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Global Technology

China Standards 2035 – Poised to Reshape a Multipolar World

Leadership has yet to be claimed for next-generation technology standards but China is quickly stepping up, creating a new kind of competition – no longer about technological superiority – but about rule making and system design.

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Leadership has yet to be claimed for next-generation technology standards but China is quickly stepping up, creating a new kind of competition – no longer about technological superiority – but about rule making and system design.

Industry View

Attractive

Reshaping a multipolar tech world. The next decades of new standards for emerging technologies have yet to be defined, opening the door for China to lead in their formulation. An ambitious plan – China Standards 2035 – lays out global standards for the next generation of technology that could be game-changing in areas where China has market, technology and application advantages, i.e., 5/6G applications, IoT, quantum networks, and blockchain. If Made in China 2025 is about the real economy, standards are about systematic influence and dominance of industries.

Standards help the incumbent. Once established, they are difficult to change and steer economic, technological and environmental trends, as well as transform both commercial and national security spheres. Standards have long been dominated by the West and have been one of the driving engines behind globalization. The dominance is now being put to the test as rules are being formed and China builds up its influence over global governance, and aligns its research and standards for next generation technologies.

Global dominance no longer seems probable. There is risk of a power shift in certain emerging industries and with that comes a re-think of the valuation multiples of today's dominant companies. China's top down approach to boost its economy, drive standards and propel innovation can trim the addressable market for global companies and helps the country compete for investment dollars in new areas of technology. The path seems less straightforward for standards controls that apply to technology used in international markets, given the strength of US software and semiconductor IP.

Will China realize its potential? China appears well placed for success in certain emerging technologies. Efforts to shape global technology standards and norms have been at the heart of China's ambitions to achieve technological self-reliance. Its purpose is very clear in support for economic growth and society's well-being. These efforts are already yielding promising results in areas like 5G networks and the country is already moving to defining standards in 6G, quantum networks (internet 2.0), the virtual economy (AI, IoT, blockchain), and services (e-commerce, logistics) with digital links to the Belt & Road initiative.

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Standards 2035 – The Race for Global Influence

A popular Chinese saying states – third tier companies make products 三流企 做 品; *second tier companies make technology* 二流企 做技 ; *first tier companies make standards* 一流企 做 准.

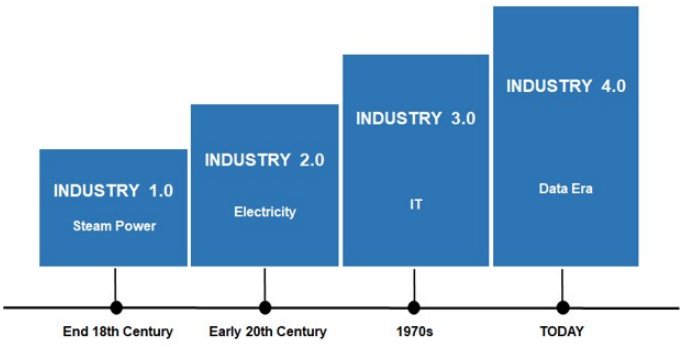
The world of standardization is about to undergo a profound period of change as economic balances of power shift, where standards define technology and technology defines the modern world. For decades, technical standards have been a driving engine behind globalization. In recent years however, they run the risk of turning into a competition over new technologies and China's growing footprint in international technical standardization is a development fueling this phenomenon. While technical standardization was mainly a matter of private self-regulation with only a marginal role for states in the past decades, China supports enterprises with strategic planning at the country level, which has the potential to fundamentally reshape the future order of technical standardization. This top-down approach, however, is not unique from a historical perspective when compared to the majority of nations that benefitted from industrialization, which were the ones that had the necessary components of land, labor and capital, as well as government support. In addition, China has incorporated a standardization dimension into its Belt and Road Initiative, which could evolve into a 'digital silk road' concept. This could contribute to a trend that weakens the existing status quo in international technical standardization institutions.

New divides. With US-China tension continuing and polarization underway globally, we foresee global standards in technology becoming gradually bifurcated as two or more standards. This brings into question the long-term sustainability of today's dominant global platforms/businesses and requires a re-think of existing valuation multiples given that a large part of their value is going to be in the terminal value. In today's multipolar world with a highly heterogenous consumer and social environment, a broad homogenous standard solution would be ideal, but in theory may not be subtle enough. The US and EU are likely to continue to exert great influence in the world of global governance rules for technology use given leading software, IP and established organizations that effectively enforce agreed norms and procedures. But we also see a world where standards of the masses matter more and China's efforts to shape global technology standards and norms are also yielding results, especially in certain nascent and emerging new technology areas, like 5G, IoT, blockchain and cybersecurity – and they may challenge advanced nations' industrial competitiveness. A world with multiple standards in itself does not necessarily present a worse outcome – today's world of multiple power plug standards is a good case in point, where a power plug adapter is readily available and always comes in handy.

The scope and breadth of standards is massive. They are the economic foundation of nations and technology is only a sub-segment of standards. They are a consensus process on technical cooperation

Exhibit 1:

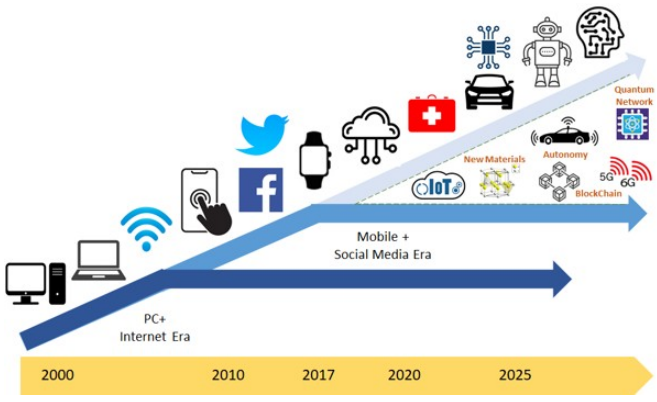
History of standards – starting from steam engine to today's industry 4.0 that has yet to be claimed



Source: Company data, Morgan Stanley Research

Exhibit 2:

Industry 4.0 standards – China is well positioned in 6 areas within next generation tech



Source: Company data, Morgan Stanley Research

where influence matters along with innovation with the end result being dominance. While the US has traditionally led in standards-setting, especially in cutting-edge technology sectors, China has raised its game substantially for global standards in next generation technologies – 5G applications, AI, and the architecture of the future internet itself (i.e., quantum internet), will increasingly be Chinese or heavily China-influenced. For existing foundational technologies, it will probably take China considerable time to replicate six decades of US semiconductor infrastructure, IP, and efficiencies before becoming competitive. But for newer technologies that are emerging in the data era, the playing field is level and China is well positioned. It all begins with the power of standards and rule making process.

- **Standards are often invisible, yet they play a fundamental part in bringing outsized benefits** to society at large.
- **They can be seen as a powerful form of transnational authority** by defining the status of public and private parties involved in standardization and regulation.
- **Authority is recognized when complying to standards**, and defines the status of public and private participants.
- **The fast-evolving technology sector will require a vast array of new industry standards** to support it.
- **China Standards 2035 is setting the global governance agenda for China's ability to shape the international norms** and widely practiced standards.

A different kind of competition – not about scale or technology superiority – but about system design competition and rule making competition. Standards for next generation transformational technologies have yet to be claimed… Standardization is increasingly recognized as a form of regulation and standards are regarded as 'instruments of control' *(Brunsson, N., Jacobsson, B. (Eds.) (2000). A world of standards p.1. Oxford: Oxford University Press)*. By defining the appropriate attributes of the standardized subject, rendering these aspects visible to external inspection and opening up the possibility of sanctioning non-compliance, standards provide their creators with a form of power that is exerted through seemingly disinterested routines and practices. By setting a set of rules across industries, especially emerging technologies, they govern the system which goods are made and transactions flow, and define next-generation technologies, resources and exchanges.

A new type of power – based not on conventional strength, but on rules. Standards are imperative as they provide precise specifications for products and services, which in turn ensures interoperability and compatibility between the various component parts that make up our burgeoning digital sector. Standards require influence, understanding of rules, leadership and, most importantly, they generate indigenous innovation that is also a central policy focus for China as the drivers that propelled the economic miracle – cheap labor and surging fixed-asset investment – gradually lose steam.

Will China's Potential be Realized?

How will China set standards? New standards can apply in areas where China has market, technology and application advantages. They are set domestically before potentially becoming the international norm. They are not about efficiency at the onset but having leading technology, a dominant market position or controlling competitive landscape.

China's increasing role in global technology governance. In this report we examine China's evolving role in global technology standards and governance. In particular, (i) where the decision-making power in global technology governance lies; (ii) how China's role in the global technology regime is evolving; (iii) what is the key to success for China in promoting its favored standards in global technology governance and, most importantly, (iv) we identify specific areas of emerging technologies where China potentially dominates future standards.

The aim is to play a decisive role in affecting and shaping the setting of standards in those industries defined as central by 'Made in China 2025'. China's geographical size, innovation gains and economic strength will likely lead to changes to the rules of international politics and the standards set for global technology governance. China's technological will, together with its distinctive one-party government system at home, is reshaping the global technological and economic order.

- **Innovation is critical to driving standards.** China's ample innovation talent is a solid foundation in its quest for strength in global standards. While innovation has lagged in semiconductor foundational technologies, China is flourishing in future technologies and becoming a global leader in innovation in areas such as 5/6G/quantum networks, IoT, new materials, digital payments and autonomy.
- **Influence and understanding the rules.** China established its national patent agency in 1980 and subsequently joined the World Intellectual Property Organization (WIPO). China joining the WTO in 2001 was a result of gradual acceptance of IP norms defined by the Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS). China has very high participation rates in the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC)

and has taken a much greater leadership role in standards-drafting technical committees in recent years. Those in a leadership capacity are able to influence the agenda, how conversations are structured, and how time is allocated. Chinese companies participating as voting members in the 3GPP (Third Generation Partnership Project), responsible for 5G standards setting, have more than doubled in the past few years to 110 in January 2020, more than twice the 53 US voting members.

- **Leadership.** Due to the legacy of strategic planning at the country level, China increasingly believes that simply relying on market forces is insufficient, as these favor the incumbent international technology governance framework. As a result, there is a strong inclination towards top-down developments of technology standard-setting among both the government and companies. *(Dr Yu Jie, senior research fellow, Nov 2019, Chatham House)*.

Disproportionate Benefits

The standards race is about profits and technological leadership. China's transformation from a standard-taker into a standard-maker bears significant economic implications for technology in the future. Global implications are that companies must be prepared to face losses of market share and become increasingly dependent on Chinese digital solutions. Companies having their technologies translate into standards earn substantial returns through market dominance and royalties. Consumers don't know what standards mean – but if there are enough users of a particular protocol, it often becomes the standard of the masses and creates a domino effect. Standards based on patented technologies require users to pay licensing fees and companies such as Nokia and Qualcomm, for example, have earned billions of dollars annually from patents that are necessary for mobile phone systems made by rivals. The competitive advantage that Microsoft, Google and Qualcomm with their standard-essential patent portfolios bring to the American economy is indicative of this point.

Technology standards are integral to modern life. Information and communication technology (ICT), particularly its ability to communicate with other devices, is reliant upon widely adopted and accepted standards. Standards can create a relatively protected environment to allow indigenous firms and technology to develop, and where there is a single global market the first mover usually wins. Companies and nations coming from behind cannot compete on the same terms as established technology players. Setting standards could also lower the expensive licensing fees paid to foreign multinationals and the US-China trade tensions have increased the sense of urgency in reducing supply-chain dependency.

Creating a Digital Silk Road

Companies having their technologies translate into standards should earn substantial returns through market dominance and royalties. We identify certain industry areas where China has established indigenous innovation, a large presence with national champions and where it could dominate future standards:

- **IoT Standards driven from manufacturing scale.** As the world is moving from sensors placed in factories to making sense of the data and talking to each other globally, China appears well-placed to define rules given its sheer global dominance in manufacturing scale and well advanced network system in place today. The Ministry of Industry and Information Technology ("MIIT") aims to build and develop an IoT basic standard system that will be implemented in two phases: 1) by 2022, establish at least 10 industry standards and clarify security requirements and 2) establish more than 30 industry standards by 2025 targeting the improvement of the security level of IoT cross-industry applications.
- **Quantum Networks – internet 2.0**. Due to the strategic importance of quantum information technology, China has listed it as one of the key frontier domains to develop (among the 2035 long-range objectives). China has devoted significant capital and resources to this field and has already achieved several milestones: in Sept 2017, the world's first quantum-safe intercontinental video conference between Beijing and Vienna, facilitated by its quantum communications-focused Micius satellite and the world's first quantum cryptography communication backbone project linking Beijing to Shanghai. Standardization in the quantum communication area is still at a very early stage, and China has played a leading role with its information security standardization technical committee (CSTC) driving the study of quantum-secured communication network specifications since 2015 and Telecommunications Union looking to establish standards for quantum communications tools.
- **5/6G – China has become a central player in writing international rules for 5G** (fifth-generation) wireless technology, as part of a national effort to shape the playing field in its favor. China submitted 830 technical documents related to wired communications specifications to the International Telecommunication Union last year, leading globally by a wide margin. China started R&D for 6G in Nov 2019 via the Chinese Ministry of Science and Technology – it is no longer an academic debate and China is in a race to be first to establish new standards along with technology developments.
- **Semiconductor new materials – Gallium nitride and silicon carbide.** Third generation semiconductor materials where China

is a decade behind on silicon but less than 3-years behind for GaN (RF) or SiC (used in power semi auto/EV). Semiconductors are a relatively weak area for China as the industry is dependent on access to US technology and is populated by small-scale enterprises. It has built a presence via M&A (Nexperia), built a global number two player in auto grade MOSFET and benefits from having ~70% of raw materials for producing wafers.

- **Blockchain standards – develop rules to which money and goods are traded.** China blockchain-based services network (BSN) – comparable to a technological Belt and Road initiative – will play a central role. BSN isn't a blockchain protocol. It is a centralized platform which developers can plug in to. It will be a key infrastructure-of-infrastructures that enables the integration of cloud computing, 5G, internet of things, artificial intelligence and big data, with fintech and other services overlaid. It will form a critical part of China's national technology strategy, and be the backbone infrastructure technology for interconnectivity both globally and domestically via the digital Silk Road. China's plans for creating its own national digital currency were based on those of other countries that have undertaken similar initiatives.
- **Set standards in how self-driving cars operate.** China unveiled a blueprint in February this year to develop its own standards for autonomous vehicles by 2025, covering technological innovation, infrastructure, legislation, supervision and network safety. China's Ministry of Industry and Information Technology is coordinating efforts to develop standards mainly for advanced driving assist systems, autonomous driving, information safety and connectivity and conduct pilot programs involving some carmakers and vehicles to evaluate the results. The objective is to further improve smart vehicle standards and pave the way for the formulation of standards for high-level autonomous driving. The blueprint targets to build a complete set of standards for autonomous vehicles between 2035 and 2050.

