Chinese President Xi Jinping is promoting standard connectivity as an important component of the BRI, his signature foreign policy proposal, to serve the ambitious goal of connecting Africa, Asia, Europe and countries throughout the world.

China developed its understanding of the importance of standards along with its closer embrace of the global economy at the beginning of the twenty-first century. Standards provide significant technical support for economic growth and governance, a necessary "passport" to facilitate China's foreign trade and break down trade protectionism, and a path toward more market share. A popular saying circulated in China's industry circle, "First-tier enterprises make standards, second-tier enterprises make technology and third-tier enterprises make products,"[1] illustrates China's awareness of the significance of standards.

Following the strategic plans made by developed countries such as Canada, Japan, South Korea, the United States and the European Union in the first decade of the twenty-first century, China developed its first national plan for standards in 2015: the Development Plan of the National Standardization System Construction (2016–2020). It set the goal of building a national standardization system to support a modernized state governance system by 2020 and to develop China into a world "standards power" by expanding the influence of Chinese standards (State Council 2015).

Standard connectivity is an important component of the BRI. As a key measure to facilitate infrastructure connectivity and trade between China and BRI countries, standard connectivity was established in the official road map[2] of the BRI issued in March 2015. The official Action Plan on Belt and Road Standard Connectivity (2015–2017) was released in October 2015, outlining 10 priority areas to promote Chinese standards "going global," facilitate investment and trade, and support infrastructure connectivity (National Development and Reform Commission [NDRC] 2015).

Along with the advancement of the BRI, the digital economy has gradually evolved into China's new engine of economic growth since 2015. The digital economy was officially incorporated into the BRI at the first Belt and Road Initiative Forum for International Cooperation (BRF) convened in 2017. At the forum, Xi raised the idea of the DSR becoming a crucial part of the BRI. He mentioned frontier technologies such as AI, nanotechnology and quantum computing, and the development of big data, cloud computing and smart cities, as well as the digital economy in general as components of the DSR (Xi 2017).

Since then, an action plan and dozens of memoranda of understanding for science and technology and innovation cooperation between China and some BRI countries were announced and signed to promote the DSR. Xi further called for "building the digital Silk Road and the Silk

1 This is a widely circulated saying, but the original source is difficult to trace. See Ding, Triolo and Sacks (2018); Shivakumar (2022).

2 The road map is titled "The Vision and Proposed Actions Outlined on Jointly Building Silk Road Economic Belt and 21st Century Maritime Silk Road."

Road of innovation" at the second BRF in April 2019 (Xi 2019). Standard connectivity remained a priority for the DSR. China signed a joint initiative on strengthening standards cooperation with 12 BRI countries at the first BRF in 2017 (Ministry of Foreign Affairs of China 2017) and called for the promotion of Chinese standards in 5G, smart cities and other information infrastructures (Dai 2017).

At that point, China began to prioritize standard setting for the digital economy. Officials from the Standardization Administration of China (SAC) stated in 2018 that global technological research and development (R&D) and standards for the next-generation information and communications technology (ICT) industry represented by AI, big data and cloud computing are still evolving, which gave China an opportunity to take the lead in industrial growth and related standards (Liu 2018). The Ministry of Industry and Information Technology (MIIT) published an official opinion document to support the BRI in November 2018, highlighting China's ambitions in setting standards in the digital economy era (State Council 2018).

Along with these high-profile official announcements and documents, Chinese SOEs such as China Telecom, China Mobile and the State Grid Corporation of China (SGCC), and private companies such as Alibaba, Tencent and Huawei have already practised promoting their standards among BRI countries. They have begun to lead standard setting in mobile networks, telecommunications, AI, big data, IoT, e-commerce, advanced manufacturing, electricity transmission and other areas.

This paper examines China's practices related to standard setting in areas such as 5G and IoT, AI and smart cities, data centres and cloud computing, submarine and territorial cables, and ultra-high voltage (UHV) electricity transmission in BRI countries and assesses how the policies of the Chinese government and the practices of the country's enterprises in the DSR impact global standard setting in the digital economy era.

Major Policies for Standard Setting and Promotion

When China developed the Action Plan on Belt and Road Standard Connectivity among BRI countries in 2015, it mainly focused on traditional infrastructure (engineering construction) in transportation, electricity and energy. Although China made some progress in standard setting in its priority area of traditional infrastructure, such as engineering and equipment among BRI countries by 2019, with its increased investment and construction contracts, Chinese standards were generally not as competitive in the international engineering market, dominating only in Chinese government-aid projects (Qin, Peng and Dong 2019, 11–16).

China has achieved progress in sectors in which it has technological advantages. For example, by 2021, China had cooperated with BRI countries and led standard setting for 682 international standards in Chinese medicine, smart grids and shipping (SAC 2021). However, China is facing great difficulties in promoting its standards due to technological backwardness; differences between the Chinese technical standards system and international ones in areas such as technical indicators, the logic behind standard making and so forth; as well as the lack of proper English versions of Chinese standards and experts who can communicate well with foreign technicians and managers.

Promoting Chinese standards in strategic emerging industries and key technologies such as next-generation ICT and smart manufacturing only began to become a priority for standards cooperation within the BRI when the DSR was launched in 2017. In 2018, the SAC proposed the country's long-term strategy for standardization, China Standards 2035, with the Chinese Academy of Engineering (Liu 2018). In terms of ICT, in 2018, China would focus on standards research for integrated circuits, virtual reality, smart health care and 5G, and promote its standards in IoT, information equipment connectivity and solar panels (ibid.).

China has raised and practised the idea of "new infrastructure" since 2019. It includes three categories of broadly defined next-generation technologies: information infrastructure, integrated infrastructure and innovation infrastructure (Xu 2020). New infrastructure initiatives accelerated the development of the digital economy in China. Provincial governments followed up by making their own investment plans for new infrastructure. SOEs and private companies seized investment opportunities in information and internet and technological innovation-based new infrastructure, focusing on AI, 5G networks, industrial internet, IoT, data centres, cloud computing, blockchain, smart traffic, smart grids and so forth to build the foundation for the digital economy and digital transformation of traditional manufacturers. (See Table 1 for China's major policies on standardization since 2015.)

The rapid pace of new infrastructure development has further encouraged Chinese companies to invest in these fields in both domestic and overseas markets, in particular in BRI countries. Since then, it has become evident that standard setting in general manufacturing, advanced manufacturing and frontier ICT had evolved into an essential component of China's national strategy for standards work in the digital economy, and standards cooperation among BRI countries had become an important front for China in trialling and promoting its standards in these areas.

Promoting China's standards at the global level and international standards cooperation were also priorities, which stressed in-depth participation in international standards organizations including the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), and engagement in the formation of international standards, in particular in renewable energy, new materials, quantum computing, digital twin technology and smart manufacturing. These also emphasized promoting standards connectivity with other countries and regional governmental organizations, in particular in BRI countries, as well as adopting more international standards in China.

Under these circumstances, leading Chinese companies, in particular ICT giants Huawei, ZTE, China Mobile and China Telecom in the areas of 5G technology, smart cities and data centres, and internet giant companies such as Alibaba and Tencent in frontier technologies such as AI, IoT, big data and cloud computing, play a role in practising and advancing Chinese standards and standards cooperation among BRI countries. Traditional infrastructure companies in general manufacturing and transportation, construction, solar panels, electricity transmission and so forth are practising digital transformation.

Strategies for Standard Setting and Promotion

China began to participate in making international standards by submitting proposals to the three prestigious international standards organizations: ISO, IEC and ITU in 2005 (The Paper 2016; China Market Regulation News 2019). The first national plan for a standardization system introduced in December 2015 emphasized that China should use its higher position and senior staff in international standards organizations to design strategies, policies and rules for international standards, and deepen international standards cooperation with other countries (State Council 2015).

In general, several strategies and tactics have been employed to promote Chinese standards worldwide. First, China has put forward proposals for international standard setting in areas in which it has advantages but lacks its own international standards. China has co-submitted proposals with developed countries for international standards in highly competitive and critical areas (China Financial Standardization Technical Committee 2017). Judging by the SAC's announced achievements in September 2019, China promoted its standards to become global standards in areas in which it has advantages; this overlapped the priority sectors in which China promoted standards in BRI countries. These sectors are home appliances, UHV electricity transmission, IT, railways, electric cars, aviation, apparel and Chinese traditional medicine (State Council Information Office 2019).

Second, China pushed to establish new technical committees or subcommittees within international standards organizations and to install Chinese experts as chairs of these committees. China actively persuaded other countries to give up the positions of chairperson or secretariat in technical committees overseeing areas that China prioritized. China also co-chaired the positions of chairperson and secretariat with developed

Table 1: China's Major Policies for Technology Standard Setting and Promotion

Policy	Major Features	Exclusive Focus on BRI or DSR	Issuing Agency and Date
Plan for the Development of the National Standardization System Construction (2016–2020)	→ China's first national plan for standard setting and standardization → Build a national standardization system to support a modernized state governance system by 2020. → Develop China into a world "standards power" by expanding the influence of Chinese standards.	No	State Council, 2015
Action Plan on Belt and Road Standard Connectivity (2015–2017)	→ Outline 10 priority tasks in cooperation with strategic BRI countries to promote Chinese standards going global. → Serve the goals of facilitating investment and trade, deepening international cooperation in standard setting and supporting infrastructure connectivity.	Yes	NDRC and BRI Leading Group, 2015
Action Plan on Belt and Road Standard Connectivity (2018–2020)	→ Expand standard cooperation in trade, e-commerce, environmental protection, health, finance and oceans based on 2015–2017 action plan. → Prioritize special projects such as mutual standard recognition, Chinese standards demonstration and promotion, and translation of Chinese standards.	Yes	SAC, 2018
Implementation Opinions of Ministry of Industry and Information Technology on Standardization Work of Industry and Communication Sector to Serve the Belt and Road Initiative	→ Outline general manufacturing, ICT and advanced manufacturing industries as three priority areas to serve standard setting in the BRI. → Encourage Chinese companies to cooperate with relevant standards organizations to promote standards application in the information and communication sector among BRI countries. → Promote standards cooperation in next-generation information technology (IT), including 5G, IoT, AI and big data, cloud computing, virtual and augmented reality, as well as areas such as smart cities, BeiDou satellite navigation systems, telecom engineering projects, network connectivity and so forth.	Yes	MIIT, 2018

Policy	Major Features	Exclusive Focus on BRI or DSR	Issuing Agency and Date
Key Points in the Work of National Standardization in 2020	→ Promote standard setting in advanced high-end manufacturing (smart manufacturing) and next-generation IT, including 5G, IoT, AI, big data, smart cities, blockchain, cloud computing and so forth, as well as biotechnology. → Encourage in-depth participation in standard governance in international standards organizations such as ISO and IEC. → Promote standards connectivity via the BRI and BRICS (Brazil, Russia, India, China and South Africa) and the exchange of standards information. → Adopt more international standards.	No	SAC, 2020
National Standardization Development Outline (China Standards 2035)	→ Set numeric indicators for improving China's standards level in 2025 and 2035, including a ratio of 50 percent standards-essential research results in crucial generic technologies and applied technological projects, an 85 percent conversion rate of international standards and establishing 50 national technological standard innovation bases. → Promote interaction between standardization and scientific innovation, strengthening standards research in crucial technologies such as AI, quantum information, biotechnology, next-generation IT, big data, blockchain, new energy and materials, and so forth. → Improve standards level in essential industries such as core electronic devices, advanced basic processes and key basic materials, as well as in advanced manufacturing and emerging industries. → Promote in-depth exchange and cooperation in standards via active participation in international standards organizations, the BRI, BRICS and the Asia-Pacific Economic Cooperation. → Intensify the role of standards for trade facilitation and convert China's standards to international standards.	No	Chinese Communist Party Central Committee, State Council, 2021

Sources: NDRC (2015); SAC (2018; 2020b); State Council Information Office (2018); State Council (2015; 2018).

nations, based on ISO policy (China Financial Standardization Technical Committee 2017).