Challenges

Creation of separate technological spheres of influence in a multipolar world. Standards committees, once shaped by international cooperation, risk slowly morphing into a dominance contest in this age of a multipolar world. The EU's traditional power in standards setting; the US' domination in terms of tech industry power; and China's ambition and sheer scale mean that tech companies may find themselves caught in the middle not knowing (a) what direction future standards will go and (b) if – or when – there will be a fragmentation that would hit sustainable returns. Competition between regions is inevitable and reduces the possibility of alliances and cooperation, as China has reached a stage in its development that enables it to take an active part in the new round of technological revolution.

The standard setting process and systems are fundamentally different for China and the US or EU and there is concern that changes in rules and norms that exist in the Chinese system could introduce weakness both in due process as well as the technical quality and long-term relevance of the resulting standards as Chinese stakeholders become more active in international standards setting. The biggest pushback to China's will to lead the global governance of technology standards is the potential for interventions by the central government. This hurdle has already sparked debates, for example over the recent issues with Huawei and its development of 5G networks. A compromise standard, adopted with broad support from the technical experts after many years of work, may thus end up getting implemented nowhere.

Conflicts of interest. China can better align domestic standards to international norms. The flip side is its ambitions using domestic standards as a base will benefit Chinese companies more, and thus raises the issue of fairness. For example, there are categories of standards that do not exist in the US in areas such as social organizations or enterprises. This can effectively block access and raise overall costs and efficiency. Standards will be crucial to building systems that are safe, trustworthy, and controllable, which is necessary to grow new industries in China and will affect the global competitiveness of Chinese tech companies. Though technological breakthroughs and the market share of different firms will propel standards development in most cases, there is also a risk that China's assertive approach to standards-setting will result in technological lock-in and stifle competition.

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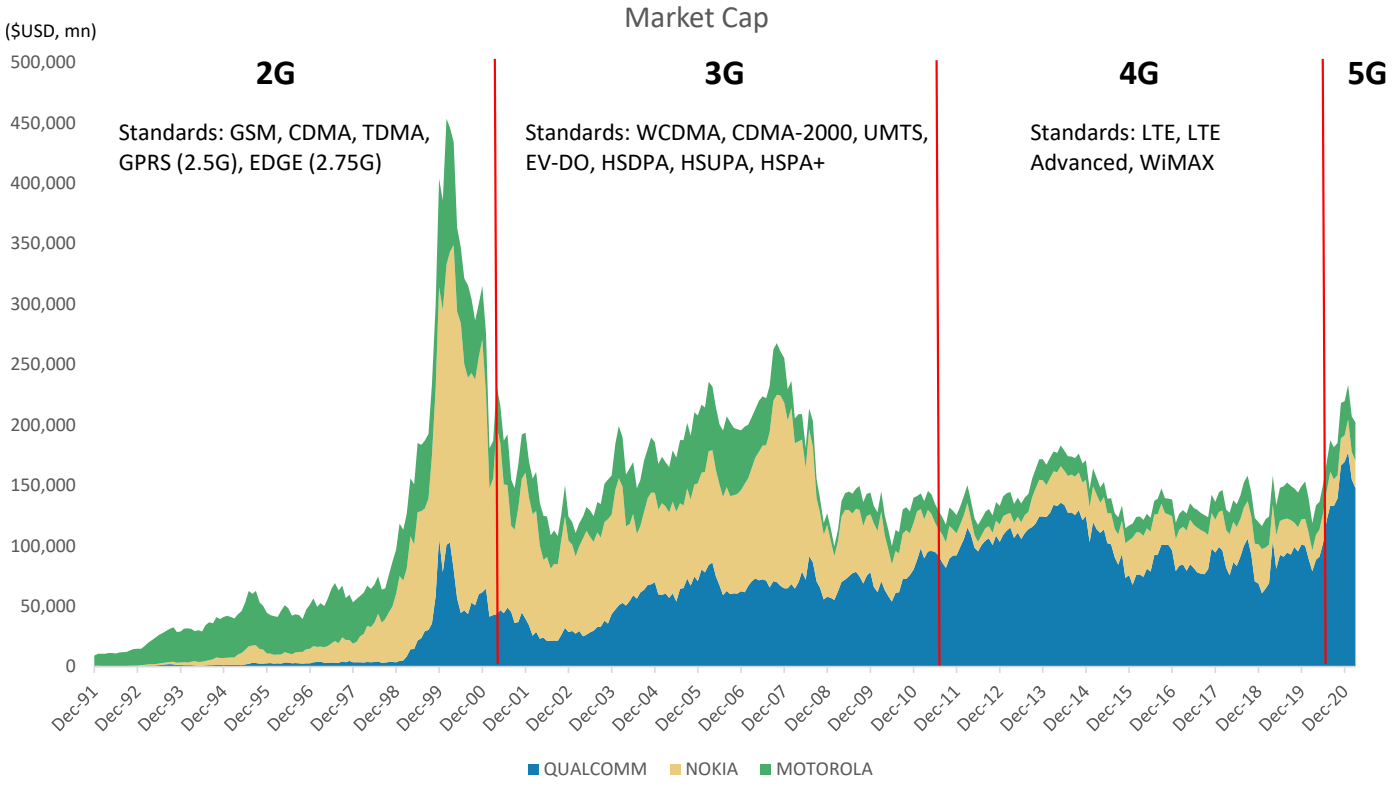
Setting Standards – Powerful Business Implications

The standards race is about profits and technological leadership. Companies having their technologies translate into standards earn substantial returns through market dominance and royalties. The competitive advantage that Microsoft, Google and Qualcomm, for example, with their standard-essential patent portfolios, gain in the US economy is indicative of this point. China's transformation from a standard-taker into a standard-maker should likewise translate into significant economic implications for technology profits in the future. Global implications are that companies could eventually face market share losses and become increasingly dependent not just on existing standards but also on Chinese digital solutions. In many ways, a standard is similar to an ecosystem-building exercise in which success means aligning companies and engineers around key technologies, maximizing investment to those technologies and delivering an end-to-end value proposition that is superior and has better economics than the alternatives.

Standards allow products to be designed and produced at scale and used worldwide. The technology industry uses standardized processes and specifications to ensure that products are built to work together, seamlessly. It defines how technologies and industries around the world work and how different systems are able to interact. Without standards, technologies would not be able to work with products designed by other companies or to work in other markets. An example is the global Wi-Fi standard for wireless networking, which is critical for seamless use. Standards can also be proprietary and for profit. For example, Google's Android operating system is open-source and promotes standardization among smartphone makers and app developers, but the economic benefits are significant for Google in terms of its ability to monetize data. Thus, the creation and deployment of standards enables consumers to reap the benefits, as companies make technology products and services accessible and interoperable.

Exhibit 3:

The power of standards – benefits in wireless standards shifted from Europe to the US as next generation 4G and 5G standards evolved



Source: Refinitiv, Morgan Stanley Research

Setting Standards Has Significant Benefits for Nations

Standards help coordinate the international order, global movement, commerce and information flow across sectors/boundaries. Once established, they are difficult to change. This harnesses the power of economic, technological and environmental trends. This works for Wall Street, Hollywood, UN, international ports, etc. One example could be that setting the standards in 6G telecommunications could be beneficial to Huawei, and not only for its entire supply chain, but also for Chinese companies relying on domestic networks and their ability to grow overseas. This could also make China a net recipient of licensing fees.

History has shown that companies and nations that translate their technologies into widely accepted standards earn substantial revenues through market dominance. That is why the international standard-setting process is often accompanied by fierce competition. A country's ability to set international standards usually affects its trade and technology landscape. China has been proactive in engaging in global standard setting for cutting-edge technologies in recent years. Huawei holds the highest number of standard-essential 5G patents, more than its closest global rivals, Nokia and Ericsson. China has also set standards for construction projects such as dams, power grids and reservoirs, while Western standard development in these fields has been stalling.

Placing firms in a first- or second-mover position when standardization becomes global. The first mover sets the international standard agenda, and laggards or second movers pay for the switching costs. National standards often inhibit trade, whereas regional and international standards increasingly serve as instruments of trade liberalization. Consequently, the setting of international standards – seemingly technical and apolitical – is rapidly becoming an issue of economic and political salience. The current US-China tensions over 5G technology and networks provides an illustrative example of the impact of global technology standards on competition.

Developing an industry-wide standard helps all market participants – one of those rising tides that lifts all ships. There are aspects of business in which competition takes a backseat to cooperative action for collective benefit. According to the American Society for Quality (ASQ), the use of quality standards is voluntary, but adopting the standard may be expected-by certain groups of stakeholders. Additionally, some organizations or government agencies may require suppliers and partners to use a specific standard as a condition of doing business.

- **For businesses:** Standards are important for the bottom line of every organization. Successful companies recognize standards as business tools that should be managed alongside quality, safety, intellectual property, and environmental policies. Standardization leads to lower costs, by reducing redundancy, minimizing errors or recalls, and reducing time to market.
- **For the global economy:** Businesses and organizations complying with quality standards helps products, services, and personnel cross borders and also ensures that products manufactured in one country can be sold and used in another.
- **For consumers:** There are many benefits to standards conformity and certification programs, including increased consumer and buyer confidence in end-products. Many quality management standards provide safeguards for users of products and services, but standardization can also make consumers' lives simpler. A product or service based on an international standard will be compatible with more products or services worldwide, which increases the number of choices available across the globe.

Creating Bluetooth and EV interface standards

Standards exist across industries and create efficiencies and cost savings for many. Standardization removes ambiguity and helps establish clarity about what processes should be followed in a particular matter and what is expected from suppliers and partners. An organization can ensure consistency and quality, help define 'what good looks like' so employees and suppliers alike can measure their performance. Standards also contribute to more efficient use of resources, better risk management and protection of people and the environment, and the ability to deliver a consistent and reliable level of service.

For example, the IEEE 802.15.1™ Bluetooth standard was developed with members of a working group coming together and agreeing on a new way for devices to transfer data over short distances, with very low power consumption to maximize battery life — this is why your earbuds, smartphone, and smartwatch can all communicate seamlessly with one another. These help ensure product functionality and compatibility, facilitate interoperability and support user safety, and data security and privacy. EVs provide another example – the IEEE 2030.1.1™ standard, published in 2015, specifies the design interface of EVs and direct current (DC) quick chargers, promoting interoperability and rapid charging.

High Returns

Setting standards can strengthen the commercial competitiveness of Chinese companies, globally. This is because technical standards included as part of a technology stack, such as for 5G next-generation mobile, incorporate essential patents, and companies that contribute intellectual property to the overall system receive royalties when other companies build equipment using their patents. This is not solely motivated by economic gains; developing standards also can improve the quality of products and services, and may also reduce the risk of societal backlash to technology. For example, China's TD-SCDMA standard for 3G networks received little interest elsewhere but it did enable its 4G TD LTE scheme to have a much higher profile to garner 124 telecom operators by July 2016 and help pave the way for 5G global influence.

Standards of quality facilitate trade through lowered transaction costs and increased efficiency... The development of competitive standards for similar or identical technology niches also pushes foreign standards alliances to reduce royalty rates. Firms of all sizes see strategic benefit in participating in standards work, since approval of standards is a sign of technological sophistication with government approval. Firms that participate in standards development are able to lower the royalties they must pay to foreign IP holders (e.g., this was the case for DVD, TD-SCDMA). This is also beneficial for firms seeking to win new customers, since government approval provides powerful advertising.

...as well as help to level the playing field. Firms can also participate in standards development for the marketing benefits. Small firms, in particular, note that participation in standards working groups affords them the opportunity to meet with technology team leaders and managers from large companies. This direct connection can be leveraged into potential contracts or sourcing agreements. Without participation in standards, these firms argue, it could be difficult or impossible to catch the attention of major companies. Participating in standards development can help small firms directly grow their business.

A Contest for Influence Over the Norms Governing the Digital Economy in a Multipolar World

We see global standards in technology becoming gradually bifurcated, as two or more standards take hold, with US-China tension continuing, and with an accelerating trend towards a multipolar world. China's efforts to implement its own standards within the framework of the Belt and Road Initiative, and the increased Chinese participation in the international standardization bodies – International Organization for Standardization [ISO] and International Electrotechnical Commission [IEC] – are among the most visible examples of the increasing strategic and political importance of what has commonly been viewed as a technical topic for proven specialists. The increasing sensitivities related to personal data and national security also play a large role in splitting global standards. One example is China's broader efforts to shape global cyberspace via greater control or protection of flow of information – a firewall can no longer be assured to hold just by tech upgrading. China may also desire to extend influence so advantages flow to China while reducing dependence on the West. (US Public Policy and Global Equity Research: Investing For a Multipolar World, 24 June 2020)

Multiple standards co-existing. There are often competing standards for a given technology – for example, GSM and CDMA in second-generation wireless telecommunications – but technology standards often achieve quasi-monopoly status in world markets. For example, although there are competing software options, including free open-source and online tools, Microsoft's Office dominates the global market in word processing, spreadsheets, and presentation software. This de facto monopoly-like status enhances Microsoft's brand value and makes it difficult for competing (and even potentially better) technologies to take root. Firms whose technology is incorporated into a dominant standard stand to earn significant returns, while those who supported a losing standard might find their R&D investment wasted.

The US dominates standards today ... The world of global governance rules for technology use today is mostly decided by developed countries and established organizations that effectively enforce agreed norms and procedures. Among the 160 or so member countries in the ISO, just a handful of developed countries define about 95% of ISO standards, with only 0.7% of all ISO standards set by China. Global technology standards are the crucial benchmark for the development of the technology regime, and nations that seek to establish new global technology standards tend to do so to project influence. Such standards can help eliminate redundancy, reduce costs that may arise from cross-border trade and manufacturing, and, to a large extent, are considered a public good for the whole world.

... but China is achieving greater technological self-reliance. China's efforts to shape global technology standards and norms are yielding results in areas such as 5G, IoT, blockchain and cybersecurity – challenging advanced nations' industrial competitiveness. There are also multiple ways of achieving greater self-reliance, such as participation in multilateral bodies, via the World Trade Organization (WTO) or by exerting economic influence in Intelligent Grouping and Resources Sharing (IGRS), such as in a joint ISO-IEC standard.

One final thought in today's multipolar world – Amid a highly heterogenous consumer and social environment, a broad homogenous standard solution would be ideal, but, in theory, may not be flexible enough. Taking the example of electricity (voltage, cycle, plugs are different by countries) or the standardization of coffee, these segments incorporate multiple versions of standards that nonetheless co-exist efficiently. Travel power adapters provide a fairly easy workaround for the various electrical standards around the world, and consumers choose between, for example, '*Nespresso*' coffee capsules vs. '*Starbucks*'. So, interoperability, rather than adoption of a single standard, seems more realistic, practical, and impactful. There is also the notion of technology constantly evolving, and sometimes that means creating a new, better standard, rather than continuing to revise an existing one – for example, adopting digital sound over DVD, or using new semiconductor materials, such as SiC over traditional silicon for power semi wafers, or adopting blockchain over traditional currency.

Leadership and Influence

China's capacity to shape the international governance of emerging technologies is unprecedented. China – a latecomer to the past two industrial revolutions – now has a historic opportunity to take the lead in a new round of transformative change. As new technologies are emerging rapidly and global technical standards are still being formed, China is moving towards an innovation-based economy, an increasingly world-leading R&D power (representing more than 2.2% of its GDP), and its policymakers view the development of technology standards as central to realizing such objectives. Pushing its own technologies into an already crowded marketplace could help gain greater footing, but taking a higher-level approach, by influencing the next set of rulemaking in accordance with its interests, could help boost China's industry and standards into leadership positions. The deployment of technology standards can also serve as a promotional tool – both for encouraging the development of indigenous innovation capabilities, and to strengthen the market position of Chinese technologies.

The importance of becoming a leader in the next generation of emerging technologies is critical for China in driving entities or companies that set the rules of the game. China may have missed out on the opportunity to shape standards for products like smartphones and software, but it is quickly dominating fields that could drive the next industrial revolution, such as consumer internet, automation and green technology. As China aims to achieve its long-desired economic rebalancing from a hub of labor-intensive manufacturing to a global innovation leader, it is cultivating national champions that can drive China's technological innovation, with the goal of using domestic suppliers to reduce reliance on foreign technology.

Strong achievement and greater benefits ahead. Chinese companies and relevant institutions have followed the rules of international standardization on most occasions rather than attempting to overturn the existing international technology governance framework. They have continued to observe the current international framework and rapidly expanded China's influence in relevant international institutions. China's steep learning curve has helped create a country that is now well versed in the formal rules of technological standardization. It has very high participation and has taken much greater leadership roles in global standard-drafting technical committees in recent years. Those in leadership capacity can influence the process, promote their own standards abroad, and eventually yield greater benefits.

Early Success

China is playing an increasingly important role in the development of standards for 5G, blockchain, facial recognition, AI and network protocols. In the post-war period, the U.S. and Europe dominated the world, and the development of technical standards was part of this. That has begun to change as China has created a strong position for itself within the most important organizations. A clear sign of this is the number of Chinese people in leadership positions in the most important organizations for technical standards. Zhang Xiaogang served as the first Chinese president of the ISO, from 2015 to 2018. In January 2020, Shu Yinbiao started his three-year term as president of the IEC.

China has achieved technological advances by implementing new national/indigenous technology standards, but to achieve significant influence will require pushing companies and ambitions internationally. In 2019, China submitted 830 technical proposals to the International Telecommunication Union (ITU) – this is more than Korea, US and Japan, combined. Since 2014, 16 of 65 proposals in the ISO and the IEC have come from China. Today, China technical committee participation of 741 is currently the second-highest globally, after the UK, and at par with Germany. Examples of domestic success areas making headway toward leading standards include:

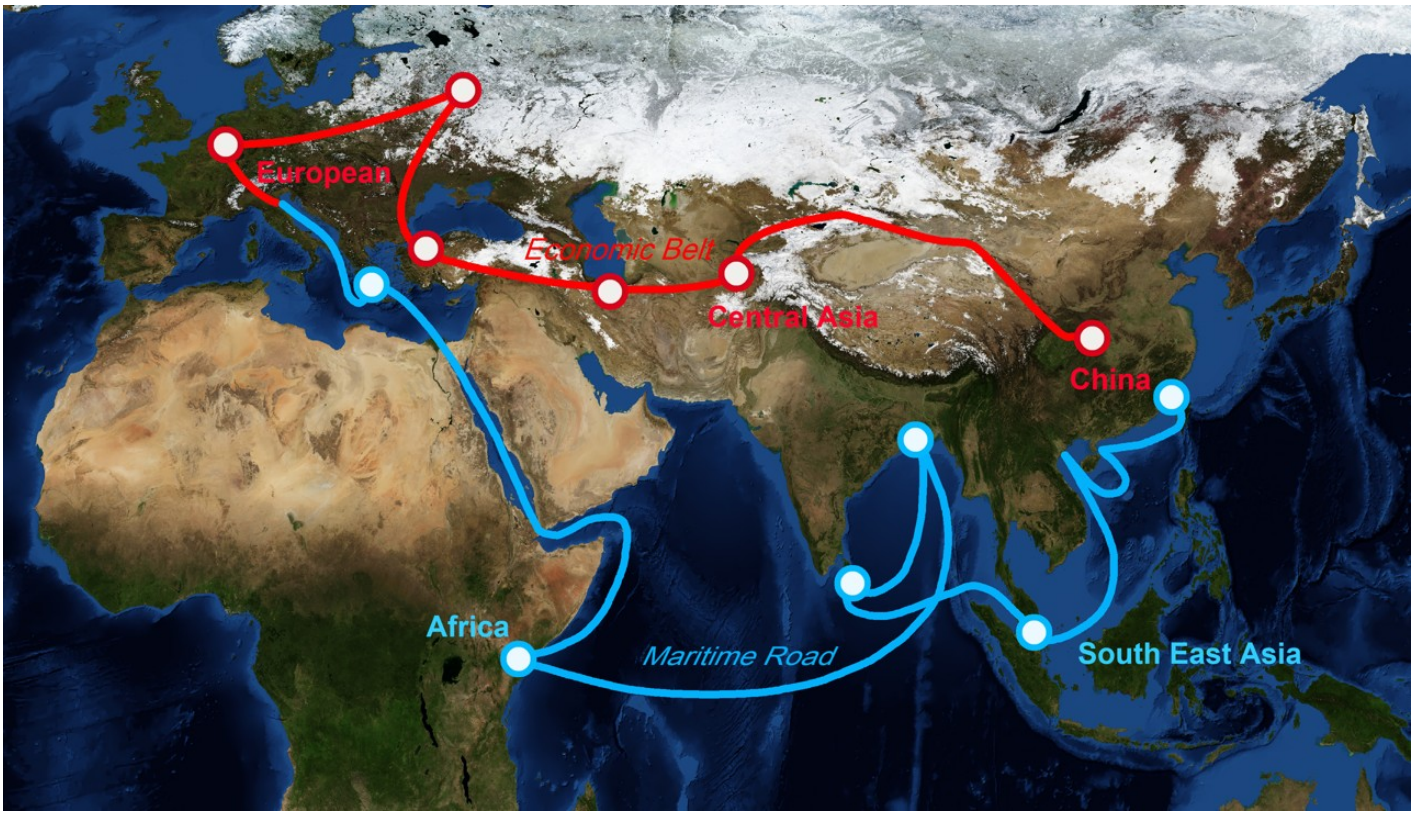
- **Internet protocol.** Huawei is working on new internet protocols for the ITU. The Chinese company is proposing a "New IP" model in which the state has more influence on digital infrastructure as compared with the TCP/IP network protocols developed in the U.S.
- **Internet of Things.** Since the approval of China's home-grown Internet of Things standards, Germany and China are cooperating closely on high-tech standardization. This collaboration is embedded in a larger multi-actor partnership linking the two countries in the domain of Industrie 4.0 — Germany's catchphrase for "the intelligent networking of machines and processes with the help of information and communication technology."
- **DJI has a near monopoly over commercial drone systems.** China's National Standardization Administration is now intent on "formulating the international standards for 'Classification of Civil Unmanned Aircraft Systems' to help the domestic drone industry occupy the technical commanding heights.
- **Surveillance.** Chinese companies such as ZTE, Dahua and China Telecom have introduced standards for facial recognition and other forms of surveillance to the ITU.

- **Blockchain.** In September 2020, the ITU – the body that regulates related systems and telecommunications globally – approved new basic standards on financial applications for blockchain, developed by the People's Bank of China, the China Academy of Information and Communications Technology, and Huawei. This is the first Chinese-developed international standard on blockchain for finance approved globally. Alibaba recently launched a new standard for blockchain used for online charities.

Another strategic approach in the field of standardization is within the framework of China's 'Belt and Road Initiative', to give international validity to Chinese standards relating to infrastructure projects via bilateral agreements with the respective countries. This can facilitate distribution of China's national standards on a global scale.

Exhibit 4:

China's Belt And Road Initiative - A Strategic Approach to International Validity of China's Standards or Creating a 'Digital Silk Road'



Source: Shutterstock, Morgan Stanley Research

China Standards 2035 Objectives – An Ambitious Blueprint

A government-led and enterprise-driven approach. China Standards 2035 sets global standards for emerging technologies and works in concert with China's other industrial policies – namely the Made in China 2025 policy – as China seeks to become a global leader in high-tech innovation. The nationwide effort is to develop industrial standards and eventually internationalize them. The document proposes to strengthen: construction of the nine standard systems of epidemic prevention and control, agriculture and rural areas, food quality and consumer quality safety, high-end manufacturing, new-generation information technology and biotechnology, service industry, social governance, ecological civilization, and national standard samples. The key areas include: blockchain, Internet of Things, new forms of cloud computing, big data, 5G, new-generation artificial intelligence, new forms of smart cities, and geographic information systems (GIS). These fields are among the core technologies of the digital economy era.

Putting forward ambitious plans for China to reshape the global technology industry. The plan is the result of a two-year research project that began at the start of 2018, led by the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) and carried out by the Chinese Academy of Engineering. It will work in concert with China's other industrial policies – in particular, the Made in China 2025 policy – as it seeks to become a global leader in high-tech innovation. It is shaping incentives and aims to ensure connection to information while also allowing freedom of operation.

China Standards 2035 builds upon Made in China 2025 (MIC 2025) – two parts of the same wider strategy. MIC 2025 was launched in 2018 for China to drive a shift from being a low-end manufacturer to becoming a high-end producer of goods and transform China into a leading tech innovator and producer. In setting global standards, China needs to be self-sufficient in designing and producing high-tech products, such as semiconductors.

China Standards 2035 will likely set standards domestically, at first, as, in practice, there is wide variation in how policies are interpreted and implemented at the local level. The central government, then, aims to prioritize coordinating standards across the country before turning its sights globally. China's prioritization of technical standards in its policy demonstrates that it understands the soft benefits of being able to set the rules of the road in a strategic technology area. Tracking the progress in setting standards, as well as the extent to which China can carve out a "right to speak" in international standards bodies, will be an important indicator for how these new technologies will be governed internationally.

China Standards 2035

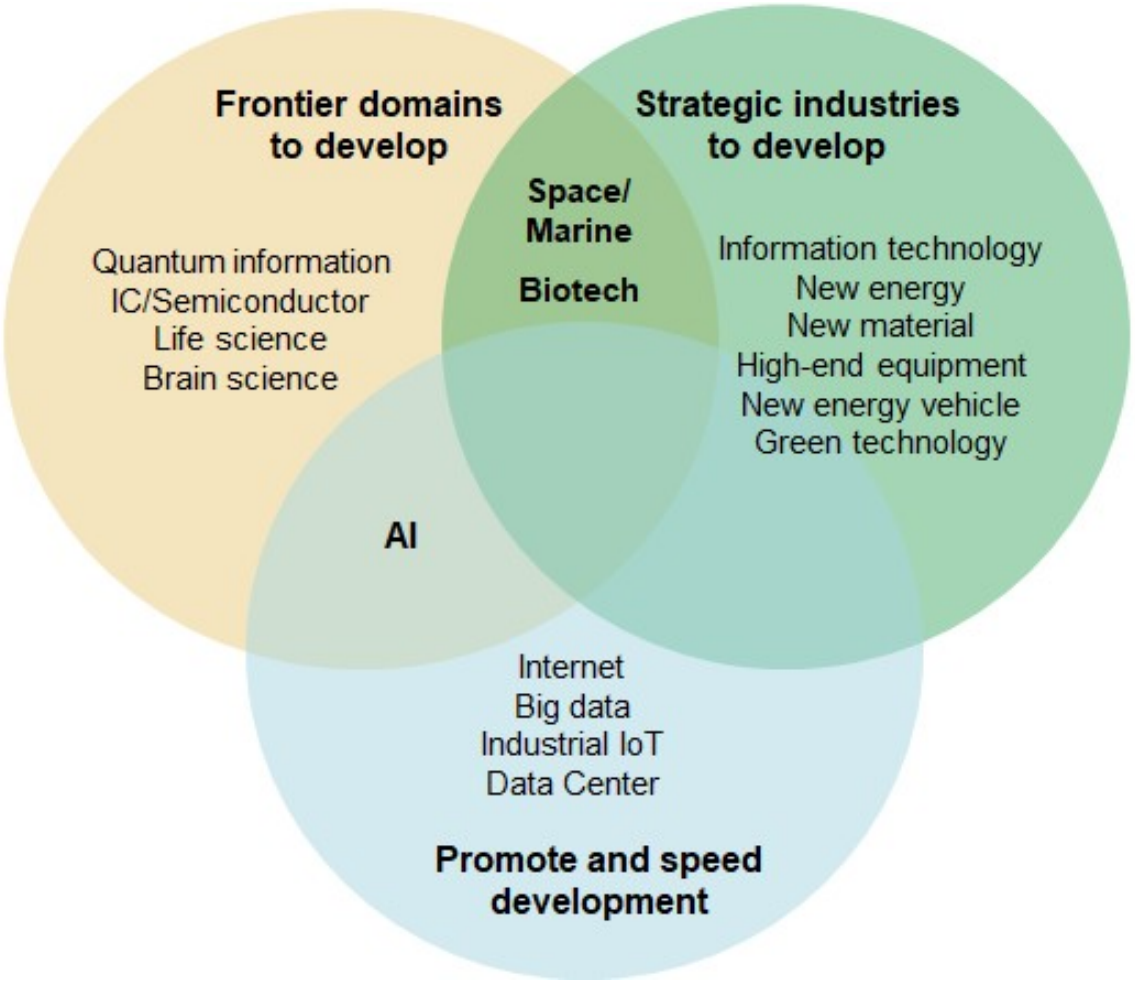
China Standards 2035 lays out a blueprint for companies to set global standards for emerging technologies, such as 5G internet, the Internet of Things (IoT), and artificial intelligence, among other areas. It will work in concert with China's other industrial policies – in particular, MIC 2025 – as China seeks to become a global leader in high-tech innovation. It is a nationwide effort to develop industrial standards and eventually internationalize them.

Highlights include:

- **Indigenous innovation** will play a key role in China's industrial modernization, and the country will make technology self-reliance an underpinning strategy for national growth.
- It pinpointed **leading sectors** in which China will strive to launch strategically important projects, including artificial Intelligence, quantum technology, semiconductors, neuroscience, genetics and biotech, health-related sciences, and space and earth discovery.
- China will devote extensive attention to basic **R&D capacity**.
- The proposal includes other accompanying measures, such as bolstering the **innovation ability of enterprises**, improving the technology innovation mechanism, and cultivating talent, as well.

Exhibit 5:

China Standards 2035 – Key strategic target areas



Source: State Council, Morgan Stanley Research

The Chinese Approach vs. the International Model

The well-established system of standards is currently being put to the test not only by developments in China, but also worldwide. For decades, the standardization systems in Europe and the US have been most influential. However, the number of those who want to have a say in this is growing, and, while China's voice is growing rapidly, others' influence in standardization work is diminishing. The further development of a third or fourth standard is possible but unlikely to be sustainable as it would lead to unnecessary obstacles for companies and costs for all parties involved. The US boasts among the strongest innovative capacity in the world, and, until now, it has preferred a more organic, bottom-up approach to standards setting versus China's more strategic and expedient top-down approach. Although this is also changing in recent months, with the US increasingly driving top-down incentives to competing for and maintaining dominance.