Third, China introduced a Standards Mutual Recognition Working Procedure to sign more standards cooperation agreements with other countries to promote its standards and facilitate trade. By 2017, China had signed agreements with 28 countries and regions, including France, Greece, the European Union and the United Kingdom, on improving standards conformance and signed lists of mutual standards recognition with standards agencies in France and the United Kingdom to facilitate trade (ibid.). Mutual standards recognition is an important part of China's action plans to promote standards connectivity with BRI countries (NDRC 2015; Ministry of Foreign Affairs of China 2017).

Fourth, China is encouraging Chinese institutions and enterprises, in particular giant and advanced enterprises, to participate more actively in international standard-setting organizations and promote Chinese standards through business practices (The Paper 2016; China Market Regulation News 2019).

Fifth, China listed its standards as preconditions when making contracts and carrying out foreign aid programs (J. Hao 2019). China's foreign aid law in 2008 stipulated that projects receiving Chinese government aid need to fully adopt Chinese standards while receiving aid (Ministry of Commerce of China 2008). The law was revised in early 2016 and relaxed the regulations for adopting Chinese standards (Ministry of Commerce of China 2015; J. Hao 2019).

Government-Business Cooperation in Standards Promotion in the DSR

With its embrace of the digital economy as a new economic growth engine since 2015 and its efforts to promote the DSR since 2017, China has put more emphasis on practising and setting standards for frontier technologies in emerging industries in the BRI. It is relatively easier to lead and set standards in frontier areas rather than in fields where standards already exist.

Government-business cooperation plays an important role when it comes to promoting standards in BRI countries. Different styles of cooperation between government and enterprises have been used to promote Chinese standards abroad since China launched its "going global" policy. By the time the DSR was defined as one of the priorities for the BRI in 2017, Chinese operators and telecommunication companies had already been practising and expanding Chinese standards for years in the prioritized areas of the BRI, such as Southeast and Central Asia, Africa, the Middle East and Eastern Europe. These approaches basically remained the same after the DSR was prioritized in 2017–2018.

First, close collaborations were formed between the government, industrial circles and companies to promote Chinese standards at international standardization organizations. The promotion of Chinese standards in third-generation (3G)[3] and fourth-generation (4G)[4] demonstrated this coordination (Stewart et al. 2011). It was the government officials in charge who made the final decision to develop China's own standards in mobile communication networks and promote them at the ITU. The ICT sector and major enterprises in China supported these efforts with R&D for 3G and 4G standards. In the 5G era, the Chinese government continued its support for the industrial sector, making concerted efforts and investments to move forward on 5G research and standard setting at 3GPP and ITU (State Council Information Office 2016).

The Chinese government focused on mutual standards recognition, signing bilateral agreements on standards cooperation, translating Chinese standards into foreign languages and prioritizing sectors in which China has advantages when it comes to standards promotion in BRI countries. The priority sectors include infrastructure, manufacturing equipment in emerging industries, and typical Chinese industries such as traditional Chinese medicine, shoemaking and so forth. The major standards promotion under China's official policy helped facilitate Chinese companies'

3 It was called time division-synchronous code division multiple access (TD-SCDMA) in China.

4 It was called time division duplexing-long term evolution (TD-LTE) in China.

investment and standards application in BRI countries. For example, the SAC and its superior government agency, the General Administration of Quality Supervision, Inspection and Quarantine, promoted standards cooperation with Turkmenistan in 2011 and registered 83 Chinese standards there in 2014. This helped the Chuanqing Drilling Engineering Company Limited, a company affiliated with the China National Petroleum Corporation, save 15 percent of the cost of its investment in projects in the Galkynysh gas field in Turkmenistan (China Financial Standardization Technical Committee 2017; Wang 2017).

Second, the Chinese government and its enterprises made a less concerted effort to promote Chinese standards on the global market.

On one hand, Chinese companies have practised their technical standards in many BRI infrastructure projects, including in the ICT area, which connects many digital standards in wireless communication, data centres and cloud computing, and smart cities. For example, partnered with Softbank, Vodafone and Clearwire, China Mobile has already practised and promoted its 4G (TD-LTE) standards via the Global TD-LTE Initiative and built a large number of base stations overseas since 2011 (Hu 2012). Huawei and ZTE had already deployed 4G and other telecom infrastructures along the BRI long before the BRI and the DSR were initiated (Li, Guo and Wang 2017). These activities carried out by enterprises would help promote Chinese standards.

On the other hand, the Chinese government's major initiatives and policies encouraged Chinese companies to use its technological standards. DSR projects and investment in the new infrastructure served as significant official policies to further endorse existing supportive measures. Government-affiliated institutes such as the China Development Research Foundation and the Research Institute of People.cn named Baidu, Alibaba, Tencent and Huawei as four major tech companies for the new infrastructure: Baidu in the area of AI; Alibaba in cloud computing and digital platforms; Tencent in industrial networks; and Huawei in 5G, IoT and related areas (C. Zhang 2020). With the increased fervour of the new infrastructure, these companies' investments in 5G and IoT equipment, AI and smart city projects could expect to bring wider applications of Chinese standards in these areas.

Chinese companies' investments in and applications of standards do not necessarily translate Chinese standards into international ones, which fall within the jurisdiction of bodies such as ITU, IEC, 3GPP and the Institute of Electrical and Electronics Engineers (IEEE), and need to be approved by these bodies through fierce competition. However, China's investment and practice would create a *fait accompli* in which more and more countries applied Chinese technologies and standards, providing China with leverage over these countries to make an impact on international standard-setting bodies. For example, ITU, with Chinese national Zhao Houlin as its secretary-general, signed an agreement with China in the BRF in 2017 to help these countries expand their ICT networks and services (Zhao 2017) and signed a letter of intent to strengthen cooperation in telecommunications and information networks within the BRI framework at the second BRI Forum in 2019 (Office of Belt and Road Construction Leadership Group 2019).

Third, a tacit, reciprocal model exists between the Chinese government and the enterprises, in which they take advantage of each other. The Chinese government repeatedly stressed the promotion of indigenous innovation and standards abroad, which has impacted how its major enterprises or national champions invest overseas. Conversely, these enterprises' practices under government guidelines have impacted government policies and, in some cases, undermined the implementation of government policy goals.

On the one hand, Chinese enterprises took advantage of political leaders' intentions to make breakthroughs in indigenous innovation and standards to ask for preferential financing and other privileged policies. For example, it turned out the cost for ICT companies' overseas expansion is huge, and experts in China's ICT industry have suggested a separate policy for accounting and assessment of SOEs in this sector when it comes to their overseas investment (Chen and Dong 2018; Liu and Lin 2018). The slogans around developing and promoting Chinese innovation and standards would win Chinese companies' substantial support from the central government and local governments.

On the other hand, Chinese companies tried very hard to show government bureaucrats and leaders that they had achieved remarkable results in developing Chinese innovation and promoting standards overseas to serve the leaders' signature projects such as the BRI and the DSR. Since politics matters most in China, sometimes these enterprises exaggerated what they had done, which, conversely, greatly contributed to the performance of the government agencies and officials involved but held back China's progress in innovation and technology. The self-proclaimed Chinese innovation and standards around TD-SCDMA and TD-LTE are a case in point (Qin 2014).

The officials responsible in the MIIT and China Mobile co-created the myth that TD-LTE is based on China's own innovation and standards for 4G. However, TD-LTE is not a true indigenous Chinese technology (ibid.) and does not represent mainstream 4G standards adopted internationally. China had used its huge market size to coordinate and organize a losers' alliance in global standards competition to establish alternative global standards. By doing so, both China Mobile and MIIT officials involved benefited economically and politically.

In short, the DSR operates as an extensive framework under which Chinese companies, particularly tech giants, take advantage of stimulus policies and financial support from the government to seek commercial opportunities. This framework is particularly important to SOE ICT companies as they can get maximum advantages in financing, policy support and other benefits from the Chinese government, such as help forging strong bilateral relations to create a favourable environment for investment. Private companies can generally benefit from the favourable political, economic and social environment that SOEs and the Chinese government have already created, leading to smoother operations.

For the Chinese government, the realization of policy goals for the DSR must rely on the practices of Chinese companies, which have their own concerns (particularly private tech giants), and their biggest motivation is to pursue commercial interests while complying with the Chinese government's policies to promote China's standards. This approach creates inconsistencies between enterprises' commercial interests and the Chinese government's strategy of making its standards go global. In addition, the SOEs' claims of innovation and inflated achievement to get more preferential political and financial support did not help achieve the government's goal for standardization. Plus, the long-standing problem in China's policy implementation process and the worsening policy execution under Xi's top-level design policy-making model (He 2020) would further hinder the advancement of his grand strategy, including the DSR and China Standards 2035.

In the following sections, the author will discuss the status quo of Chinese companies' investments in different areas of the digital economy, as well as the impact on global standard setting in these fields. Among them, 5G and IoT are the areas in which Chinese enterprises have invested heavily and are taking the lead.

Chinese Companies' Investment in the Digital Economy and Impacts on Standard Setting

5G

Breakthroughs in technologies and standards in 5G were among the top strategic goals stipulated in China's *Strategical Outline for the Development of National Informatization*, released in July 2016 (Xinhua 2016). They were also among the central elements of the new infrastructure developed since 2019. The Chinese government has left its footprint on 5G standard setting and research through support of its ICT industry to create the International Mobile Telecommunications-2020 (IMT-2020) (5G) Promotion Group for 5G research and cooperation with foreign entities, organizing both Chinese and foreign companies to test key 5G technologies and sponsoring the first global 5G conference. China has made progress in radio technology, antennas, network architecture and other aspects of 5G technologies. Chinese enterprises such as Huawei, ZTE and Da Tang have been doing R&D in 5G equipment and standards and have made significant progress.

During China's push for 5G and IoT standard setting, Huawei, as a leading 5G patents (both standard-essential patents [SEPs] and general patents) holder and standards researcher, has played an important role. In the 4G era, Huawei owned only one percent of 4G SEPs while ZTE, the most successful Chinese company with the largest percentage of SEP patents, owned six percent (Jefferies Group

2017). Huawei began to do research on 5G in 2009 (Gan 2019) and announced a US$600 million investment in 5G technology and standard research (Ifeng.com 2019). The early investment helped Huawei achieve an advantageous position in 5G development. Huawei ranked as number one on the IPlytics list of 5G declarations after 2012, when the main 5G technology inventions began to emerge (Pohlmann and Heß 2020). When the 3GPP consortium started developing the specifications for 5G standards in 2015, Huawei was already a leader in applying 5G patents and began to prepare commercial 5G equipment (Gan 2019).

Huawei won its first significant victory in 5G standard setting in 2016, when major ICT companies worldwide joined the 3GPP conferences to discuss which channel-coding schemes should be adopted for enhanced mobile broadband (eMBB), one of three 5G usage cases[5] for enhanced indoor and outdoor broadband, enterprise collaboration, and augmented and virtual reality. Among the low-density parity-check (LDPC) code and Polar code in which Huawei holds the most patents, the latter was finally adopted as the channel-control coding for eMBB data while the LDPC code was adopted as the channel coding, which is more significant for 5G communication.

In retrospect, business interests prevailed over purely geopolitical considerations. Polar code failed to become the channel coding for eMBB data because no companies, including Chinese companies, wanted Huawei to become another Qualcomm and collect billions in patent fees in the 5G era. And most companies want to have a unified communication standard in the age of 5G. Almost all major companies supported LDPC as it has been verified as technologically reliable after decades of use and is cheaper to use because most of its essential patents have expired. Many companies, including Qualcomm, Ericsson and Samsung, own patents on Polar code as well, which determined that they could accept Polar code as the channel-control code, although Huawei would benefit most from it. Huawei accepted LDPC code for the channel coding for eMBB data as it also owned patents on LDPC code.

Huawei has maintained its technological advantages in 5G development since then. By January 2020, the company had the largest declared number of 5G patent families, followed by Samsung, ZTE, LG and Nokia. Huawei's influence on 5G standards can be measured by other factors. Huawei tops other companies in terms of its share of 5G technological standards contributions, the number of 5G contributions approved, the number of 5G standards it contributed as the first contributor and the number of attending engineers at 3GPP's 5G standard-setting meetings (see Table 2).

Huawei was second to Samsung in the number of declared 5G patent families that have been filed internationally (through the United States Patent and Trademark Office [USPTO], European Patent Office [EPO] or the Patent Cooperation Treaty [PCT]), and lagged behind Samsung, Nokia and LG in the number of granted 5G patent families; however, Huawei is still regarded as leading the global 5G patent race because 5G is a relatively new technology, and it takes time for recently filed 5G patents to be granted. Huawei's number of granted 5G patents is expected to increase in the future.

Led by Huawei, Chinese companies account for 32.97 percent of total 5G declarations, the largest share by country of origin of patent holder, followed by 27.07 percent held by Korean companies, 16.98 percent by European companies and 14.13 percent by American companies (Pohlmann and Heß 2020).

SEPs play an important role in standardization. However, the exact number of SEPs each company owns for a specific set of standards is not available to the public as relevant data is not always released. Data on self-declared SEPs by companies is available from some standards organizations, such as the European Telecommunications Standards Institute. Table 3 shows the companies, including Huawei, that are believed to be major holders of 5G SEPs, based on analysis and estimation by IPlytics (2019) and Amplified and GreyB (2020), and research by Robert L. Stoll (2020).

Huawei is also a leading 5G equipment manufacturer and signed 91 commercial 5G contracts worldwide (Li and Cheng 2020) by August 2020, second only to Ericsson (Ofweek

5 The eMBB is one of three classes of 5G usage cases the ITU defined (ITU 2018). The other two are ultra-reliable and low-latency communications (URLLC), which applies to technologies such as autonomous vehicles, smart grids, remote patient monitoring and telehealth, industrial automation, and massive machine-type communications (mMTC), which applies to technologies such as IoT, smart cities, smart homes and remote monitoring.

Table 2: 5G Patent Statistics by Company

Company	Number of Declared 5G Patent Families	Number of Declared 5G Patent Families Filed in the USPTO, EPO or PCT	Number of Declared 5G Patent Families Granted in at Least One Office	Technological Contributions Submitted to 5G Standards	Number of Attending Engineers at 3GPP's 5G Standard-Setting Meetings	SEP Declarations for 5G
Huawei	3,147	2,342	1,274	19,473	3,098	2,343
Samsung	2,795	2,633	1,728	4,573	2,142	9,665
ZTE	2,561	1,878	837	4,692	1,128	n/a
LG	2,300	2,236	1,415	2,578	1,096	59
Nokia	2,149	2,074	1,584	11,555	1,618	n/a
Ericsson	1,494	1,461	768	15,072	2,193	5,990
Qualcomm	1,293	1,210	831	5,994	1,701	9,980
Intel	870	855	148	3,656	1,259	744

Sources: IPlytics (2019); Pohlmann and Heß (2020).
Note: Red figures indicate highest number in each category.

2020), and shipped more than 600,000 5G massive multiple-input multiple-output active antenna units (J. Zhang 2020). Huawei's shipment of 5G equipment tops the global 5G equipment market, with a share of 35.7 percent (Ofweek 2020). This can be largely attributed to the huge domestic 5G market in China, which has already built 400,000 5G base stations, accounting for 70 percent of the world total (ibid.).

In terms of geographical distribution, Huawei and ZTE are two leading Chinese companies that have expanded their 5G networks into the global market. Most of Huawei's contracts are from Europe (47 contracts are with European countries) (Li and Cheng 2020), 27 contracts are from Asia and 17 contracts are from other regions (J. Zhang 2020). In Europe, Huawei's deals and investments in 5G went mostly to developed countries in Western Europe, such as Belgium, France, Germany, the Netherlands, Portugal, Spain, Switzerland and the United Kingdom. Data from the Australian Strategic Policy Institute's database, Mapping China's Tech Giants, shows the same trend. Among Huawei's 75 overseas 5G deals, most of them are from Europe, the Middle East and Southeast Asia.[6] Many of them are with countries in the BRI. ZTE followed almost the same route as Huawei in terms of overseas 5G deals and cooperation, but with a smaller number. ZTE signed 31 5G deals in 18 countries[7] and has most of its overseas 5G deals with developed economies in Western Europe and the Asia-Pacific region as well as deals with some Southeast Asian countries.

IoT

In addition to the eMBB, Huawei has made progress in standard setting in two other classes of 5G use cases (URLLC and mMTC), in particular mMTC, which is used in applications such as IoT. In the eyes of Wen Tong, Huawei's 5G chief scientist, IoT is the more important use case for 5G development and would change almost all industries through upgraded digitalization fuelled by IoT, which, conversely, would provide 5G huge opportunities (Wang 2019).

In the area of mobile IoT,[8] there are two types of low-power wide-area (LPWA) technology standards that support the development of the usage of mMTC in connected devices, machines and vehicles (GSMA 2016). One is called Narrowband-

6 See https://chinatechmap.aspi.org.au/#/map/f2-Huawei,f6-5G,f2-Huawei,f6-5G.

7 See https://chinatechmap.aspi.org.au/#/map/f2-ZTE,f6-5G.

8 Mobile IoT refers to LPWA networks designed for IoT applications that are low cost, have low power needs and low data rates, and require long battery lives. It will play an important role in connecting the billions of new devices that make up the IoT. See www.gsma.com/iot/mobile-iot/.

Table 3: Estimated 5G SEP Portfolios by Company

Company	5G SEP Family Share		
	Data from IPlytics	Data from Amplified and GreyB	Data from Stoll
Huawei	7.92%	19.36%	9.4%
Qualcomm	8.6%	11.52%	n/a
LG	7.38%	13.75%	n/a
Ericsson	6.74%	9.17%	16.1%
Samsung	5.77%	15.44%	11%
Nokia	3.48%	12.18%	n/a
ZTE	4.1%	n/a	n/a
Intel	3.04%	n/a	n/a

Sources: Pohlmann (2018); Amplified and GreyB (2020); Stoll (2020).
Note: Red figures indicate highest number in each category.

Internet of Things (NB-IoT), which is a narrowband radio networking technology that operates independently of LTE networks. It would be able to handle high volumes of IoT devices in the other two classes of use cases and allow network operators to control cost, coverage and power consumption (ibid.). The other is long-term evolution for machine type communication (LTE-M). The 3GPP launched the NB-IoT study focus in 2014.

China was one of the pioneering countries to develop NB-IoT standards. Its national basic IoT standards working group released a white paper on the standardization of IoT in 2016. Chinese companies, including Huawei, along with other telecom giants such as Ericsson, Qualcomm and Vodafone, have contributed to standards in the 3GPP. Huawei submitted the most proposals for NB-IoT standards, and its accepted proposals account for 41 percent of total approved proposals (Huang 2017). The 3GPP finalized the standardization of NB-IoT in its Release 13 in June 2016. This was a groundbreaking event for the development of IoT, and China, with the contribution of Huawei, was taking the lead in the development of NB-IoT standards and applicable devices. Since 2017, the Chinese government has issued several national policies to comprehensively promote IoT development based on NB-IoT standards.[9] In industrial circles, China released the industry-standard water meter in October 2018 and approved the release of the group standard for a smart gas meter-reading system in April 2019.

However, the completion of 3GPP standardization of NB-IoT in 2016 did not lead to rapid development of IoT as expected. NB-IoT, at the time, was good enough for most 5G eMBB use cases. With the rapid 5G technology development in the other two classes of use cases, LTE-M and NB-IoT became compatible with 5G New Radio (5G NR)[10] and seamlessly coexisted with and provided support for mMTC and URLLC. 3GPP Release 16 was finalized in July 2020, aiming to broaden the use cases where 5G NR can be applied and improve capacity and performance of 5G systems, including meeting diverse requirements for IoT. As 5G rapidly evolved to meet the use cases and diverse requirements for IoT and define global IoT standards, 5G and IoT standardization began to converge.

After three years of development in NB-IoT, a Chinese delegation comprised of the China Academy of Telecommunications Technology, Huawei, ZTE, China Mobile, China Telecom and China Unicom identified NB-IoT as an IMT-2020 (5G) LPWA candidate technology and submitted

9 The MIIT issued three circulars in 2017, 2019 and 2020 to support the development of mobile IoT in China. See Jin (2020).