Chinese approach to standards versus the current international model are often presented as mutually exclusive... The top-down approach has helped China's standards and conformance systems develop rapidly. The role of government in things like basic research can do the early work that companies cannot afford to take risks on. But many examples also show that top-down vs. bottom-up approaches to driving standards or innovation have their own distinctive merits, and any single approach does not have to be adopted at the expense of others. Further, the formation of multiple standards within a category can co-exist, as explained previously.

... but throughout history, governments played important roles in facilitating industrialization (as in Germany and Japan), creating or developing intellectual property or in encouraging and subsidizing private sector industrialization as in the US. According to Professor Kurt Mandelbaum (*The Industrialization of Backward Areas, B. Blackwell, 1961*), successful industrialization required directional thrust by the state via a step up in public expenditure – whether on subsidies to consumption or on public investment, financed by state enforced savings mobilized through a policy of redistributive measures. Professor Rhys Jenkins' paper, '*The Political Economy of Industrialization: A Comparison of Latin American and East Asian Newly Industrializing Countries, 1991*' also points to East Asia's export success that was not at all guided by liberal economic principles or free market ideology but rather by strong 'autonomous' states capable of micro managing the capitalist accumulation process (which meant dictating to private oligopolistic firms what they were to produce) in highly selective ways. Examples of past top down approaches that resulted in standard setting include:

- **The innovative engine in places like Silicon Valley was born out of public funding**, but it later thrived because the internet enabled distributed entrepreneurship and decentralized power. The precursor to the Internet was invented in 1969 at the Advanced Research Projects Agency, a branch of the US Department of Defense.
- **The federal government played a central role in the creation of the US semiconductor industry.** World War II funding for electronics and materials R&D provided essential support for the invention and refinement of semiconductors. Large, coordinated industrial research and federal investments in computing advances also created an important application for semiconductors and much of today's global standards in computing.
- **More top down influence to fend off competition.** In the face of formidable competition from Japanese companies in the 1980s, the US Congress co-funded SEMATECH, an industry research consortium devoted to developing the technologies needed by US firms to remain competitive. In 2020, the US CHIPS Act, USA Telecommunications Act, and Endless Frontier Act can also be seen as a top down approach to maintaining technology supremacy.

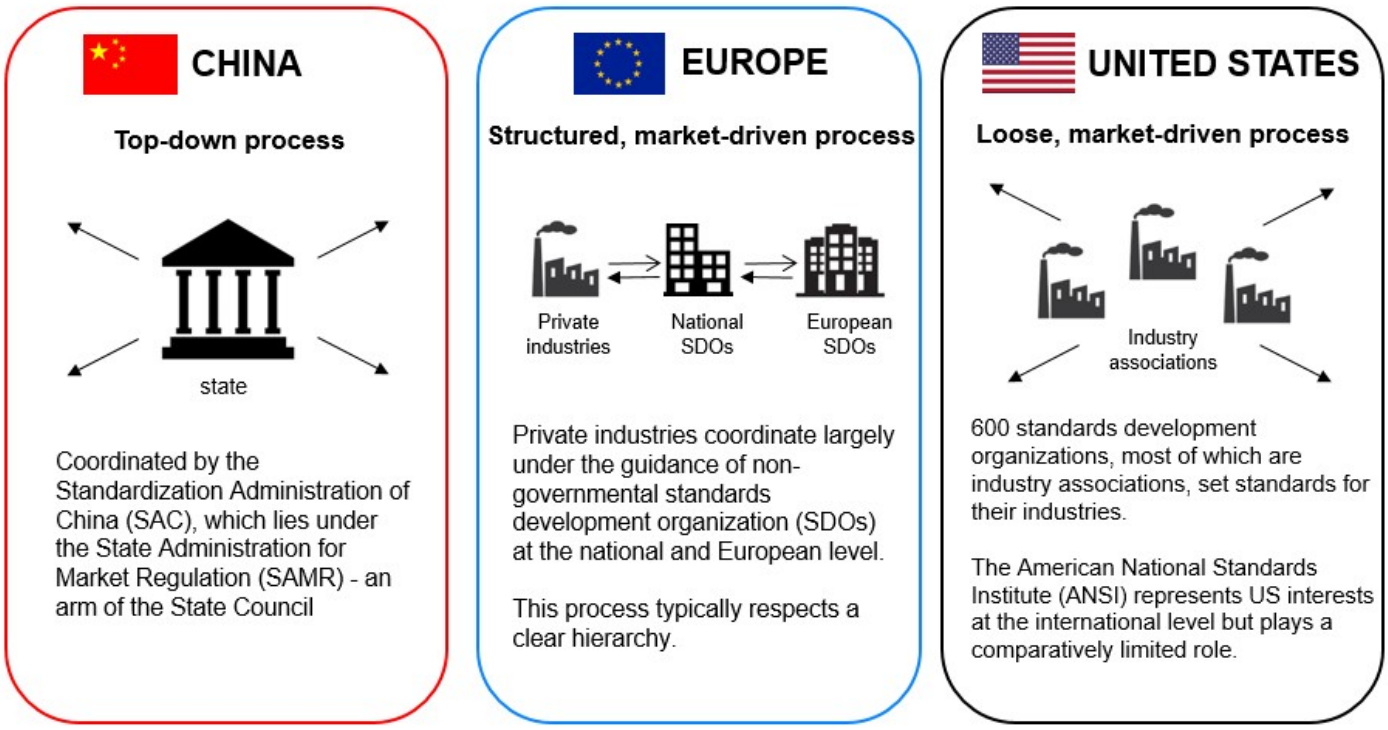
China's strategic approach to standardization is much more focused on, and dependent on, the participation of state actors in the standardization process and the strategic use of standards. There are much closer links between the state and business, and industry is given much less leeway to participate in non-focus areas, and the requirements for standardization activities are essentially determined by ministries and subordinate authorities. Conclusions can already be drawn about the general direction of China's program via its China Standards 2035 blueprint, suggesting an ability to create national champions in the field of standardization, for example through the control of large state-owned companies, and to expand its own influence in international bodies in this way. In the past, it was not sufficiently equipped with the necessary technical expertise, presenting a major disadvantage, but clearly this is no longer the case for emerging new technologies. China, today, is also more deeply involved in standardization work with international bodies.

The US and EU emphasize the leading role of industry today...
The US focus is on the technical aspects of standardization and the most efficient achievement of interoperability, with voluntary commitment by industry. The US government is a participant in private entities (such as not-for-profit American National Standards Institute), and the work is bottom-up consensus driven, where the private sector takes the lead and works in partnership with the government. This has established the successful and effective system we know today. European Standards also work in a decentralized way and are developed by the European Standardization Organizations. This consists of three organizations – CEN, CENELEC and ETSI – that are officially recognized as competent in the area of voluntary technical standardization. Around 25% of European standards published by CEN (European Committee for Standardization) have been developed in response to standardization requests (Mandates) issued by the European Commission.

China's Perspective on Standards

Historically, China's companies had viewed technology as a costly input, and one that should be accessed as cheaply as possible, whether through negotiations with foreign IPR holders or by setting new norms. So long as Chinese firms remain committed to manufacturing, the goal was to pursue technology access at low prices. However, in recent years, a new approach has emerged, in which Chinese enterprises may be initiating a new norm for IPR in technology standards. China's leading technology firms, e.g., Huawei and ZTE, take a similar perspective on intellectual property and standards, where the value of intellectual property is in its ability to increase the quality and price (or lower input costs) of their physical products.

Exhibit 6:
Standard setting in China, Europe and the US



Source: IFRI, Morgan Stanley Research

China's perception of the top-down approach as a means to help the economy become more innovative is not unique. Just as Japan caught up with the US technologically in many industries during the three decades after World War II, China is now doing the same through government support and incremental innovations. Adapting technology has become a standard and highly lucrative practice. China's centralized policy initiative may narrow the room for bottom-up innovations, but that does not necessarily mean the end of adaptive local policy implementation or success in outright "innovative" behavior, that has been encouraged to various degrees, top-down. Innovation or "being innovative" is stressed from the top, and local leaders go to great lengths to embrace it, as it is beneficial. One main goal of centralization efforts is the focus toward execution, emphasizing "coordination and harmonization".

China has no lack of entrepreneurs or market demand, and given the government's substantial wealth and political will, it has the potential to set the kind of economic policies and build the kind of education and research institutions that propelled the US to technological dominance. Innovation is happening from the top down, from the bottom up, through acquisition, and through education, and highlights the promise China faces in its quest to become a world innovation leader. Such ambitions could jump-start innovation in much the same way that government-funded programs did in the US in the second half of the 20th century. This approach has the potential to create widespread and immediate change when applied effectively. Because China may become the largest economy in the world, the size of its market incentivizes companies to meet these standards and produces a ripple effect throughout the industry.

US Perspective on Standards

Katy Huberty

China's top-down approach to boost the economy and drive innovation can trim the addressable market for US companies, help China compete for investment flows, and, in a less likely scenario, impact US technology companies' competitive edge on a more global scale.

First, we think it is fair to assume that China will continue to support the growth of domestic (Chinese) technology providers over providers from other regions, including the US, to serve local demand – a dynamic that is largely baked into financial forecasts and US stock valuations. This is a continuation of a decade-long "localization" trend. For instance, proprietary 2G and 3G wireless networks and the requirement for licenses to sell products capable of communicating on these networks slowed Apple's share gains in the early days of the iPhone (Exhibit 7). However, with Apple's investment in iOS, in-house component IP, and a brand that resonates with Chinese consumers, iPhone share has grown to a level on par with the PC market (Exhibit 9) where IP is similarly controlled by US vendors such as Intel, AMD and Microsoft. But, other enterprise-oriented technology hardware markets were hit harder. For instance, US OEMs only account for 24% of the server and storage market in China today, down from 37% five years ago and 79% 10 years ago (Exhibit 8). With the Data Era largely focused on driving data insights and productivity in enterprise markets, we would expect Chinese standards to similarly limit US hardware OEMs' ability to tap into local demand in China.

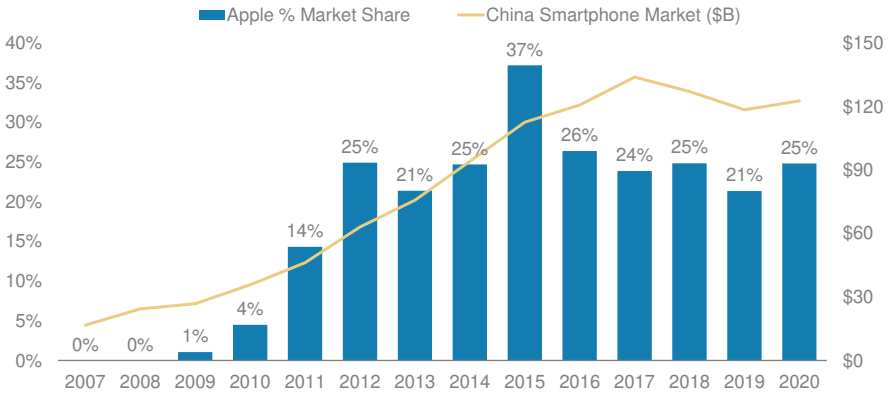
Second, centralized standards and government investment pave the way for faster adoption of new technologies in China, as evidenced by China's lead in global eCommerce, mobile payments, and smart factories. Because China remains a fast-developing country, adoption of new technologies can have significant impact on economic growth. The smartphone provided many Chinese consumers their first internet access, as PC penetration was much lower than developed market levels. Mobile payments provided Chinese consumers with their first credit line, spurring consumer spending. If adoption of new technologies such as quantum communications, electric vehicles (EVs), and digital currencies is faster in China than in other developed markets, it could allow for faster economic growth and drive positive investment flows relative to the US.

Third, and more uncertain in our view, is a scenario in which China controls the standards that apply to technology used outside China. Given the strength of software and semiconductor IP in the US, combined with concerns over China's more business-friendly privacy standards, this path seems less straightforward. However, as key components, such as silicon carbide in the case of EVs, are sourced mainly from China relative to key components in legacy technologies largely sourced from US companies, there is risk of a power shift that is worth monitoring.

Exhibit 7:

Proprietary 2G and 3G wireless networks and other regulation slowed Apple's share gains in the early days of iPhone

Apple Share of China Smartphone Market (Revenue Share, 2007-2020)

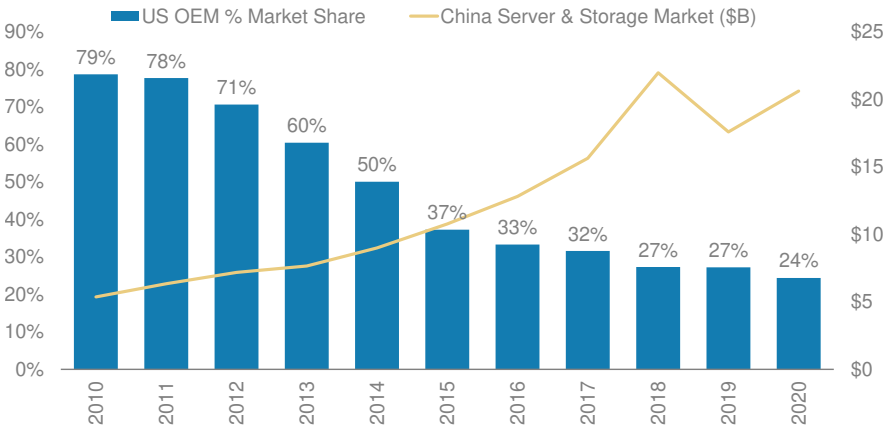


Source: IDC, Morgan Stanley Research

Exhibit 8:

US OEMs represent 24% of the server & storage market in China today, down from 37% in 2015 and 79% in 2010…

US OEM Share of China Server & Storage Market (Revenue Share %)

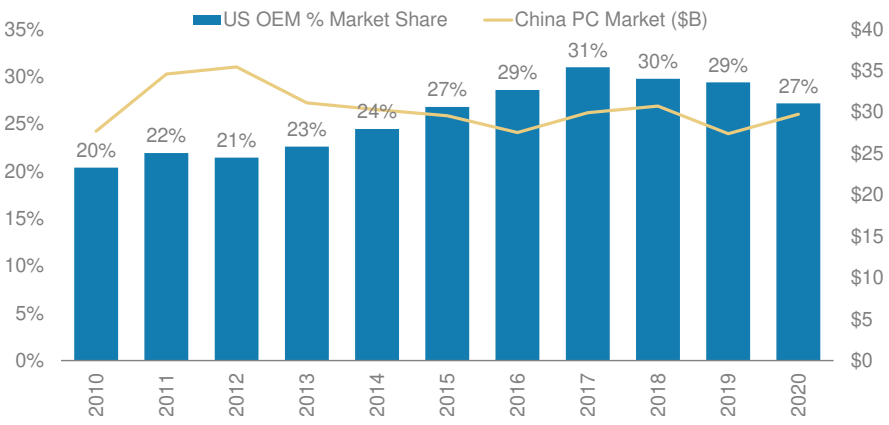


Source: IDC, Morgan Stanley Research

Exhibit 9:

…however, PCs have fared better, and US OEM market share in China is flat from 5 years ago

US OEM Share of China PC Market (Revenue Share %)



Source: IDC, Morgan Stanley Research

EU Perspective on Standards

Ben Uglow, Edward Stanley, Katie Self

Summary

(1) European companies lead the world today in certifying factories and underwriting common standards. (2) Europe, and Germany in particular, is relatively advanced in its implementation of Industrial IoT technologies. (3) Creating different standards in China-based manufacturing does not really solve the main barrier that exists today: factory automation depends on providing a comprehensive solution, not just 'standardised products'. (4) In the event that lower latency with 5G effectively replaces traditional controllers, this could provide an opportunity for China-based IoT vendors to make a significant advance. (5) Standards are proliferating – we believe that this makes 'leadership' by any one country – even China – difficult.