10 5G NR is a non-standalone 5G mode that allows backward compatibility with existing 4G LTE systems. 3GPP declared two sets of specifications: Release 15 (phase 1) and Release 16 (phase 2) for 5G standards in late 2017. Release 15 was the milestone for 5G standardization, and 3GPP approved the first set of specifications for 5G communications (5G NR) in December 2017. The enhanced 5G NR can support high-performance IoT use cases. By June 2018, 3GPP finalized Release 15, which introduced and standardized the portion of standalone 5G NR, the 5G core.

it to the ITU Radiocommunication Sector (ITU-R) in 2019. At the ITU-R Working Party 5D meeting on July 9, 2020, the ITU announced that the 3GPP technology package was officially recognized as an ITU IMT-2020 5G standard. The technology comprises 3GPP NR plus NB-IoT radio interface technology (RIT) submitted by China, 3GPP NR RIT submitted by South Korea, and NR plus LTE SRIT (set of radio interface technologies) and NR RIT submitted by 3GPP. On the same day, in an apparent move to promote China's 5G standard proposal, the Chinese government-coordinated IMT-2020 (5G) Promotion Group announced that it had organized multi-company participation in 5G equipment security testing, and Huawei had passed with a score of 100 percent (Zhou 2020).

This means NB-IoT has been officially recognized as a 5G standard. It coexists with 5G NR, and new NB-IoT terminals can access the 5G core network. It will accelerate scaled 5G commercialization and boost the development of the IoT industry in the next decade. LTE-M meets the requirements for IMT-2020 5G standards as well to support massive IoT and seamless coexistence with NR. Both NB-IoT and LTE-M are officially part of the 5G family now. With 5G bringing major investments and upgrades in the 5G NR and core 5G networks, the deployment of NB-IoT and LTE-M will accelerate as well.

With its early investment over the past few years, China has developed a complete industrial and supply chain, including standards, chips, modules, system equipment and solutions for NB-IoT. NB-IoT naturally became China's preferred LPWA technology over LTE-M. China's three big operators, in particular China Telecom, rapidly deployed the NB-IoT network and built more than 830,000 base stations across China by August 2020 (Vzkoo.com 2020). ITU's recognition of NB-IoT as a 5G core standard has greatly encouraged the industrial sector in China, and an even more rapid deployment of NB-IoT network and related industrial chains is expected in the near future. With Huawei and ZTE's significant percentage of patents in both NB-IoT and LTE-M standards, China sees the opportunity for building an IoT industry that is less dependent on foreign patents and IP.

In terms of IoT patents, ZTE is among the top three companies that owns the most patents for the LTE-M 5G standard, along with Nokia and Samsung, and owns the second-most patents for the NB-IoT, after Nokia (Pohlmann and Buggenhagen 2020). Huawei, by comparison, ranks number one for its contributions to NB-IoT standards and number two for its contributions to the LTE-M standard (ibid.). This indicates that Huawei is going to be one of the leaders in both IoT standards and NB-IoT and LTE-M technology and patents in the years to come.

In general, technology availability and cost considerations are the main reasons for choosing between LTE-M and NB-IoT. Operators typically deployed LTE-M first in regions where LTE coverage already existed. Otherwise, it is cheaper to build new NB-IoT infrastructure (Onomondo 2021). Geographically, like other new technologies, mobile IoT technologies are first available locally, typically in urban areas or through nationwide deployment, and then go global. Generally, operators in Asian and European countries first focused on NB-IoT and then LTE-M, facing competition from other operators in the same regions offering the alternative. China, along with some countries in Asia and Europe, deployed only NB-IoT.[11] In North America, operators did the opposite, deploying LTE-M first, then NB-IoT.

Smart Cities

Smart cities are supposed to make use of a variety of advanced ICT technologies, including AI, IoT, big data and cloud computing, to make urban life easier and more efficient. Surveillance systems are widely used to improve the performance of smart cities, such as through better monitoring and management of traffic and parking, preventing crime, improving public security and so forth.

China's huge demand for surveillance equipment under many government surveillance initiatives (mainly overseen by the Ministry of Public Security), such as Safe Cities (2003) and Skynet Project (2005), Smart Cities (2012) for urban areas and Project Sharp Eyes (2015) for rural areas, helped China's security industry prosper in recent years. The huge amount of image data collected by cameras deployed across every corner of China contributed to the rapid growth of big data, AI and cloud computing.

The introduction of the BRI brought Chinese companies in the security and surveillance industry great opportunities for exporting their equipment to countries in the BRI. Most overseas smart city projects by Chinese companies were done by Huawei. Using AI, big data, cloud computing,

11 See www.gsma.com/iot/deployment-map/.

IoT and other rapidly evolving technologies, Huawei provided smart city solutions to more than 160 cities in 100 countries by July 2019.[12] Huawei leads in overseas smart city/public security projects in many countries in the BRI, especially in Europe, the Middle East and Central Asia, Southeast Asia, Africa and Latin America, but it does not have any footprint in the United States, Canada, Australia, Japan, South Korea, the United Kingdom, Ireland or Scandinavian countries.

In the field of surveillance equipment, Hikvision, Dahua and Uniview are three Chinese companies that account for one-third of the world market. Other Chinese companies such as Megvii, Yitu and DSJ also worked on a few security and surveillance systems overseas. These companies took advantage of the BRI, which acts as the greatest salesperson for Chinese companies. With the Chinese government's endorsement, these companies and their capabilities are easily being recognized and can open up global markets. (See Table 4 for an introduction to Chinese companies in the field of smart cities/AI/AI-based facial recognition.)

AI

The rapidly booming smart city/public security projects by Huawei, Hikvision and Dahua, and AI technology-based surveillance companies such as Uniview and Megvii have gained momentum in video surveillance and facial recognition with their years of expansion overseas, including in BRI countries. In addition to these companies, there are Chinese AI start-ups that focus more on advanced AI algorithms and standard setting, for instance, Yitu, Cloudwalk, SenseTime and Cambricon Technologies. Relevant AI technologies and standards have been deployed in a wide range of countries and regions through these Chinese companies' investments and practices, which has helped China indirectly gain more leverage at international AI standard-setting bodies.

China has long realized the importance of standards in technological development in all sectors, stating that standards are more important than technology itself and are key to scale up development of technology-based industries to achieve market domination. Due to its lagging R&D, talent pool, technologies and platforms, China falls behind other developed countries in AI standard setting. However, global standard setting is still in its fledgling stage for emerging AI technologies and industries, and China sees the opportunity to lead.

Under the supervision of the SAC and MIIT, the China Electronics Standardization Institute, along with dozens of tech companies and institutions, published a white paper on AI standardization in 2018 and proposed China's vision on establishing AI standards in a systemic framework (China Electronics Standardization Institute 2018a). Five government agencies (the China National Information Technology Standardization Committee [NITS], the Cyberspace Administration of China, the SAC, the MIIT and the NDRC) co-issued *Guidelines for the Establishment of the New Generation of Artificial Intelligence Standards System*[13] in August 2020, which initially required establishing China's AI standards system by 2023. The system includes more than 200 standards in eight parts, including:

- foundational and general standards such as terminology and reference architecture;
- standards for supporting technologies and products such as big data, IoT and cloud computing;
- basic software and hardware platforms such as AI chips and system software;
- key general-purpose technologies such as machine learning, quantum computing and knowledge graphs;
- key special technologies such as natural language processing, computer vision and bio-recognition;
- products and services such as intelligent robotics and industrial applications such as smart manufacturing, smart cities, smart traffic, smart health for industries and smart services; and
- security and privacy/ethics such as security of AI fundamentals, data, algorithms and models (SAC 2020a).

In the same month the white paper was published, China established the National Artificial Intelligence Standardization General Group, which is responsible for coordinating China's participation in

12 See https://e.huawei.com/en/solutions/industries/government/smart-city.

13 See https://sesec.eu/Archive/2020/others/guidelines-for-the-establishment-of-the-new-generation-of-artificial-intelligence-standards-system-released-by-sac-cac-ndrc-most-and-miit-in-china/.

Table 4: Chinese Companies in the Field of Smart Cities/AI/AI-based Facial Recognition

Company	Main Feature	Main Businesses	Overseas/BRI Presence
Huawei	Leader in deploying overseas smart city/ public security projects	Smart city solutions	Smart city solutions in 160 cities in more than 100 countries
Hikvision	World leader in global video surveillance market since 2011	Manufacturer and supplier of video surveillance equipment	66 subsidiaries and branches worldwide, serving 150 countries
Uniview	Ranked third in China with fourth-largest share of global IP video surveillance market	Internet protocol video surveillance devices and solutions	50 cities in 40 countries (mostly in BRI)
Meiya Pico	A cybersecurity company with close ties to the Chinese government	China's top company in digital forensics and big data for public security	50 training programs in 39 BRI countries
Megvii	One of the world's leaders in facial recognition technology	AI-based facial recognition, Face++ system	30 countries, including 11 BRI countries
Yitu	An AI-based facial recognition company	AI-based facial recognition systems	Singapore, Malaysia and the United Arab Emirates
SenseTime	World's most valuable AI company in 2019 and leading global AI algorithm provider	A deep-learning platform company providing AI algorithms for sectors such as education, health care, smart cities and automobiles	East and Southeast Asia, Saudi Arabia and the United Arab Emirates
Cambricon	A leading company in designing high-performance AI chips and processors with low-power consumption	Commercial deep-learning processor for smart-terminal products such as smartphones, security surveillance, wearables and drones; AI chips for edge computing and cloud computing	

Sources: See websites of Huawei (https://e.huawei.com/en/solutions/industries/government/smart-city); Hikvision (www.hikvision.com/en/about-us/company-profile/); Uniview (https://global.uniview.com/News/News/201809/804999_169683_0.htm); Megvii (https://en.megvii.com/about_megvii); Meiya Pico (www.meiyapico.com/about-us_d14); Yitu (www.yitutech.com/en/about-us); SenseTime (www.sensetime.com/en); and Cambricon (www.cambricon.com/).

23 international organizations related to AI standard setting, including the Big Four in the area: ISO/IEC Joint Technical Committee (JTC) 1, ISO, IEC and ITU (China Electronics Standardization Institute 2018b; Dong 2020). China's priorities focus on the areas in which it has the upper hand, such as language processing, human-machine interface, biometric identification and recognition, and computer vision. The NITS is the technological organization in the IT field that exclusively focuses on connecting with ISO/IEC JTC 1 on standardization issues. But, in general, Chinese representation within the Big Four is outweighed by the European Union and the United States, especially in the key standard-setting entities such as subcommittees, study groups and technical committees in ISO/IEC JTC 1, ISO, IEC and ITU (Patrahau et al. 2020).

Many Chinese technology and AI companies participate in standard setting. Representatives from big tech companies such as Huawei, Tencent, Alibaba Cloud, JD.com, Xiaomi, iFlytek, video surveillance company Hikvision, Dahua and AI start-up SenseTime were included in the 48-member technical group of the NITS's AI Subcommittee (TC28/SC42) (SAC 2019). These companies are also listed as parts of 173 institution members of the subcommittee. In the realm of facial recognition, Chinese companies' technological and data advantages were gained through widespread use of this technology in China. Representatives from SenseTime, Hikvision, Cloudwalk and iFlytek were listed in the second technical group (59 members) of NITS's Biometric Subcommittee (TC28/SC37) (SC37 Biometric Identity Standardization 2019).

Among these companies, SenseTime, a leading global AI platform company and the largest AI algorithm provider in China and Asia, has cooperated closely with the Chinese government. It was designated by the Ministry of Science and Technology as a next-generation AI open-innovation platform. SenseTime has fully participated in China's national AI standard setting (SenseTime 2020a). As well as being chosen as the delegate for the computer vision industry in the NITS's AI Subcommittee (TC28/SC42), China's first AI national standardization organization, SenseTime is a member institution of NITS's Biometric Subcommittee (TC28/SC37). The company also participated in dozens of domestic and international AI-related standards organizations in computer vision, facial recognition, big data, augmented reality, smart cities, smart traffic and finance. In November 2020, SenseTime chaired the working group for standards for augmented reality in mobile services at IEEE (SenseTime 2020b).

SenseTime was considered the world's most valuable AI company in 2019 (Marr 2019). The deep-learning technologies SenseTime developed have been applied in many industries. SenseTime also has expanded into overseas markets such as Singapore, Japan, South Korea, Thailand, the Philippines, Indonesia, Saudi Arabia, the United Arab Emirates, Hong Kong, Taiwan and Macau.[14] The latest investment of an AI industrial park in Malaysia was regarded as a case of SenseTime taking advantage of the BRI to export China's innovative technologies.[15]

Similarly, Yitu was also chosen as a computer-vision representative to cooperate with the Ministry of Science and Technology to build a next-generation AI open-innovation platform, which is designed to mutually optimize and deeply fuse algorithms and chips. Yitu was listed as a member of the NITS's AI Subcommittee (TC28/SC42) and selected as deputy leader of the chip and system group. According to Yitu, it has been deeply involved in China's standard-setting work and participated in more than 30 standards in AI, big data and computer vision (People.cn 2020).

Yitu established its first overseas R&D centre in Singapore and began its global expansion. It invested in AI chip maker ThinkForce and moved quickly into AI-based facial recognition and has a footprint in Singapore, Malaysia and the United Arab Emirates for developing AI-based surveillance systems for crime prevention, law enforcement (body cameras using facial recognition to identify suspects), and related health care, smart cities and hardware. In 2018, Yitu signed a strategic partnership with a UN agency in Austria (the Investment and Technology Promotion Office), which would benefit the company's overseas expansion in the fields of intelligent health care, public safety, financial services and smart city initiatives (He 2018).

In the area of AI chips, China's Cambricon Technologies is a world leader in the design of terminal intelligent processors (Cambricon 1A, 1H and 1M series), cloud-intelligent chips and accelerators (MLU series), and edge-intelligent chips and accelerators. The company has accumulated a set of core technologies and essential patents in optimized chip architecture for AI applications and algorithms. Cambricon owned 205 granted patents for AI chips, of which 39 patents were approved overseas, as well as 55 granted patents for AI chip-related basic system software by the end of 2020 (Cambricon 2021, 22–26). According to data from Clarivate Analytics, Cambricon has one of the largest patent portfolios in AI acceleration hardware or chipsets, larger than that of Nvidia, which is regarded as one of the leaders in the area of AI chips (Trippe 2020). Led

14 See www.sensetime.com/me-en/about-index#1.

15 See Y. Hao (2019) for details of how SenseTime connected with Malaysia.

by Cambricon, China is taking the lead in the competition with the United States in terms of AI chip patent innovation, with its number of patent innovations published in specialized AI chips surpassing those of the United States in 2019 (ibid.).

Data Centres, Cloud Computing and Submarine and Territorial Cables

Other key digital infrastructures identified by the Chinese government include submarine and terrestrial cables, data centres and cloud computing. Chinese companies are investing in these areas along the DSR.

The 13th Five-Year Plan for National Informatization issued in December 2016 detailed China's plan for installing submarine and terrestrial cables to connect strategic cities along the Maritime Silk Road and terrestrial cables connecting important countries and regions along the BRI, including Pakistan, Myanmar, Central and Western Asia, Russia, and Central and Eastern Europe (State Council 2016). Chinese companies including the big three telecom operators (China Mobile, China Telecom and China Unicom) and Huawei have participated in building 62 submarine cables and 48 terrestrial cables worldwide.[16] Among BRI countries, China has built 34 terrestrial cables with 12 BRI countries and dozens of submarine cables to connect Asia, Africa and Europe since 2017 (Li and Gao 2017). China also engaged in a variety of partnership arrangements in ICT infrastructures with BRI countries.

Data centres and cloud computing were regarded as crucial components of the DSR. The 2016 outline encouraged China's ICT companies to engage in building information infrastructures including data centres in BRI countries, emphasizing the deployment of data centres, cloud-computing platforms and content delivery network platforms in key strategic cities along the BRI (State Council 2016).

As in other parts of the world, telecom operators, third-party data centre providers and cloud service providers are the main data centre providers in China. Big internet companies such as Alibaba and Tencent are also leading in China's data centres to provide their cloud service. Basically, for Chinese companies, including telecom operators such as China Telecom, internet giants Alibaba and Tencent, and telecom equipment giant Huawei, their overseas deployment of data centres and cloud services mainly aim to serve and meet the demand of other Chinese companies that have invested globally, in particular Chinese companies operating overseas under the framework of the "going global" strategy and the BRI. They also can meet the demand of foreign companies that operate globally or intend to explore the Chinese market.

With regard to standard setting in submarine and territorial cables, data centres and cloud computing, China generally follows the standards set by international standard-setting organizations and falls far behind in participating in standard setting in these areas. There are a few Chinese nationals representing China in some of the subcommittees and study groups seeking to participate in the standard-setting process via engaging international organizations such as ITU, ISO and IEA, but the European Union and the United States still dominate standard setting for these areas in these organizations. Furthermore, standards in these areas are more technologically neutral and less strategic and geopolitically significant.

As for data centres, China is currently one of 23 participating members of ISO/IEC JTC 1/SC 39, the subcommittee responsible for standard setting for sustainability, IT and data centres.[17] Aside from that, China basically follows standards and best practices made in this industry by the United States and other countries to develop its own standards and build its own data centres. The standards for data centres include factors such as choosing a site; whether it is built in a green, energy-saving way; and whether it is easy to manage and maintain. These are basically neutral technology standards. China made its latest national standards on data centres, GB50174, by following the ANSI/TIA-942-B-2017 by the United States and tier standards by the Uptime Institute, the widely recognized organization and third-party certificate institution for standard setting in data centres.

In the area of cloud computing, China involved itself in standard setting as a participating member of several standard-setting bodies such as ISO/IEC

16 See https://chinatechmap.aspi.org.au/#/map/f2-China%20Mobile,f2-China%20Telecom,f2-China%20Unicom,f2-Huawei,f5-Cable.

17 See www.iso.org/committee/654019.html?view=participation.

JTC 1/SC 38, the subcommittee responsible for standard setting for cloud computing and distributed platforms,[18] and related bodies such as ISO/IEC JAC 1/SC 7, ISO/IEC JAC 1/SC 27, ISO/IEC JTC 1/SC 38, ITU-T Study Group 13 (SG13) and so forth. Chinese nationals assumed the positions of vice-chairman of ITU-T SG13 and vice-chairman of ITU-T SG13 Working Party 1 (WP1) and Working Party 3 (WP3).[19] Similar to the field of data centres, China basically follows and studies the international standards made by the United States and other countries to develop its own standards while promoting them to converge with international standards in cloud computing (China Electronics Standardization Institute 2014). In addition to these international standard-setting bodies, there are also open-source projects or organizations such as OpenStack and Cloud Native Computing Foundation that have been making standards for cloud computing for years.

Similarly, China is a latecomer in the area of submarine and territorial cables and is following international standards in the field to make its own standards while actively participating in international standard setting. ITU-T Study Group 15 (SG15) is the long-time leader in optical fibre and cable standardization.[20] Dan Li from Huawei was vice-chairman of the study group during its 2017–2020 study period.[21] China, with one of its MIIT officials becoming a management member of the ITU Telecommunication Development Advisory Group, had suggested to the ITU Telecommunication Development Sector to coordinate with ITU-T to establish a cross-border international territorial optical fibre network in 2017.[22]

18 See www.iso.org/committee/601355.html?view=participation.

19 ITU-T SG13 leads ITU's standardization work on next-generation networks. Its WP1 is responsible for standards for IMT-2020 and beyond: networks and systems, WP1 for cloud computing and data handling, and WP3 for network evolution, trust and quantum-enhanced networking. See www.itu.int/net4/ITU-T/lists/mgmt.aspx?Group=13&Period=16.

20 The ITU-T SG15 develops international standards for global communication infrastructure, including networks, technologies and infrastructure for transport, access networks and home networking. Its work includes the development of standards for the optical transport network, optical fibres and cables, and so forth. See www.itu.int/en/ITU-T/about/groups/Pages/sg15.aspx.

21 See www.itu.int/net4/ITU-T/lists/mgmt.aspx?Group=15.

22 See www.itu.int/md/D14-TDAG22-C-0054/en.

UHV Transmission Systems and Smart Grids

China has been a leader in the area of UHV transmission systems and built a world-leading set of UHV grids, including direct current (DC) and alternating current (AC) lines across China. Over decades of development since the beginning of the twenty-first century, China's SGCC has achieved the highest level of technology capability in UHV transmission.

UHV transmission systems enable transportation of electricity over long distances with minimal power loss. UHV DC transmission produces less energy loss when travelling over greater distances, while UHV AC transmission can allow for branches within the transmission lines and thus connect to several different cities (IEC 2020). To date, the SGCC has built 24 UHV lines, including ±800 kV DC lines and ±1,000 kV AC lines to transport electricity over thousands of kilometres from western and northern China to eastern areas of the country. China has the highest technological capability in ±800 kV DC lines and ±1,000 kV AC lines in the world.

The technological advancement of Chinese companies in UHV transmission has translated into the country's leading position in standard setting. China developed hundreds of its own national standards for UHV and actively participated in making international UHV standards in IEC, the International Council on Large Electric Systems (CIGRE[23]) and IEEE. Among them, SGCC (2021) proposed 53 international standards at IEC and 25 international standards at IEEE since 2009, and 42 proposals were approved by IEC and IEEE. They include seven UHV standards approved by IEC and three UHV standards being approved by IEEE out of 42 proposals. In addition, the SGCC also proposed to establish 18 technical groups at CIGRE, including one that relates to UHV (ibid.). China has increased its influence in many international standards organizations including the IEC in recent years. At the IEC, a Chinese national has served as the president since 2020, and China participated in the most technological groups and holds 12 secretariats of technical committees and subcommittees.[24] This could help China gain more influence in UHV transmission standard setting at the IEC.

23 The French acronym of le Conseil international des grands réseaux électriques.

24 See www.iec.ch/national-committees.

China has sought to expand its UHV technological advancement into the world through the global energy interconnection initiative, which was founded by former SGCC president Liu Zhenya in 2016. The idea is to build a global energy network consisting of the UHV backbone grid to connect and transmit energy, in particular clean and green energy over great distances. The proposed transcontinental and intercontinental energy network, including three key elements of a UHV grid, smart-grid infrastructure and clean energy, will allow for efficient distribution of power from where most clean (renewable) energy is generated to where it is in greatest demand.