Germany leads the world in Industrial IoT expertise

Through organisations such as DIN and DKE, which govern multiple industrial standards, Germany has a very well-established roadmap for its implementation of Industrie 4.0 (Version 4 was published in March 2020). Put simply, this refers to the digitalisation of industrial processes: in particular, interoperability and machines talking to other machines (see Exhibit 10 to understand the industrial ecosystem). Europe, and Germany in particular, has a substantial lead in Industrial IoT for the following reasons: (i) breadth of knowledge in electrical engineering and related academic sponsorship; (ii) significance of the automotive segment within the industrial base, and related supply chain, including factory control and robotics industries; (iii) market-leading companies, such as Siemens have globally dominant shares in IoT equipment (including in China). In principle, Industrial IoT is the core business of German industry, and it receives sponsorship at a national, political level.

IoT hardware is governed by ISO guidelines

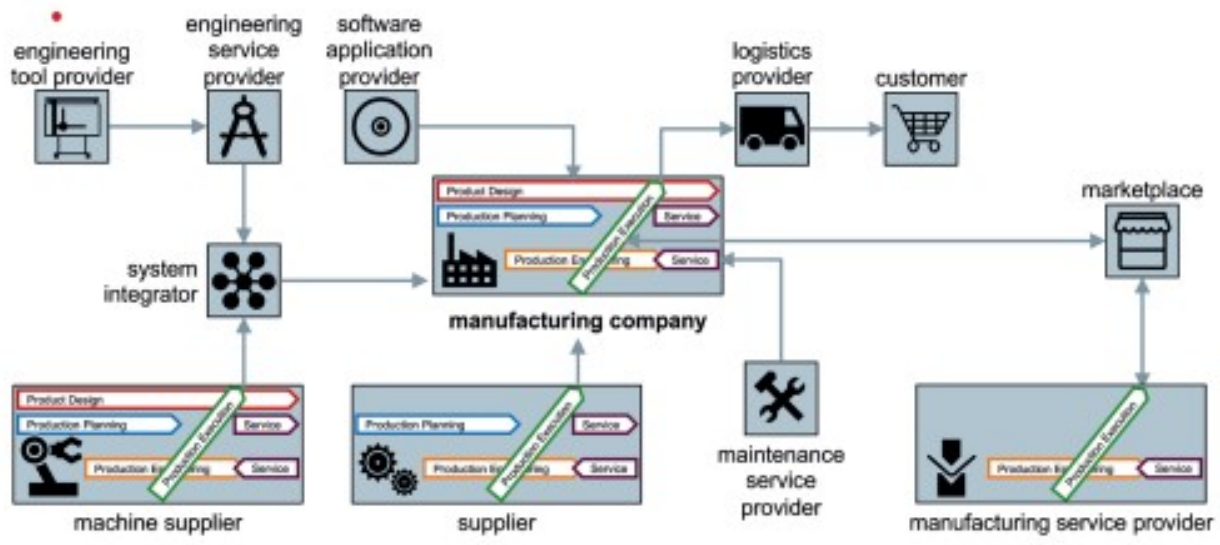
In an industrial setting, the standards for the design of typical IoT Hardware components (sensors, actuators, microcontrollers, processors, etc.) are most often set by ISO as guidelines, rather than strict regulation. It is in the RF modules and other wireless communication systems where regulatory considerations are more strict – in Europe these are governed by the Radio Equipment Directive (RED), established in 2014, which sets essential requirements for wireless IoT products sold within the EU, covering health and safety, electromagnetic compatibility, and the efficient use of the radio spectrum. Crucially, it also provides the basis for further regulation governing some additional aspects, such as the protection of privacy, personal data, and against fraud.

Future growth in IoT depends on having a comprehensive platform – not standards

Standards do play a significant part in the factory control area – specifically, IEC 61131-3 in programming languages for programmable

Exhibit 10:

The industrial ecosystem – needs interoperability and a comprehensive offering



Source: The German Standardisation Authority

logic controllers ("PLC," the key factory control equipment used today). In China, despite attempts to create national champions (as in areas such as power transmission), we believe that '*Made in China 2025*' could've placed more focus on the factory hardware environment, also in robotics (though this is changing to some extent with the relationships with leading German medium-sized companies, such as KION and Kuka). The largest factory hardware vendors remain Germany, US and Japan. Although China may benefit locally from introducing its own approach in the factory domain, simply selling PLCs, drives, or industrial motors is not where the value-add is. Increasingly, companies (including Chinese manufacturers) demand a whole package that runs from design to operations and logistics. Regardless of any potential standardisation process, Chinese equipment suppliers still do not have a comprehensive product range. In our view, this presents a meaningful barrier to their future growth.

Implementation of 5G could be important for Chinese IoT hardware vendors

One area, however, where Chinese suppliers can potentially challenge the western automation vendors is in the implementation of 5G in Industrial IoT. Since the 1950s, factory control has been dominated by the PLC – even the advent of the internet more than 20 years ago did not phase it out, as many expected. However, the significantly reduced latency that 5G brings could begin to change the way that factories and machines operate. The implementation of cloud-based and / or Edge control systems that are fast and proprietary could become a challenge over time.

European companies assess common standards for factories globally, including in China

There are only three major global certification companies in the world: SGS, Bureau Veritas and Intertek. These companies perform the lion's share of factory audits, product testing and homogeneity assurance for multinationals across the world, via their network of >100,000 auditors. The bulk of these companies' work is focused on China for several reasons:

- Europe and the US have tended to have the most stringent standards globally for health, safety and product conformity. However, product testing and factory/supply chain inspections usually happen in the country of manufacturing origin rather than the country of destination or sale (assuming the two are different).
- Many western buyers and retailers set procurement hurdles – such as ISO9001/14001 certification – for suppliers to enter their supply chain. Consequently, over time, the volume of these ISO certifications has been gravitating towards Asia Pacific, where the supplier factories have tended to be located.
- The Chinese export market (certifying CE marks for Europe-bound products or FCC marks for US-bound products) has presented the largest addressable market for these testing companies for many years. However, as perception around quality and safety of products has increased in China's domestic market, growth in CCC mark certifications for Chinese-made and consumed products has grown substantially quicker than CE/FCC certifications in recent years. This mix of growth towards domestic Chinese testing, inspection and certification is showing no signs of slowing.

Evolution of standards in Europe: increased complexity prevents national leadership

It is worth noting, however, that the history of European "standardisation" shows a path of anything but. The number of standards and certifications tends to proliferate over time rather than diminish. While ISO9001 remains the most commonly known, its growth is slow, and its usefulness is hindered by its voluntary (rather than mandatory) nature. Consequently, hundreds of standards and certifications have evolved rather than companies conforming to a "go-to" or "must-have" standard. In fact each industry (resources/products/electronics/forestry/food/emissions/construction/fire) ultimately has its own certification body and mission-critical certificate. This makes "leadership" by any one country highly challenging, because it requires leadership across all (or at least the most important) categories of standards. In our view, however, once Electronics, Food, Safety and Emissions standards leadership is established (in China, for example, versus US/EU), it is more than likely that other industries will follow suit in this national prioritisation of standards and certificates because of top down government guidance and geopolitical tension.

China consumer may hold the key to a 'power shift' in standards

What ultimately will facilitate China to lead in certification and compel Europe and the US to conform, is the desire for European and US companies to sell to Chinese consumers (the inverse of the historical status quo). As that happens, China's ability to call the shots on international standard-setting can or should become unrivalled, effectively turning the EU and US into standard-takers rather than standard-makers. This process will, however, not be a fast one.

Exhibit 11:

A condensed example of the complexity of standard/certification conformity, by country

Source: Morgan Stanley

Innovation Is Critical to National Power

In the midst of a major spurt of innovation, China is rapidly approaching the cutting edge in a variety of emerging sectors. However, this is occurring in a context of both extensive top-down drives from the government alongside a market composed of fast-moving private firms of all sizes that are exploring new horizons. The interplay between these two forces has led to a highly innovative market that has thrived either because of, or in spite of, either approach. In areas where market players have thrived in pushing innovation forward, the government commonly gives sufficient space to firms to experiment in, only to then begin to regulate the activity once a market is established.

Despite support and even state sponsorship, a company must compete in the market. Standards are not ends in themselves; they only have value if they are incorporated into technologies used in goods and services. Having a successful standard, one that is adopted domestically or internationally, is meaningless if it fails to gain market traction. So the market acceptance of a standard is the ultimate goal. And, in the end, companies will favor standards that enable them to sell more products. As a result, they tend to support international standards. This means China's most capable innovators may not necessarily be backing or significantly contributing to China's unique domestic standards. As such, leading in innovation becomes critical to succeed.

Innovation is the process by which scientific discoveries, new knowledge and technological advances that shape the modern world are created. An economy's capacity to innovate is dependent on its commitment to R&D, the quality of its workforce, and the effectiveness of the system in place, from government institutions to the private sector. From this perspective, China appears to join the ranks of a global leader in innovation as it works to upgrade its long-term economic competitiveness and prospects for global leadership.

Standards tend to be differentiated by their size, with the biggest ones tending to be viewed as the best. A standard is adopted because it has the highest amount of people agreeing to it. China is big, centralized, deliberate, and motivated by a long-term vision, whereas the rest of the global system is fragmented, short-term, and looking to maximize profit. This makes it easier for China to evolve into a leading influence over the world's companies and multilateral institutions.

China's Rise in Innovation

When measuring China's growing international influence, it is essential to consider the sources of Chinese innovation. As a global benchmark, China's improvement in the Global Innovation Index (GII) ranking enables a comparison with advanced economies, especially in new emerging technologies, given the more level starting point. The GII is an annual ranking of countries by their capacity for and success in innovation. The GII ranks countries based on the simple average of two sub-indexes – the Innovation Input Index and Innovation Output Index – and it is composed of seven different pillars of innovation. These are based on subjective and objective data from the ITU, World Bank and World Economic Forum.

- **R&D** supports the development of new products and services, which can boost growth and productivity. China has prioritized R&D, with spending rising from 0.72% of GDP in 1991 to 2.4% in 2020. This level surpassed the OECD average of 2.37%, but the size of China's economy means that its R&D expenditure is now second only to the US. Much of China's R&D usage is geared toward commercial applications, while higher education is a smaller portion of R&D relative to advance countries but is quickly closing the gap with its sheer number of people and online learning.

Exhibit 12:

China ranked 14th for the 2nd time in a row; it is the only middle-income economy in the GII top 30

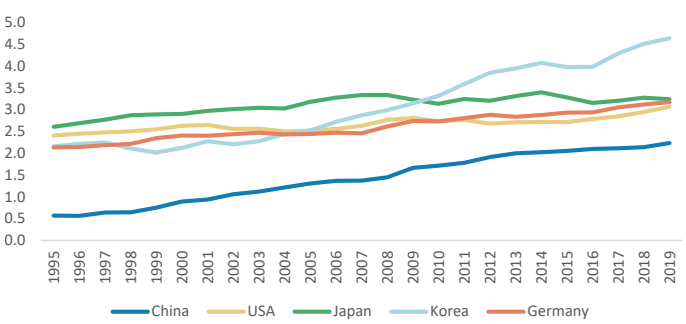
Global Innovation Index 2020 Rankings

Rank	Country/Economy	Score (0-100)	Median 30.94
1	Switzerland	66.08	
2	Sweden	62.47	
3	United States of America	60.56	
4	United Kingdom	59.78	
5	Netherlands	58.76	
6	Denmark	57.53	
7	Finland	57.02	
8	Singapore	56.61	
9	Germany	56.55	
10	Republic of Korea	56.11	
11	Hong Kong, China	54.24	
12	France	53.66	
13	Israel	53.55	
14	China	53.28	
15	Ireland	53.05	
16	Japan	52.7	
17	Canada	52.26	
18	Luxembourg	50.84	
19	Austria	50.13	
20	Norway	49.29	

Source: GII, Morgan Stanley Research

Exhibit 13:

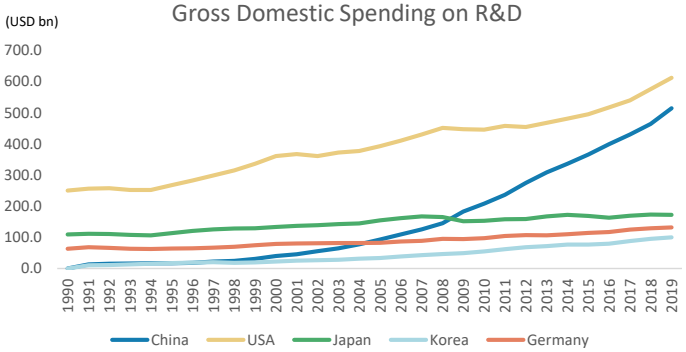
China R&D as % of GDP increased from 0.9% in 2000 to 2.2% in 2019



Source: OECD, Morgan Stanley Research

Exhibit 14:

Also, in absolute terms, China is catching up in R&D spending

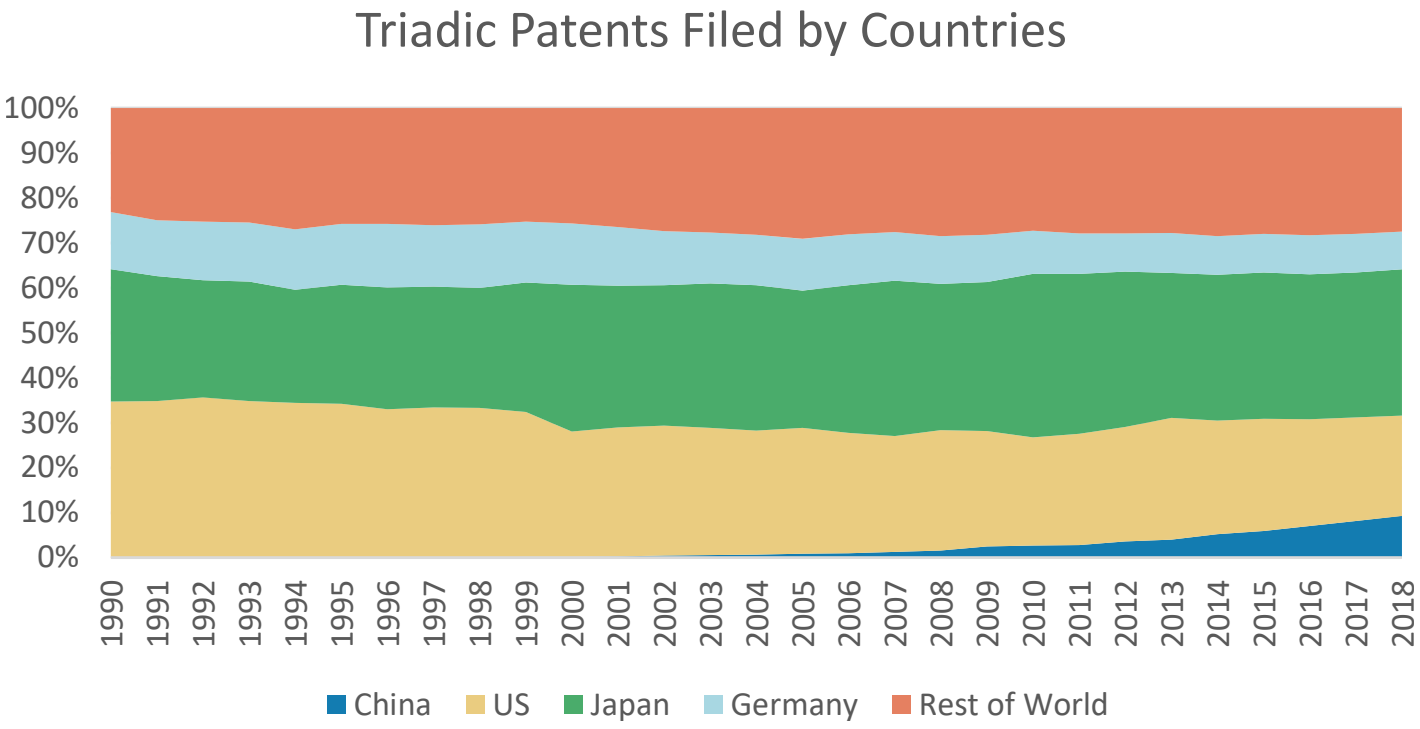


Source: OECD, Morgan Stanley Research

- **Intellectual property (IP) is critical for innovation.** This includes patents and provides legal safeguards for innovators and serves as a helpful measure of a country's innovative capacity. China's reliance on foreign IP has diminished substantially as the world shifts to digitization of everything. China has rapidly become the world leader in patent applications, with more than 1.3 million, accounting for 40% of all applications in 2017, based on the World Intellectual Property Organization. This is up from 161,000 patent applications in 2007, or just 8.5% of the global total. This high output has helped China move up the GII ranking.
- **Not all patents are equal.** The patent quality may be lagging in terms of overseas revenues generated from its patents, but it is becoming more valuable. While the explosion of domestic patent applications in China is impressive, this growth does not necessarily correspond with dramatic advances in innovation. Considering the relative value of patents in terms of the frequency of citations, we look to China's triadic patents – a set of patents filed at three major patent offices – in the EU (EPO), Japan (JPO) and US (USPTO) – which are difficult to obtain, but generate more revenue than other patent types. China was the fourth largest, behind Japan, US and Germany. However, its rate of growth in filings remains among the highest.
- **Business environment.** Urban hubs, such as Beijing, Shanghai, and Hangzhou, are beginning to challenge Silicon Valley's dominance in fostering startups. These three cities were responsible for more than 30% of global growth in venture capital investment, 2015-17, and home to 75% of China's "unicorns" (i.e., startups with a value of at least US$1bn).

Exhibit 15:

China's patent filing share more than tripled since 2010



Source: OECD, Morgan Stanley Research

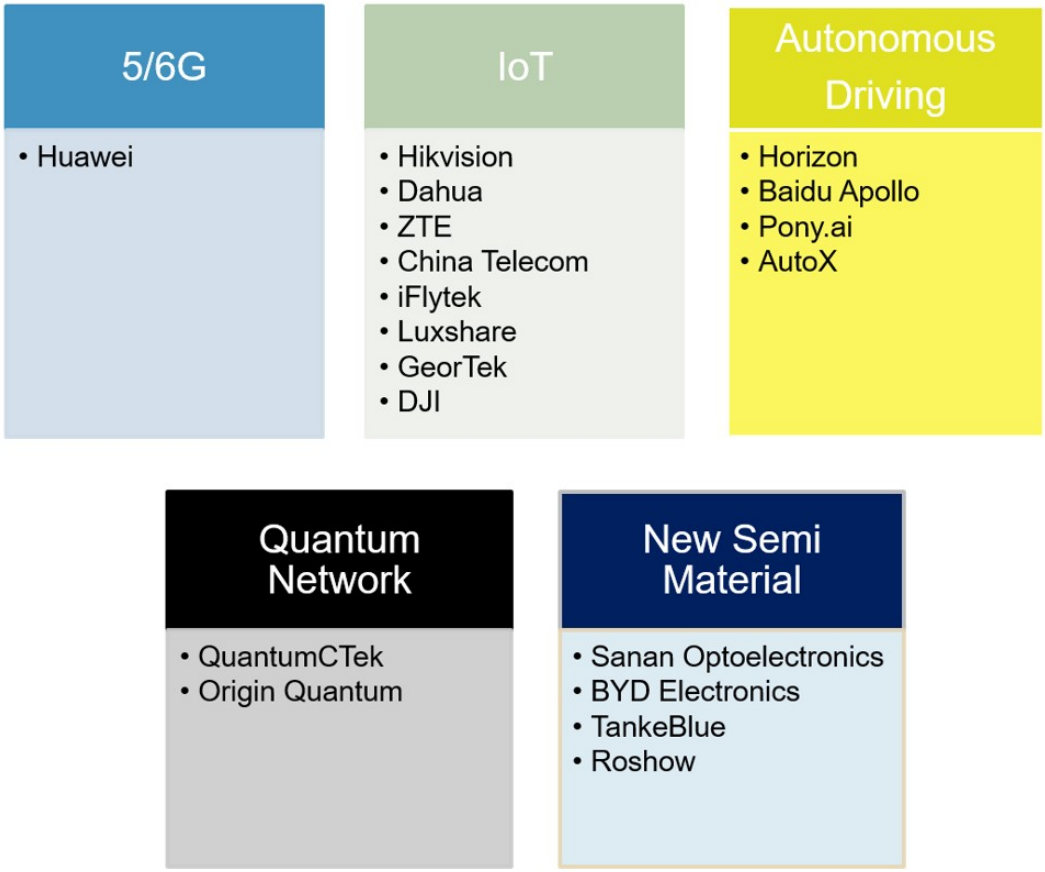
Will China's Potential Be Realized?

How will it affect emerging industries? There are several key areas within the technology sector where China could make advances in innovation with market advantages and where there is greater Chinese involvement with international standard-setting bodies. We note that: 1) China already leads the newly created international research group on IoT; 2) quantum communications and networks are already commercial from Beijing to Shanghai; 3) 5G's significance for powering virtually all disruptive applications, from driverless cars to AI; 4) new semiconductor materials; 5) China ITU-approved block-chain standardization on financial applications in June 2020; and 6) autonomy, such as in self-driving and drones. Popularizing Chinese standards is also part of the Belt & Road Initiative's (BRI) design, more recently referred to as the Digital Silk Road (DSR).

While still too early to fully assess, we also identify companies leading in these key areas of new standards in terms of innovation, investments, and market presence. The list consists mainly of domestic companies leading respective emerging industries.

Exhibit 16:

Leading Chinese companies in emerging industries



Source: Morgan Stanley Research

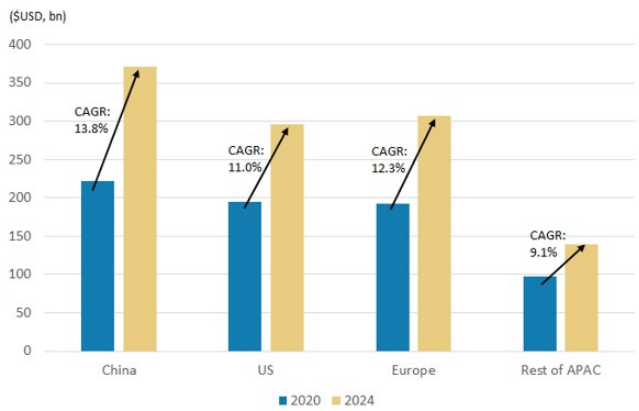
Internet of Things

Developing a set of standards is clearly going to have a critical role to play if the goal is to realize digital potential in the 'Internet of Everything'. Currently, the use of standards for digital manufacturing varies significantly by industry. Robotics, for example, already has a large number of standards relating to digital manufacturing but it is a very different story by industries addressed, individual companies, countries and even within the same proximity. Many companies are only working to their own in-house standards, at worst, and at best to standards that relate to their own industry. This is resulting in a lack of transparency and a need for greater integration. It calls for the development of a steering arrangement for digital manufacturing standards – led by key industrial, academic and institutional stakeholders – to ensure that there is a clear vision in policy setting, governance and processes that 'have vision' but that are also straightforward to implement. The other key area is developing appropriate cross-sector policies, regulations and light touch standards to support integrated supply chain development, particularly as there will be more requirements to include digital data management in contracts and procurement.

A strategic race for IoT influence and cooperation globally. The Ministry of Industry and Information Technology (MIIT) released draft guidelines for the construction of basic security standard systems for the Internet of Things ('IoT') in January this year. The guidelines set the goal of "the initial establishment of an IoT basic security standards system" by 2022 and outline basic principles, as well as general safety, terminal, platform, and getaway security requirements for the construction of IoT systems. The draft guidelines also provide for international cooperation between China and other countries on setting basic security standards for IoT, as well as to facilitate China's active participation in the formulation of international standards for IoT security. China's IoT reference architecture ISO/IEC 30141 has been approved by the International Organization for Standardization back in 2018, and it already released water (2018) and gas (2019) metering standards based on IoT technologies in China.

Exhibit 17:

Worldwide IoT Markets – Substantial TAM Where China Has Significant Presence



Source: IDC forecasts, Morgan Stanley Research..

China's two-pronged strategy to pursue IoT projects as a path to becoming a global player. China is following a centralized plan to effect change at both at a high level and from the ground up. Top down, China is increasing participation in and preference for multilateral (one country, one vote) standards institutions. This is different than the US-backed multi-stakeholder institutions. From the bottom up, it is also pursuing state funding in new technologies to encourage others to adopt its technologies with its standards. The key challenge is addressing data vulnerability with regard to data security or authorized access and issues with unauthorized data collection and surveillance. Key opportunities include China's widespread IoT solutions based on robotics in place within its large manufacturing base. China will surpass the US to become the world's largest IoT market in 2024, according to IDC, with spending expected to reach around US$300bn and a 13% CAGR over the next five years. China will account for 27% of global spending in the IoT segment, followed by the US at 24%, and western Europe at 23%.

Industry standardization is essential to guarantee the interoperability of devices globally. IoT basic security standards refer to the security standards of key basic links – IoT terminals, gateways, and platforms. The data exchanged via devices must be managed, processed, transferred, and stored securely. Collaboration is key, and this will be enabled by the interoperability of both machines and data which, in turn, needs open systems, architectures and common languages and data platforms. These are not yet fully developed, so companies are forced to develop 'bespoke' bridges or interfaces between machines. But this, in turn, reinforces the need for more secure and resilient manufacturing systems and cross-enterprise digital security systems. The five major standards for the IoT basic security standard system China wants to implement are general security requirements, terminal security, gateway security, platform security, and security management.

- **General Security.** Security management standards are mainly used to guide the industry to implement general safety management requirements and include safety information coordination, safety management and maintenance, and certificate management standards.

- **Terminal Security.** This applies to standards applicable to the IoT basic security system. This includes card security, module security, communication chip security, terminal equipment general security, industry terminal security, terminal testing, and evaluation standards.
- **Gateway Security.** These include IoT gateway device security, data exchange and processing security, communication and interface security, physical environment security, component security, and testing and evaluation.
- **Platform Security.** IoT platform security standards include platform general security, platform business system security, platform interaction security, as well as platform testing and evaluation.

What is it? The Internet of Things (IoT) is the interconnection of physical and virtual things via information and communication technologies. In recent years, it was about getting sensor networks deployed, but now it is about getting AI to understand and interpret/infer the data coming out of the sensors. Both China and the US have their own advantages and dominate investments. It is becoming the next big thing in global network infrastructure, involving billions of connected devices, and to be adopted in essentially all economic sectors. Setting IoT standards addresses its operations, safety and security. This means how international standards develop, approach risks and vulnerabilities in a 5G network, and how consumer data will be used and protected. Once a global IoT standard is established and accepted, it can put pressure on countries and/or companies developing other standards to conform to the existing norm, ceding these important benefits to whichever nation's preferences manage to be adopted as the international standard.

Quantum Communications and Networks

The internet has fundamentally transformed China and internet-based technologies help China drive it digital economic development, connect its massive population to one another, and support R&D. Understanding the opportunities and challenges presented by the internet in China, such as future quantum networks, is critical when evaluating its long-term development.