Until recently, China's push for its idea of global power interconnection through UHV-grid and smart-grid infrastructure and expertise was not impressive. The SGCC successfully built the first UHV DC project in Brazil. Brazil's Belo Monte mega dam adapted China's ±800 kV DC lines to transmit power to its metropolitan areas where electricity is most needed.[25] The first stage of the project was finished and put into operation at the end of 2017, and phase 2 of the project is under way. This project is a rare successful case for China's UHV technology and standards going global. Except for this example, the export of UHV technology and equipment to other countries, including many BRI countries that need to move electricity efficiently to areas where it is most needed, did not go very well. The lack of urgency and high cost of the UHV grid may explain the slow progress.

Smart grids, as one of three key elements of China's proposed global energy interconnection initiative, involve the application of AI, IoT and big data. They include AI technology for power-load forecasting, intelligent inspection robots, intelligent distribution transformers, intelligent image recognition, drones for automatic inspection and so forth. The SGCC has proposed three standards on smart distribution networks at IEEE, one standard on smart hydropower plants at both IEEE and IEC, and one standard on smart-grid user interfaces at IEC (ibid.). It also takes the lead in several CIGRE technical reports on IoT and AI technology application in electricity systems, robot application in substations, global power interconnection networks and so forth (ibid.).

25 See www.sgcc.com.cn/html/sgcc_main_en/col2017112817/column_2017112817_1.shtml.

Looking into the future, UHV and smart grids and the idea of continental connected energy transmission are promising due to the great demand for generating and transporting clean and renewable energy in an efficient way to regions and cities where electricity is most needed, while addressing concerns about climate change, cleaner air and carbon use. These options offer a constructive solution for the world to address resource shortages, environmental pollution and climate change. Certainly, the risk of cascading blackouts caused by a unifying transcontinental UHV grid is another concern for many countries intending to adopt the technology.

Evaluation of Chinese Companies' Impact on Standard Setting in the DSR

Based on the discussion above, a few initial conclusions can be drawn about Chinese companies' practices in standard setting in the DSR.

First, China is taking the lead in a few cutting-edge digital technologies and promoting them along the BRI. Through investment and market expansion, Chinese companies have also achieved increasingly larger market shares and widely promoted application of these technologies in BRI countries, including 5G and IoT, AI and AI-based smart cities, facial recognition and supervision technologies, and smart grids. At the same time, China has actively and widely participated in international standard-setting organizations with regard to these types of IT, and Chinese nationals, including government officials and company representatives, are assuming more positions as chairs and vice chairs of technological committees within these organizations in recent years. Under these circumstances, China's influence on standard setting in these areas is expected to improve.

Second, in the evolution of 5G and IoT technology, Chinese companies, represented by Huawei, finally made progress and have significant influence on global standard setting after decades of R&D investment and market expansion. Along with other competitors such as Qualcomm, Samsung, Nokia and Ericsson, Huawei is taking the lead in contributing to 5G and IoT standard setting at international standards organizations such as 3GPP and ITU. Huawei also leads in 5G equipment manufacturing and deployment around the globe. In short, Huawei's significant percentage of ownership of 5G SEPs and massive contribution to 5G standards, and Huawei and ZTE's leading position in IoT standards and patents contributed to China's influence on 5G and IoT standard setting. By comparison, however, Huawei's and ZTE's influence on 5G standards is far from dominant and is equivalent to or even less than that of companies in the European Union, South Korea or the United States.

Third, the advantages that Chinese companies possess in AI and AI-based smart cities, facial recognition and supervision technologies, and smart grids are more the result of an expansion of China's domestic industries that have grown for years and achieved global technological advantages and significant dominance in supply chains. China's industrial policies and relevant government subsidies played a role in Chinese companies' rise in these sectors. China's advantages in technology and supply chains in these industries would have a different impact on the recipient countries that adopt Chinese companies' technologies and standards, depending on the forms of government and governance quality in these nations.

With respect to standardization in these areas, China is overshadowed by the United States and the European Union. Although there is Chinese representation in relevant technological standard-setting bodies such as ISO/IEC JTC 1 SC 42 on AI and ISO/IEC JTC 1 SC 37 on biometrics, the United States is a leading country in control of secretariats, where standards are being developed. China has some leadership positions in strategic advisory groups, which give important directions to subcommittees. This may indicate that China would gain more influence in planning and overseeing the development of AI and biometrics standards, but at this point, Chinese companies' advantages in technologies and market share in these areas have not translated into more clout in international standard-setting bodies.

Fourth, in the areas of data centres and cloud computing, and submarine and territorial cables, although big telecom operators in China and large internet companies such as Alibaba and Tencent are leading in China's data centres to provide their cloud service, they are not yet able to compete with global cloud-computing services such as AWS and Microsoft Azure on the global market. The Chinese government also encouraged development of the public cloud for the purpose of providing digital infrastructure for economic growth. In terms of standard setting in these areas, China falls far behind and basically follows the international standards set by the European Union and the United States in making its own national standards.

Fifth, China's grand strategy to promote its innovative technology and standards helped Chinese companies rise in this regard, especially at international standards organizations and in BRI countries as well. The Chinese government's coordination of enterprises' research and testing for 5G and IoT technologies helps them gain influence in 3GPP and ITU. Through the IMT-2020 (5G) Promotion Group, the Chinese government does coordinate its champion enterprises such as Huawei's and ZTE's 5G patents applications and standard setting. The China Standards 2035 strategy and the 2018 MIIT opinion document on promoting standards for digital technologies in BRI countries encouraged Chinese companies to promote Chinese standards in the information and communication sector.

China's policies and initiatives also influence Chinese companies' direction for market expansion and priorities, especially SOEs such as China Mobile and China Telecom. For example, submarine cables and data centres are deemed key digital infrastructures, and the Chinese government encourages investment and expansion in these areas overseas. Both SOEs and private companies have participated in these two industries. SOEs are more often following state strategies and building submarine and territorial cables and data centres along the BRI and other regions with important geopolitical implications. Chinese companies' expansion in these areas, including in 5G and IoT, raised concerns over data and national security from the United States and other developed countries, as these areas constitute key components of digital infrastructure.

China's technological advantages in smart grids and UHV transmission systems demonstrated the importance of government support and huge investments. They also indicated China's powerful SGCC's ambition and aggressive approach in promoting its technology and standards in electricity transmission and the energy sector, although not much progress has been made so far.

Sixth, Chinese companies' investment in emerging technologies is influenced by market expansion strategy, their own technological advantages and profit-driven goals rather than by China's national strategies. Technological maturity, supply chains, competition for market share and other business considerations are the primary reasons why Chinese companies choose to invest in certain European and Asian countries. Before being negatively impacted by accusations of threating national security, Huawei prioritized its overseas 5G expansion in EU countries, such as Germany and the United Kingdom, where most economies are equipped with technological and market conditions for 5G deployment. This is the primary reason why Huawei prioritized Europe for its 5G deployment. Internet giants Alibaba, Tencent and Huawei's deployment of data centres and cloud services abroad is part of their market-driven goals to meet the demand of Chinese companies that invested overseas.

Concurrently, Chinese companies took advantage of policies promoted by the Chinese government such as the DSR and benefited from their exploration of overseas markets. For many Chinese companies, the BRI or the DSR acts more like an opportunity that they can exploit. The BRI or the DSR is more like an extra privilege for Huawei's or other Chinese companies' investment. Accordingly, technology, supply chains and market share largely explain enterprises', in particular private companies', decision to choose certain technologies and standards rather than national strategies and policies. Conversely, wide use of Chinese technologies and standards and expanding market shares of China's tech enterprises along the BRI complement China's efforts to link up its national standards to international standards and gain more influence in these international standard-setting organizations.

Conclusion and Implications

China's first national plan for building a standardization system was introduced in 2015, when the BRI began to operate in full swing and the digital economy began to surge in China. Accordingly, standards connectivity between China and BRI countries and the promotion of China's standards along the BRI became one of the national plan's priorities. In the following years, the DSR gradually evolved into a crucial part of the BRI. The practice of using Chinese technology standards through the DSR is an important complement to China's promotion of its standards at international standards organizations and industry groups.

Before the DSR was established in 2017, Chinese SOEs were the major drivers in standard setting in traditional sectors such as engineering and construction for railways, power stations, electricity transmission and so forth in the BRI. Mutual standards recognition and standards cooperation were the priorities of China's standards promotion in BRI countries. Since the DSR gained momentum in 2017, private companies are becoming the backbone of China's influence in the digital economy and standard setting in some fields of the digital economy. Telecom equipment giant Huawei is the main driving force behind China's increasing role in standard setting in 5G, IoT and smart cities. Chinese AI start-ups Cambricon and SenseTime have a say in AI patents and standards. Internet giants such as Alibaba and Tencent, and Huawei are gaining significant influence in data centres and cloud-computing services in the Asia-Pacific region. Uniview, Megvii and Yitu became rising leaders in the areas of AI and big data-based facial recognition.

China's SOEs have also become involved in the DSR. Telecommunication carriers such as China Mobile and China Telecom play an important role in telecom infrastructure such as 5G base stations, submarine and terrestrial cables, and data centres. The SGCC has its own unique influence on the standard setting of UHV electricity transmission worldwide. Other Chinese SOEs such as Hikvision and partially state-owned Dahua have significant global market shares in areas such as video surveillance systems.

Driven by the desire to have its own homegrown international standards, the Chinese government has become deeply involved in its state-owned telecom companies' efforts to have a say in 3G and 4G standard setting. In the 5G era, Huawei made real progress, and the Chinese government has relied more on Huawei's influence on 5G and IoT standard setting and paid more attention to coordinating instead of directly intervening in Chinese companies' efforts to gain influence in standard setting. When it comes to its influence on standard setting at international standards organizations, China is overshadowed by traditional powers. Except for its increasing influence on 5G and IoT at 3GPP and ITU, China's representation and influence in other areas of the digital economy including AI, biometrics, data centres and cloud computing, optical fibres and cables at international standard-setting organizations are still outweighed by the European Union and the United States.

Judging from their operations overseas, Chinese private companies would rather cooperate with the Chinese government in pushing for government initiatives such as the DSR and China Standards 2035 as they can benefit from these initiatives, but their investment in frontier technologies is mainly driven by market-oriented strategies for larger market shares and maximum profits. Their investment can be facilitated under the framework of the DSR and standards-promotion strategies but are not always consistent and help to achieve the goals of the Chinese government.

China's standards-promotion activities in the DSR have a few implications for global standard setting and US-China technology competition in the digital economy era.

First, the role of China's promotion of Chinese standards through the DSR should not be overstated. It did not automatically translate into influence at standard-setting organizations, although it is an important complement to China's efforts. Chinese companies' leading position in technologies and market share in AI-based facial recognition and surveillance has not translated into more influence at main standard-setting organizations. China's representation and influence at international standard-setting organizations are still outweighed by the traditional powers of the European Union and the United States, except for China's increasing influence on 5G and IoT at 3GPP and ITU.