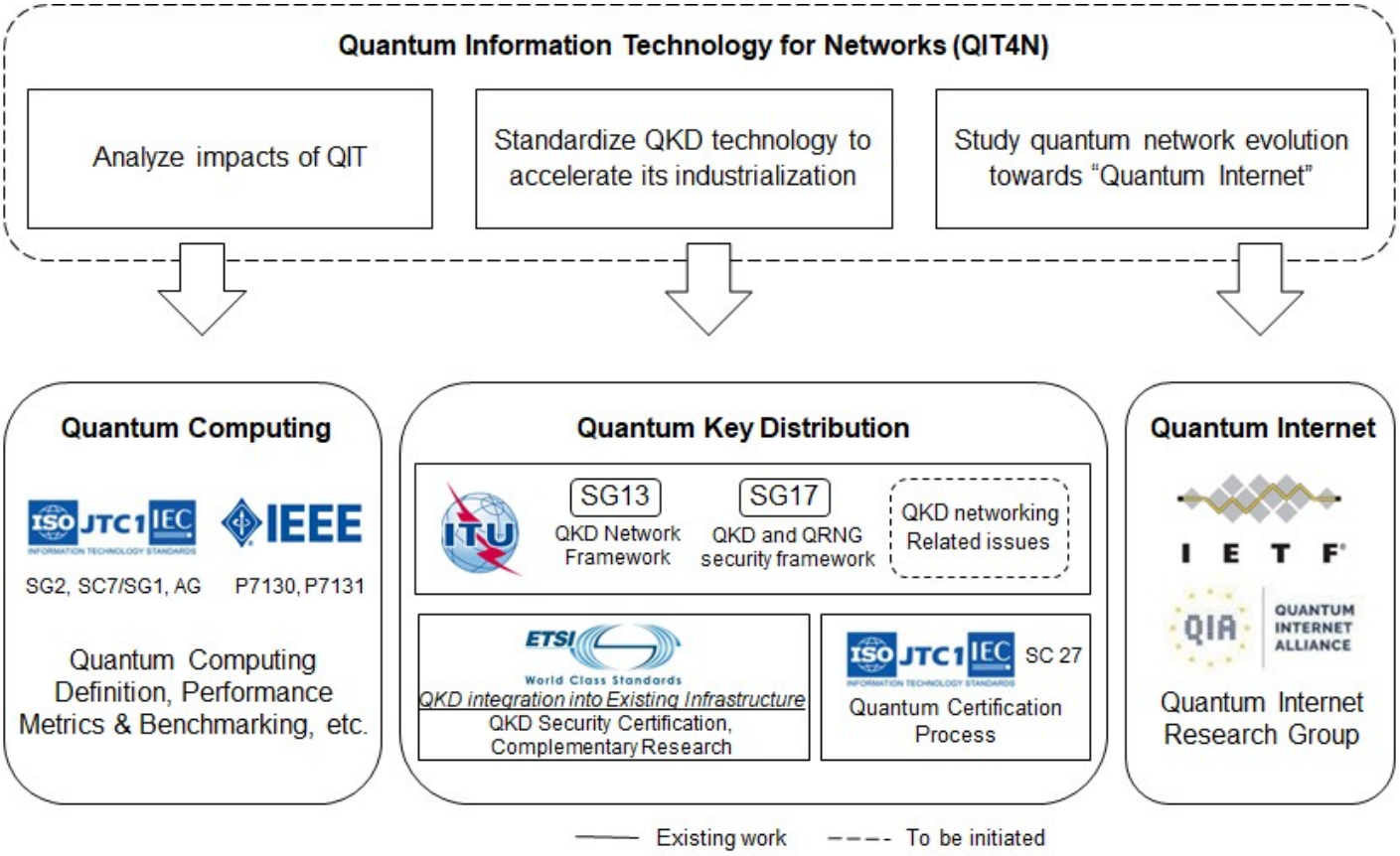
China has the greatest number of internet users in the world. Mobile phones have helped to expand internet access given it has the largest number of mobile phone subscribers in the world, averaging more than one mobile phone per person. China Academy of Information of Communications Technology (CAICT) estimated the total value of China's digital economy at US$4tr in 2017, or roughly a third of its GDP. The internet has also given rise to new forms of entertainment such as video streaming platforms. China is also seeking to promote its internet technology abroad. The Belt and Road Initiative has expanded to include the Digital Silk Road (DSR), a US$200bn plan to install Chinese internet and communications technology within BRI countries.

Quantum network – disruptive innovations of the 21st century. Rising demand for information security and quantum supremacy makes quantum communication a highly relevant domain of disruption (Disruption Decoded: The Rise of Quantum Networks, 16 Dec 2020). Due to the strategic importance of quantum information technology, China has listed it as one of the key frontier domains to develop (among its 2035 long-range objectives). China has devoted lots of capital and resources in this area and several milestones have been achieved: in Sept 2017, China achieved the world's first quantum-safe intercontinental video conference between Beijing and Vienna, facilitated by its quantum communications-focused Micius satellite. During the same year, Beijing-Shanghai Backbone, which spans more than 2,000 km, was formally put into use. This is also the world's first quantum cryptography communication backbone project. In December 2020, China's new light-based quantum computer Jiuzhang achieved quantum supremacy.

While standardization in the quantum area is still at a very early stage, benefits will likely accrue to companies that can innovate while meeting or establishing industry standards. China has played an active part in that. In 2015, China Information Security Standardization Technical Committee (CSTC) initiated a study of quantum-secured communication network specifications. QuantumCTek, a world leading Chinese quantum communication company, led two international standards: security requirements, test and evaluation methods for quantum key distribution; and security requirements for QKD networks – key management. Besides China, South Korea's SK Telecom and ID Quantique have worked through the International Telecommunications Union to establish standards for quantum communications tools. We think companies that can adapt to voluntary international standards for technical devices and data can establish a market advantage as other companies and countries around the world begin to integrate that technology into their own infrastructure. Chinese companies can bring real expertise and experience in quantum technology to international standards organizations. They are well placed for their technical approaches to be integrated into the standards, which would make them competitive in the long run.

Exhibit 18:

Quantum Information Technology Standardization Landscape



Source: ITU, Morgan Stanley Research

5G Networks and 6G

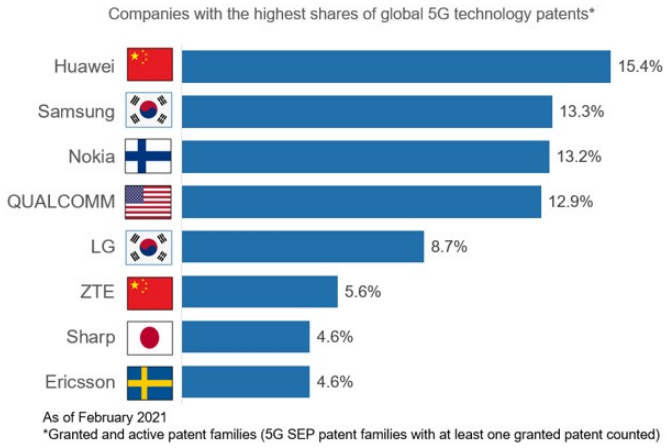
China has become a central player in writing international rules for 5G (fifth-generation) wireless technology, as part of a national effort to shape the playing field in its favor. China submitted 830 technical documents related to wired communications specifications to the International Telecommunication Union last year, the most of any country and more than the next three — South Korea, the U.S. and Japan — combined, according to an industry group. These documents serve as a basis for deliberation and influence on new standards. Huawei provided more overall contributions to end-to-end 5G standards than any other company in the world and leads a group that includes Ericsson for technical specifications, Nokia on 5G contribution papers, and Qualcomm and China Mobile as top contributors to the standard.

Specifications for 5G are developed by the 3GPP (3rd Generation Partnership Project), a collaboration of standards organizations in Asia, Europe and North America. The ITU (International Telecommunications Union) is responsible for the overall standardization process for the industry and is a specialized agency under the United Nations. Unlike 4G standards, which were led by European and US firms, 5G has firms from China contributing more than 50% of the standards.

Key obstacles remain national security and commercial interests that are all connected, and it is very hard to separate them.

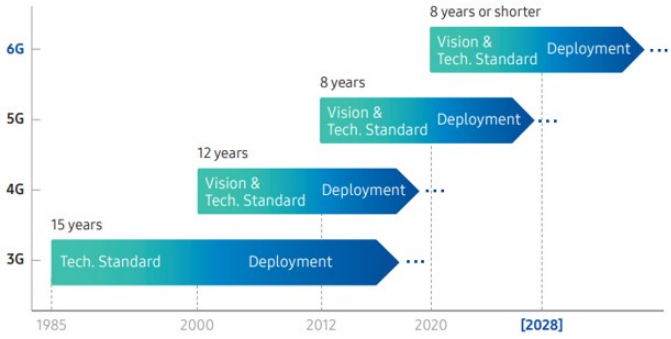
6G – the next unclaimed standard. It is still early days for 6G. There is still no definition for the technology, and the technical hurdles such as network congestion and signal transmission obstacles will need to be addressed first as they raise serious questions over health, privacy and urban design. But the race toward 6G superiority has the potential to advance telecommunications standards significantly, just like how 5G was far ahead of its predecessor. 6G could make mobile internet speeds of 1TB per second mainstream. This would mean users could download around 100 films in less than a second. The main use would be in sectors including Internet of Things, self-driving automobiles and smart factories. China launched a satellite in November to test airwaves for potential 6G transmission, and Huawei has a 6G research center in Canada, according to Canadian media reports. ZTE has also teamed up with China Unicom Hong Kong to develop the technology.

Exhibit 19:
5G Patent Race



Source: Company data, ETSI IPR and Morgan Stanley Research

Exhibit 20:
6G Timeline



Source: Samsung 6G report, Timeline of different generations.

Semiconductor New materials – Gallium Nitride/Silicon Carbide

The SiC material market is in its infancy and a new opportunity for China. As electric vehicles become more common, the use cases for newer materials are becoming more apparent. Materials like gallium nitride (GaN) and silicon carbide (SiC) in semiconductor transistors are newly applied in power electronics, and allow for higher voltages, which are required for faster switching speeds. This in turn improves the power conversion efficiency, and therefore the range of the EV. Pricing may be an issue at the beginning because these materials are more expensive than current materials but they facilitate lower overall costs due to the simplification of the surrounding circuitry. As EV brands compete to achieve longer range vehicles, demand will increase and with it will come scale and a reduction in pricing.

China has a large presence via M&A. In the global power electronics semiconductor market, Nexperia, a spin off from NXP, is Chinese-owned and controls 7-10% of the market (in terms of volume), and it accounts for more than 13% of the traditional MOSFET market. It is ranked number two globally for automotive grade MOSFETs behind Infineon. Nexperia, at the forefront of global EV power electronic semiconductors competing with TI, NXP, Infineon, ONSemi, and Rohm, should grow in China along with the domestic EV industry. Huawei also invested in Oriental Semiconductor, a MOSFET IDM, which to date has very limited market share.

China's advantage in Silicon Carbide. TankeBlue (6-inch wafers), Roshow, BYD, and Sanan are all Chinese companies seeking to build out their own capacities. Importantly, in 2018 China produced ~70% of SiC materials and has an advantage when producing its own wafers.

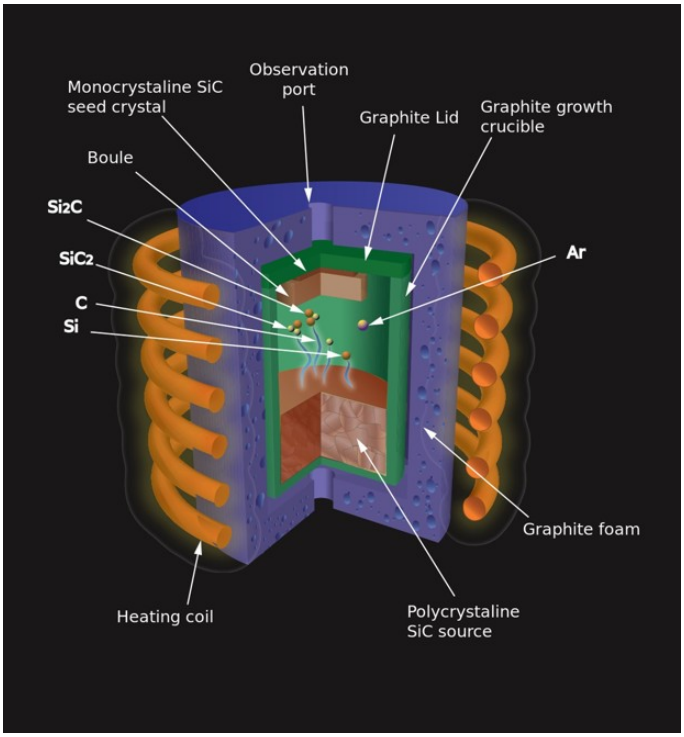
Did you know…

SiC started making headlines when Tesla chose a SiC-based drive inverter for its Model 3, proclaiming that this was key to range extension and cost reduction. A drive inverter in an electric vehicle is used to convert DC current from the battery pack into AC current for the motor, and its efficiency affects energy consumption. Compared to conventional silicon-based power semi devices, SiC has 10 times the breakdown field strength and three times the thermal conductivity, making it ideal for high-voltage applications, and specifically electric vehicles.

Gallium Nitride (GaN) is built on SiC substrates and its power-efficient qualities make it very attractive for 5G RF communication infrastructure. It can efficiently handle higher voltage in a smaller footprint and reach a much wider range of mmWave frequencies than standard silicon. SiC is also used in fast charging stations, able to handle more voltage in less time. In short, there are very attractive end markets.

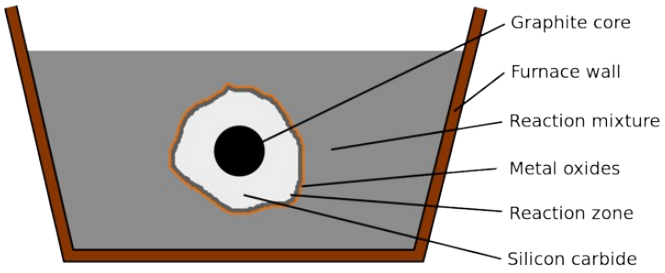
Both occur in nature; however, SiC is much more difficult to produce at scale. In power electronics and other devices that require high levels of voltage and temperature resistance, SiC provides superior performance and efficiency due to its wider bandgaps and thermal conductivity. Silicon carbide crystals are much more difficult to grow than silicon. They don't melt, they require larger seed crystals and furnace temperatures are nearly twice as high. This process usually takes two weeks to form the ingot. For those that lack the expertise, defects make it difficult to compete on costs as lower production yields eat into profit margins and profitability.

Exhibit 21:
An illustration of the deposition of SiC in the bottom and upper portions of the graphite crucible



Source: Wikipedia

Exhibit 22:
Cross-section of an Acheson furnace, showing that SiC forms along the outer edge of the graphite core



Source: Wikipedia

Semiconductors are a relatively weak area for China as the industry is dependent on access to US technology and is populated by small-scale enterprises. According to MIIT, 90 domestic Chinese companies, including Huawei, Xiaomi and SMIC, filed a joint application to establish the National Integrated Circuit Standardization Technical Committee earlier this year, with its proposed secretariat at the China Electronics Standardization Institute. The focus is on the research and formulation of the following standards:

- **Improve the relevant standards for the assessment of integrated circuit products**, including conducting research on the assessment requirements of integrated circuit bare chips and organizing the formulation of relevant standards.
- **Track the development of emerging packaging technologies**, focusing on the standardization of high-density FC-BGA packaging, wafer-level 3D rewiring packaging, through silicon via (TSV) packaging, SiP radio frequency packaging, and ultra-thin chip 3D stacked packaging technologies. And solidify the results into the assessment procedures and requirements for flip-chip bonding, chip-scale packaging (CSP), wafer-level packaging (WLP), and system-in-package (SiP).
- **Conduct research and standard formulation** in response to the performance, reliability and information security requirements of integrated circuit products in emerging applications. For example, for mobile Internet, cloud computing, Internet of Things, big data, etc., for key integrated circuits with a large amount of supporting and a wide range of applications, such as microprocessors, memories, field programmable circuits, custom circuits, system-level circuits (SoC and Related IP cores), etc., carry out corresponding standard research and formulation work.
- **Carry out parameter index system and quality assurance** element research, formulate blank detailed specifications, so as to provide a basis for the preparation of detailed specifications for integrated circuit products, and ensure that product parameter indicators can fully meet the performance requirements, reliability requirements and information security of integrated circuits in the above application fields.
- **Improve the standard system of testing methods**, as well as mechanical and environmental testing methods to ensure that the testing and testing of various parameter indicators have standards to be followed.

What are third generation semiconductors?

Compared with the 1st generation semiconductor material of silicon (Si) and the 2nd generation semiconductor material of gallium arsenide (GaAs), 3rd generation semiconductors are made of materials such as silicon carbide (SiC) and gallium nitride (GaN). They have the features of fast switching speed, small size, high efficiency, and fast heat dissipation. Therefore, they can operate at high frequency and in higher power and temperature environments, and are widely used in 5G radio frequency chips, military-grade radars and electric vehicles.