Second, geopolitical and national security concerns in the real world unavoidably play an important role in the global competition for standardization of frontier technologies. Chinese enterprises, both SOEs and private companies, are under great pressure from geopolitical and security concerns when investing globally, including in developed economies in Europe and North America and other countries along the BRI. Huawei is being forced out in most developed economies in the European Union and the Five Eyes security alliance between Australia, Canada, New Zealand, the United Kingdom and the United States due to US-led sanctions. Trying to keep a low profile might be the best strategy for many Chinese high-tech companies that seek to invest and expand on the global market. They can use legal and market means to defend themselves when being sanctioned by the United States or other countries. Private electronics company Xiaomi's legal victory in May 2021 against the US government and the Department of Defense's removal of Xiaomi from the list of "Communist Chinese military companies" encouraged other Chinese companies to defend themselves at court.

Third, the suspicion of China held by Western developed economies and other countries is further aggravated by the Chinese government's growing tendency to impose tighter control on the rising private sector, in particular the national champion Huawei and internet giant platforms and start-ups, and by its cooperation with them on frontier technologies. China's influence on the digital economy and related standard setting increasingly relies on Huawei and other private big tech firms and start-ups. This could partially explain the greater pressure on these Chinese companies' investment on the global market, particularly in key areas for commanding leadership in global technology competition such as 5G, AI and big data, as well as other related fields that could be used for a surveillance society, such as smart cities, facial recognition and video surveillance.

Fourth, the geopolitical reasons for the adoption of different technologies and standards should not be exaggerated. Chinese companies' practices and promotion of Chinese standards through the DSR may indicate the prospect of China gaining more influence on market share and standard setting in some frontier technologies. But technology itself and the supply chain behind it are the more important reasons for adopting different technologies and standards. For instance, reliability and technology advancement, and bargaining and compromising (such as between big companies including Qualcomm, Huawei, Samsung and Ericsson over business interests instead of geopolitical concerns) are the main reasons for adopting 5G standards of channel coding and channel-control coding in 2016. For the same reason, technology requirements and availability to ensure smooth interoperability and roaming largely explain why China and some BRI countries tend to deploy first NB-IoT standards for mobile IoT while operators and companies in North America and Western Europe tend to deploy first LTE-M standards for mobile IoT.

In conclusion, for the most part, Chinese companies' leading position in technologies and market share has not translated into more influence at main standard-setting organizations, although it is an important complement to China's efforts in this regard. China's representation and influence at international standard-setting organizations are still outweighed by the traditional powers of the European Union and the United States, except for China's increasing influence on 5G and IoT at 3GPP and ITU. Geopolitics plays an important role in the global competition for standardization of frontier technologies, but is not the main factor.

Works Cited

Amplified and GreyB. 2020. *Exploration of 5G Standards and Preliminary Findings on Essentiality*. June. https://info.greyb.com/hubfs/5G%20Report%20-%201st%20Release.pdf.

Cambricon. 2021. *2020 Annual Report*. http://static.sse.com.cn/disclosure/listedinfo/announcement/c/new/2021-04-27/688256_20210427_5.pdf.

Chen, Hui and Jianjun Dong. 2018. "加快推进 '一带一路' 信息通信业'走出去'" [Accelerate "going out" for information and communications industry along "the Belt and Road"]. *信息通信技术与政策* (*Information and Communications Technology and Policy*) No. 9: 1–4.

China Electronics Standardization Institute. 2014. "*云计算标准白皮书*" [White Paper on Cloud Computing Standardization]. www.cac.gov.cn/files/pdf/baipishu/CloudStandardization.pdf.

———. 2018a. "*人工智能标准化白皮书(2018版)*" [White Paper on AI Standardization (2018)]. www.cesi.cn/images/editor/20180124/20180124135528742.pdf.

———. 2018b. "国家人工智能标准化总体组和专家咨询组成立" [National AI Standardization General Group and Expert Group established]. January 19. www.cesi.cn/201801/3539.html.

China Financial Standardization Technical Committee. 2017. "ISO主席张晓刚主席对金标委提出问题的解答" [ISO President Zhang Xiaogang's answer to questions raised by China Financial Standardization Technical Committee]. July 27. www.cfstc.org/jinbiaowei/2929546/2929554/2972382/2017110613580116202.pdf.

China Market Regulation News. 2019. "吴正平: 三种方式实现中国标准国际化" [Wu Zhengping: Three ways to internationalize Chinese standards]. October 16. www.sohu.com/a/347364481_487612.

Dai, Xuan. 2017. "我国将推动5G等国标在 '一带一路' 沿线国家应用实施" [China will promote 5G and other Chinese standards to be applied in BRI countries]. 新京报 [*Beijing News*], December 22. https://m.bjnews.com.cn/detail/155152516314848.html.

Ding, Jeffrey, Paul Triolo and Samm Sacks. 2018. "Chinese Interests Take a Big Seat at the AI Governance Table." *New America* (blog), June 20. www.newamerica.org/cybersecurity-initiative/digichina/blog/chinese-interests-take-big-seat-ai-governance-table.

Dong, Hongwei. 2020. "人工智能国际标准制定情况及我国应对策略" [International AI standard-setting and China's strategy]. *安全内参* [Serrss.com], April 29. www.secrss.com/articles/19092.

GSMA. 2016. "3GPP Low Power Wide Area Technologies." GSMA White Paper, October 7. www.gsma.com/iot/wp-content/uploads/2016/10/3GPP-Low-Power-Wide-Area-Technologies-GSMA-White-Paper.pdf.

Hao, Jiangting. 2019. 中国工程建设标准海外应用情况分析及对策 [Analysis and advice for the global application of Chinese construction standards]. *标准科学* [*Standard Science*] No. 1.

Hao, Yang. 2019. "沿 '一带一路' 走出去 中国AI企业与马来西亚再结缘" [Going out along the Belt and Road, Chinese AI Startup reconnected with Malaysia]. 新民晚报 [*Xinmin Evening News*], July 12. www.sohu.com/a/326524949_202969.

He, Alex. 2020. *Top-level Design for Supremacy: Economic Policy Making in China under President Xi*. CIGI Paper No. 242. Waterloo, ON: CIGI. www.cigionline.org/publications/top-level-design-supremacy-economic-policy-making-china-under-president-xi/.

He, Wei. 2018. "AI startup YITU signs deal with UN body to aid developing nations." *China Daily*, September 20. https://global.chinadaily.com.cn/a/201809/20/WS5ba350d3a310c4cc775e757f.html.

Hu, Yuhui. 2012. "中移动提速建4G刺激股价 中兴和大富直接受益" [China Mobile's acceleration of building 4G boosted stock prices, ZTE and Tatfook Technology benefited from it]. *每日经济新闻* [*National Business Daily*], March 17. www.cs.com.cn/gg/gsxw/201203/t20120317_3284659.html.

Huang, Xin. 2017. "物联网产业进入商业应用元年" [The IoT industry enters its first year of commercial application]. *经济日报* [*Economic Daily*], May 31. www.gov.cn/xinwen/2017-05/31/content_5198269.htm.

IEC. 2020. "IEC standardization of ultra high voltage transmissions." IEC, April 23. www.iec.ch/blog/iec-standardization-ultra-high-voltage-transmissions.

Ifeng.com. 2019. [Yu Chengdong: Huawei 6G is in the process of research and 10 more years are needed]. [Ifeng.com], September 30. https://tech.ifeng.com/c/7qNkg4It5Bc.

IPlytics. 2019. "Who is leading the 5G patent race? A patent landscape analysis on declared 5G patents and 5G standards contributions." November. www.iplytics.com/wp-content/uploads/2019/01/Who-Leads-the-5G-Patent-Race_2019.pdf.

ITU. 2018. *Setting the Scene for 5G: Opportunities & Challenges.* Geneva, Switzerland: ITU. www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-BB.5G_01-2018-PDF-E.pdf.

Jefferies Group. 2017. "Telecom Services: The Geopolitics of 5G and IoT." *Jefferies Franchise Note*, September 14. www.jefferies.com/CMSFiles/Jefferies.com/files/Insights/TelecomServ.pdf.

Li, Lauly and Cheng Ting-Fang. 2020. "Huawei claims over 90 contracts for 5G, leading Ericsson." *Nikkei Asia*, February 21. https://asia.nikkei.com/Business/China-tech/Huawei-claims-over-90-contracts-for-5G-leading-Ericsson.

Li, Shu, Yujing Guo and Xiaojie Wang. 2017. "跨界交流趣事多—各界热议 '数字丝绸之路'" [Interesting exchanges and heating discussion on "Digital Silk Road" among all walks of life.]. *新华社* [*Xinhua News Agency*], May 15. www.xinhuanet.com//world/2017-05/15/c_1120976705.htm.

Li, Wenxue and Yuting Gao. 2017. "工信部部长苗圩: 加强与各国信息通信基础设施互联互通" [Miao Wei, Minister of MIIT: Strengthen connectivity for information and communications infrastructure with other countries]. 央视网 [CCTV.com], May 14. http://big5.cctv.com/gate/big5/news.cctv.com/2017/05/14/ARTIh4fx6jrRbJj4IIOuBsk3170514.shtml.

Liu, Yuying. 2018. "国家标准委: 正制定《中国标准2035》" [SAC: Making of "China Standard 2035" is in progress]. *中国新闻网* [*China News Service*], January 10. www.chinanews.com/gn/2018/01-10/8420700.shtml.

Liu, Yongwang and Xiaoyu Lin. 2018. "'一带一路' 信息通信业 '走出去' 策略探讨" [Discussion on "going out" strategy for information and communications industry along "the Belt and Road"]. *信息通信技术与政策* [*Information and Communications Technology and Policy*], No. 9.

Marr, Bernard. 2019. "Meet The World's Most Valuable AI Startup: China's SenseTime." *Forbes*, June 17. www.forbes.com/sites/bernardmarr/2019/06/17/meet-the-worlds-most-valuable-ai-startup-chinas-sensetime/?sh=f36be86309fc.

Ministry of Commerce of China. 2008. *对外援助成套项目管理办法(试行)2008* [Administrative Measures for Complete Foreign Aid Projects (For Trial Implementation) 2008]. www.mofcom.gov.cn/article/b/bf/200901/20090105986557.shtml.

———. 2015. *对外援助成套项目管理办法(试行)2015* [Administrative Measures for Complete Foreign Aid Projects (For Trial Implementation) 2015]. www.gov.cn/gongbao/content/2016/content_5041556.htm.

Ministry of Foreign Affairs of China. 2017. "一带一路"国际合作高峰论坛成果清单 (全文)" [List of deliverables of the Second Belt and Road Forum for International Cooperation (Full Text)]. www.fmprc.gov.cn/web/zyxw/t1461873.htm.

NDRC. 2015. *标准联通"一带一路"行动计划（2015—2017）* [Action Plan on Belt and Road Standard Connectivity (2015–2017)]. www.ndrc.gov.cn/fzggw/jgsj/kfs/sjdt/201510/t20151022_1085956.html.

Office of Belt and Road Construction Leadership Group. 2019. 共建 "一带一路" 倡议: 进展, 贡献与希望 [Joint Construction for the Belt and Road Initiative: Progress, Contribution and Hope]. April 22. www.xinhuanet.com/world/2019-04/22/c_1124400071.htm.

Ofweek. 2020. "爱立信在5G合同数上居于第一名, 却在5G基站出货量上败给华为" [Ericsson ranks no. 1 for 5G contracts but second to Huawei for 5G base station shipment]. *维科网* [Ofweek], August 14. https://tele.ofweek.com/2020-08/ART-8320500-8400-30452429.html.

Onomondo. 2021. "NB-IoT vs LTE-M: A Comparison." www.iotforall.com/nb-iot-vs-lte-m-a-comparison. July 16.

Patrahau, Irina, Hugo van Manen, Tycho de Feijter and Michel Rademaker. 2020. *Standards for Critical Raw Materials: Strategic standard setting in China, the EU and the Netherlands.* The Hague, the Netherlands: The Hague Centre for Strategic Studies. https://hcss.nl/wp-content/uploads/2021/01/Standards-for-Critical-Raw-Materials.pdf.

People.cn. 2020. "依图、电子标准院当选全国信标委人工智能分委会芯片与系统研究组副组长" [Yitu and CESI elected as deputy leader of the chip and system group of the NITS's AI Subcommittee (TC28/SC42)]. http://it.people.com.cn/n1/2020/1116/c1009-31931854.html.

Pohlmann, Tim. 2018. "Who will be the technology leader for 5G? Part two." IPlytics GmbH, July 18. www.iam-media.com/who-will-be-technology-leader-5g-part-two.

Pohlmann, Tim and Magnus Buggenhagen. 2020. "Who owns patents, SEPs and develops standards for smart home technologies?" IPlytics GmbH, July 22. www.iam-media.com/who-owns-patents-seps-and-develops-standards-smart-home-technologies.

Pohlmann, Tim and Knut Blind Philipp Heß. 2020. "Fact finding study on patents declared to the 5G standard." Berlin, Germany: IPlytics GmbH. January. www.iplytics.com/wp-content/uploads/2020/02/5G-patent-study_TU-Berlin_IPlytics-2020.pdf.

Qin, Min. 2014. “TD式创新” [TD-style innovation]. *财新周刊* [*Caixin Weekly*], No. 47. December 8. https://weekly.caixin.com/2014-12-05/100759605.html.

Qin, Yin, Fei Peng and Jun Dong. 2019. 我国工程标准在 “一带一路” 沿线国家的应用 [The application of Chinese standards in engineering construction in countries along “the Belt and Road”]. *建筑经济* [*Construction Economy*], No. 4.

SAC. 2019. *关于对拟成立的全国信息技术标准化技术委员会人工智能分技术委员会进行公示的通知* [Circular of the SAC on publication of announcement on the planning establishment of AI subcommittee of technology committee of National Information Technology Standardization]. October 21. http://org.sacinfo.org.cn:8088/tcrm/recruit-index/notice/2401.do?menuItem=1#.

———. 2020a. *国家新一代人工智能标准体系建设指南* [The Guideline for Establishing National Next-Generation AI Standard System]. August. www.gov.cn/zhengce/zhengceku/2020-08/09/5533454/files/bf4f158874434ad096636ba297e3fab3.pdf.

———. 2020b. *国家标准化管理委员会关于印发《2020年全国标准化工作要点》的通知* [Circular of the SAC on Issuing the Key Points in the Work of National Standardization in 2020]. March 10. www.gov.cn/zhengce/zhengceku/2020-03/24/5494968/files/cb56eedbcacf41bd98aa286511214ff0.pdf.

———. 2021. 架设标准之桥, 联通 “一带一路” [Building bridge of standard to connect “the Belt and Road”]. August 4. www.sac.gov.cn/zt/jdbn/bzgs/202108/t20210804_347434.html.

SC37 Biometric Identity Standardization. 2019. 全国信息技术标准化技术委员会第二届生物特征识别分技术委员会（SAC/TC28/SC37）组成方案获国家标准化管理委员会批复 [SAC’s Approval of the composition plan for SAC/TC28/SC37]. August 30. http://sc37.cesinet.com/view-30-149f8e0537564d139fb5ed56134f8cbf.html.

SenseTime. 2020a. “商汤科技作为计算机视觉企业代表入选首届AI国家标准化组织” [SenseTime as the delegate for computer vision industry to join the first China’s AI national standardization organization]. *商汤科技新闻中心* [SenseTime Newsroom], August 13. www.sensetime.com/cn/news-detail/54645?categoryId=72.

———. 2020b. “SenseTime to Chair IEEE Standards Working Group for Augmented Reality on Mobile Devices.” SenseTime Newsroom, November 24. www.sensetime.com/en/news-detail/55202?categoryId=1072.

SGCC. 2021. *国际标准* [International Standards]. www.sgcc.com.cn/html/sgcc_main/col2017042000/column_2017042000_1.shtml?childColumnId=2017042000&WxUg5ztDmi=1622301657195#tab.

Shivakumar, Sujai. 2022. *Securing Global Standards for Innovation and Growth*. Washington, DC: Center for Strategic and International Studies. https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/220127_Shivakumar_Securing_Global_Standards.pdf.

State Council. 2015. *国务院办公厅关于印发国家标准化体系建设发展规划（2016–2020年）的通知* [Circular of the General Office of the State Council on Issuing the Plan for the Development of the National Standardization System (2016–2020)]. December 30. www.gov.cn/zhengce/content/2015-12/30/content_10523.htm.

———. 2016. *国务院关于印发“十三五”国家信息化规划的通知* [Circular of the State Council on Issuing the National Informatization Outline during the 13th Five-Year Plan Period]. www.gov.cn/zhengce/content/2016-12/27/content_5153411.htm.

———. 2018. *工业和信息化部关于工业通信业标准化工作服务于“一带一路”建设的实施意见* [Implementation opinions of Ministry of Industry and Information Technology on standardization work of industry and communication sector to serve the Belt and Road Initiative]. www.gov.cn/zhengce/zhengceku/2018-12/31/content_5442657.htm.

State Council Information Office. 2016. *《国家信息化发展战略纲要》政策解读* [Policy interpretation on the Strategical Outline for the Development of National Informatization]. July 28. www.scio.gov.cn/34473/34515/Document/1485534/1485534.htm.

———. 2018. *标准联通共建“一带一路”行动计划(2018–2020年)* [*Action Plan on Belt and Road Standard Connectivity (2018–2020)*]. www.scio.gov.cn/xwfbh/xwbfbh/wqfbh/37601/39274/xgzc39280/Document/1641459/1641459.htm.

———. 2019. “新闻办就中国标准化改革发展成效有关情况举行发布会” [SCIO press conference on the result of reform and development of China’s standardization]. September 11. www.gov.cn/xinwen/2019-09/11/content_5429188.htm.

Stewart, James, Xiaobai Shen, Chengwei Wang and Ian Graham. 2011. “From 3G to 4G: standards and the development of mobile broadband in China.” *Technology Analysis & Strategic Management* 23 (7): 773–88.

Stoll, Robert. 2020. "5G SEP Leadership in 2020." SSRN. https://ssrn.com/abstract=3710223.

The Paper. 2016. "首任ISO中国主席: 中国GDP全球第二, 制定标准不到1%" [The first Chinese president of ISO: China's GDP ranks world no.2, but it made less than 1% of world's total standards]. *澎湃新闻* [The Paper], April 5. www.thepaper.cn/baidu.jsp?contid=1452463.

Trippe, Anthony. 2020. "China Is Gunning To Be The World Leader in AI Chips While Restricting Exports." *Forbes*, August 31. www.forbes.com/sites/anthonytrippe/2020/08/31/china-is-gunning-to-be-the-world-leader-in-ai-chips-while-restricting-exports/?sh=1fdfc2ae6d4e.

Vzkoo.com. 2020. 物联网专题报告: NB-IoT正式跻身5G标准, 产业链发展渐入佳境 [IoT Special report: NB-IoT formally ranks as a 5G standard, the development of supply chain getting better gradually]. *未来智库* [*vzkoo.com*]. August 31. https://finance.sina.com.cn/stock/stockzmt/2020-08-31/doc-iivhuipp1761132.shtml.

Wang, Xiaodong. 2017. "我国已与21个 '一带一路' 沿线国家签署标准化合作协议" [China has signed standard cooperation agreement with 21 countries along "the Belt and Road"]. *中国日报* [*China Daily*], May 11. https://cn.chinadaily.com.cn/2017-05/11/content_29302519.htm.

Wei, Qing. 2019. "'一带一路'国家共享中国人工智能, 旷视让多国进入'刷脸时代'" ["The Belt and Road" countries share China's AI, Megvii makes many countries enter "the age of face scan"]. *北京晚报* [*Beijing Evening News*], April 26. https://xw.qq.com/cmsid/20190426A0BMED00.

Xi, Jinping. 2017. "Speech at the opening ceremony of the Belt and Road Forum for International Cooperation." *Xinhua*, May 14. www.xinhuanet.com/english/2017-05/14/c_136282982.htm.

———. 2019. "在第二届"一带一路"国际合作高峰论坛开幕式上的主旨演讲 (全文) [Speech at the opening ceremony of the Second Belt and Road Forum for International Cooperation (Full text)]. *Xinhua*, April 26. www.xinhuanet.com/silkroad/2019-04/26/c_1124420187.htm.

Xinhua. 2016. "中共中央办公厅 国务院办公厅印发《国家信息化发展战略纲要》" [The General Office of the CPC Central Committee and the General Office of the State Council issuing the Strategical Outline for the Development of National Informatization]. *新华社* [Xinhua News Agency], July 27. www.gov.cn/zhengce/2016-07/27/content_5095336.htm.

Xu, Weina. 2020. "发改委明确 '新基建' 范围 将重点做好四方面工作" [NDRC clarifies the scope of "New Infrastructure" and will focus on four priorities]. *人民网* [People.cn], April 20. http://finance.people.com.cn/n1/2020/0420/c1004-31680443.html.

Zhang, Chao. 2020. "BATH: 新基建的企业力量" [BATH: Strength of enterprise for new infrastructure]. *经济参考报* [*Economic Information Daily*], August 13. http://5gcenter.people.cn/n1/2020/0813/c430159-31820700.html.

Zhang, Jie. 2020. "5G in SE Asia will bring opportunity to Chinese telecom businesses." *China Daily*, June 9. www.chinadaily.com.cn/a/202006/09/WS5edf3dbca310834817251e10.html.

Zhao, Houlin. 2017. "China's One Belt, One Road can improve lives at scale through ICT investment." ITU News, May 16. https://news.itu.int/chinas-one-belt-one-road-can-improve-lives-at-scale-through-ict-investment/.