Blockchain Standardization – develop rules by which money and goods are traded

Blockchain and its distributed ledger system have the potential to be used in fields far removed from the world of finance. Everything from the management of patients and their records across the healthcare sector to anonymous online voting could be accomplished by blockchain applications in the fullness of time. But blockchain today does not have the ability to work seamlessly and interoperably worldwide to meet business critical applications. From terminology and taxonomy to the technology itself – it will be necessary to simplify the emergent landscape and ease the concerns of companies around the transition to a new way of working.

The new basic standards on financial applications for blockchain, developed by the People's Bank of China, the China Academy of Information and Communications Technology, and Huawei, were approved by the ITU (the body that regulates related systems and telecommunications globally) in September 2020. This is the first Chinese-developed international standard on blockchain for finance approved globally and serves as the basis for further specific standards that can grow China's role on the world stage of blockchain.

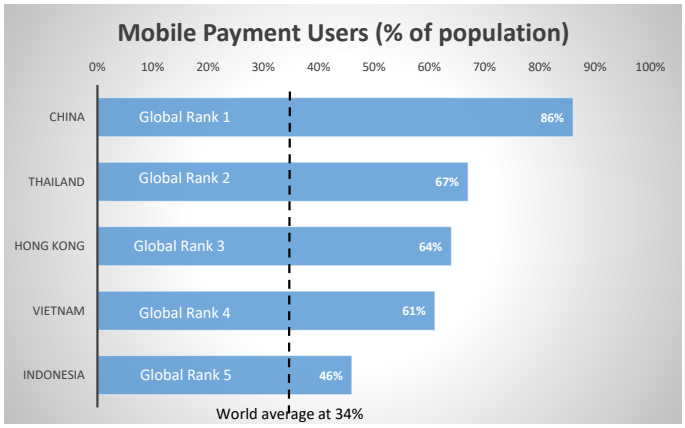
China's plans for creating its own national digital currency. In this section, we explore how a national digital currency can be used to enhance China's finance and technology sectors, as well as its economy as a whole. We also offer views on what China's timeline might be for rolling out its own digital currency, particularly in light of the economic impact of the COVID-19 pandemic.

The evolution of the e-commerce market in China and its impact on the Chinese economy is significant. We examine fundamental differences between the e-commerce markets in China and the United States, and discuss the shifting consumer landscape toward digital trends. According to McKinsey, China accounted for 42% of the global e-commerce market in 2016, surpassing US$811 billion in retail e-commerce sales. This placed China well ahead of the US, which accounted for 24% (US$462 billion) of the global market.

China has moved rapidly toward a cashless economy in recent years. This is largely thanks to the proliferation of the financing arms of Alibaba (Alipay) and Tencent (Wechat pay). Not only have consumers enjoyed convenience when making purchases, paying bills and transferring funds, small enterprises like street vendors have benefited too. China leads the world in the adoption of mobile payment technologies. According to a PricewaterhouseCoopers study, 86% of people in China used mobile payment platforms to make purchases in 2019. This was well ahead of Thailand, which had the second highest percentage of mobile payment users (67%) and more than double the global average (34%).

Exhibit 23:

Comparison of mobile payment users



Source: PricewaterhouseCoopers, Morgan Stanley Research

However these two platforms are not within the control of the central bank. The People's Bank of China (PBOC) Governor Yi Gang has made clear that these large companies pose "challenges and financial risks" therefore, China's Central Bank Digital Currency (CBDC) is expected to be one tool with which Chinese authorities check the dominance of the technology companies that operate mobile payment platforms.

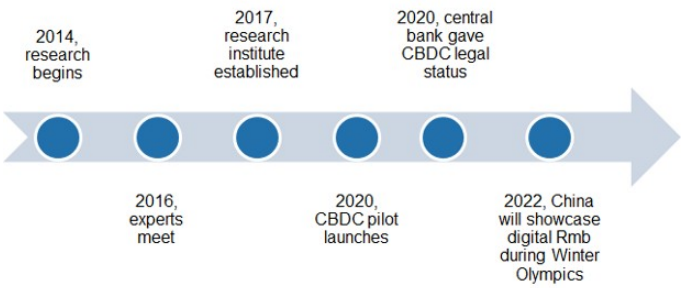
China is leapfrogging other countries with its CBDC rollout. Although China has not yet launched the digital rmb nationally, it is far ahead of other major countries in rolling out a CBDC on the back of Chinese consumers' familiarity with digital payment platforms, as well as the country's strategic planning at the national level. Exhibit 24 shows the timeline regarding China's CBDC roll-out.

China will benefit from currency digitalization, economically, socially and politically. First, CBDC will eventually replace a significant portion of the physical money in circulation. Doing so would reduce the costs of securing and maintaining physical cash supplies, which could free up 0.5% of China's GDP. That said, there will be new costs associated with establishing and securing the digital infrastructure that allows the CBDC to function. Secondly, a digital renminbi would also enhance the government's capacity to monitor and control economic activity and combat illicit activity, though it poses concerns about privacy. Thirdly, the CBDC will also allow policymakers to set more nimble and tailored monetary policies. For instance, the government could issue stimulus money to be used only for necessities like housing and food. Meanwhile, it will also pose risks of disruption to commercial banks and the financial ecosystem. (for details: Digital Disruption: The Inevitable Rise of CBDC, 12th April, 2020)

CBDC will help with the internationalization of the rmb but China's currency is unlikely to challenge the USD's role in global payments. We think the CBDC will facilitate the rmb internalization trend. For instance, China could provide financial aid to other countries in the form of the digital rmb. It could also push to incorporate the CBDC into cross-border payments related to Belt and Road Initiative projects, and in bilateral trade. However, many of the fundamental concerns about the rmb have still not been addressed in the CBDC, namely strict controls on capital flows across its borders and a tight hold over the exchange rate. Therefore, the CBDC is unlikely to challenge the USD's dominant role in international payments. The rmb was only used in about 2.2% of all international payments in Feb 2021, vs the USD at 38% and the EUR at 37%, according to SWIFT, the world's largest international electronic payment system.

As for cryptocurrencies, China has placed tight restrictions on their use for two reasons: de-centralized system and speculative nature. Crypotocurrencies rely on distributed ledger technology (namely blockchain), which allows users to make peer-to-peer transactions without going through a bank or other third party. Also, the value of Bitcoin and many other cryptocurrencies is set not by a central authority but by markets, which has made them appealing as speculative assets but led to very high price volatility.

Exhibit 24:
China Central Bank Digital Currency Roll-out Timeline



Source: Morgan Stanley Research

Exhibit 25:
Comparison of major digital currencies

	Digital Renminbi	Libra	Bitcoin
Type	Central bank digital currency	Stablecoin	Cryptocurrency
Issuer	People's Bank of China	Facebook/Libra Association	Decentralized network
Status	Pilot launched in April 2020	In development	In use since 2009
Primary Usage	Consumer purchases	Consumer purchases	Speculation
Value Determination	Identical to renminbi	Pegged to multiple currencies	Market
Blockchain Used	Limited usage*	Centralized	Decentralized network

*The extent to which the digital renminbi will rely on blockchain remains unclear

Source: China Power, Morgan Stanley Research

Autonomy – Self-Driving Already Into the Fast Lane

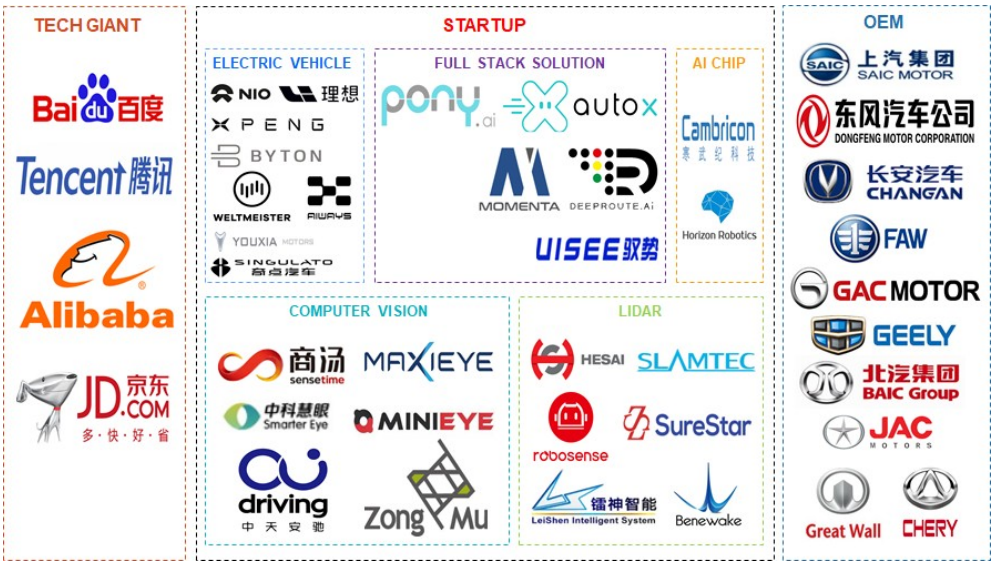
In transport, autonomous vehicles will completely reshape our infrastructure and urban planning as we know it and China unveiled a blueprint in February this year to develop its own standards for autonomous vehicles by 2025, covering technological innovation, ecosystems, infrastructure, legislation, supervision and network safety – all aimed at providing an ecosystem for intelligent vehicles to develop in China. China's Ministry of Industry and Information Technology is coordinating efforts in developing standards mainly for advanced driving assist systems, autonomous driving, information safety and connectivity, and conducting pilot programs involving some carmakers and vehicles to evaluate the results. The objective is to further improve smart vehicle standards and pave the way for the formulation of standards for high-level autonomous driving. By 2025 the goal is to have conditional autonomous vehicles (i.e. L3) in large scale production and high-level autonomous vehicles (i.e., L4 or above) commercialized for specific environments; smart cities will have intelligent transportation systems; and 5G should be blanketing cities and highways. The blueprint targets to build a complete set of standards for autonomous vehicles between 2035 and 2050. The goal is for the China standard intelligent vehicle system to have been fully completed with the country becoming an intelligent vehicle powerhouse.

Large amounts of available capital from the private sector and active involvement of the government help to shape the competitive landscape for autonomous vehicles in China. At the same time, the industry is integrating itself with global ecosystems to avoid differences with the rest of the world and participating in the global arena on standards making. High-level technology requirements from Chinese companies are fundamentally similar and transferable across markets and regions. The computing platform and system integration is where China lags on capability but the country is faring well in other areas of autonomy and as with any new technology, efforts to standardize as many elements of self-driving technology as possible could be of great benefit. For example, chips to process what car sensors are detecting are being made by start-ups like Horizon Robotics (partner with Audi for its Journey 2 automotive AI processor) and Black Sesame (with some key R&D personnel previously employed by Huawei). However, EV company Nio is using Nvidia's Orin SOC in its automotive processing.

China has strategic advantages in the development of intelligent vehicles – including the mass market, new technologies and ecosystem, 5G, networks, infrastructure, Beidou satellite system (China version of GPS) and future smart city developments. However, it is not just China business that confers an advantage but also Chinese consumers and their willingness to adopt autonomous technology. China aims to make breakthroughs in key fundamental technologies such as complex system architecture, environment perception, intelligent decision control, human-computer interaction and human-computer co-driving, vehicle-road interaction and cybersecurity, high-precision spatiotemporal benchmark services and basic maps for intelligent vehicles.

Exhibit 26:

Autonomous Driving Ecosystem in China is Advanced



Source: Company data, Morgan Stanley Research

We anticipate that robotaxis will be the most important business mode for autonomous driving in the passenger vehicle market. China has drafted new laws which would allow the testing of autonomous vehicles on highways for the first time, bringing it in line with countries such as the UK, US, and Germany, which already allow self-driving cars to be tested on public roads. In a draft rule on the ministry's website, the ministry requires autonomous vehicles for testing to obtain certain approvals and operate in designated areas. Companies should also record the data gathered from the vehicles and a person should be seated on the driver's seat.

How does China stack up against the US? The California Department of Motor Vehicles (DMV) publishes data on companies with permits to do autonomous driving testing in California. As most of the top Chinese autonomous vehicle companies also participate in this testing scheme, these data may offer some indication of the progress by different companies. A 'disengagement' happens when the human safety driver intervenes. In simple terms, companies with higher miles per disengagement and higher total testing mileage should have a more reliable system. Baidu, AutoX, and Pony.ai are among the top five in terms of miles per disengagement. One thing to note is that Waymo which was ranked second has over 13 times more testing mileage than Baidu, while AutoX also has limited testing mileage at 32,054 miles. According to DMV, as of February 26, 2020, a total of 64 companies have California autonomous driving test licenses, including full solution providers, component suppliers, technology companies, and autonomous driving startups, etc. Among them, five companies are allowed to use autonomous vehicles to transport passengers, namely Aurora, AutoX, Pony.ai, Waymo, and Zoox, two of which are Chinese companies. Waymo is the only company with a driverless road test license (no safety driver required).

Exhibit 27:

2020 Total Autonomous Mileage in California

Company	2020 total autonomous mileage in California	Disengagement	Miles per disengagement
Cruise	770,049	27	28,520
Waymo	628,839	21	29,945
Pony.ai*	225,496	21	10,738
Zoox	102,521	63	1,627
Nuro	55,370	11	5,034
AutoX*	40,734	2	20,367

Source: The California Department of Motor Vehicles, Morgan Stanley Research. *Headquartered in China in 2020.

A number of leading Chinese players are focused on bringing autonomous vehicles to the consumer passenger market, while specialists are targeting operations for service and logistics companies.

- **Baidu Apollo.** Chinese search engine giant Baidu began developing self-driving technologies under a special business unit in 2013. By the end of 2019, Baidu Apollo had filed more than 1,800 patents for autonomous driving technologies in China and overseas, ranking it No 1 in China. It has been granted 120 Chinese government-issued licenses to test autonomous cars, racking up a total of 3mn km of road tests. Baidu's Apollo robotaxi service was launched in Changsha, Hunan province, in September 2019, with an initial fleet of 45 autonomous cars. In April Apollo made the robotaxi service accessible via its regular search and navigation apps in addition to a standalone ride-hailing app.
- **Pony.ai.** Toyota-backed Poni.ai currently has a fleet of 50 autonomous cars – including robotaxis and testing cars – operating in a 200-square km designated area in Guangzhou. The company, co-founded in 2016 by James Peng and Lou Tiancheng – former Silicon Valley-based engineers for Google's autonomous driving unit and Baidu – has been running the robotaxi fleet in Guangzhou since December 2018.
- **AutoX.** Hong Kong-based start-up AutoX recently won a permit from the California Department of Motor Vehicles to start testing fully driverless cars in designated areas in San Jose, California – the first Chinese company to receive such approval. AutoX holds open road testing licenses in four US states (including California) and in major Chinese cities including Shanghai, Shenzhen, and Guangzhou. It was also granted approval to operate robotaxis in a geofenced area in Wuhan. Founded in 2016 by Xiao Jianxiong, a former assistant professor at Princeton University, AutoX counts Alibaba Group, MediaTek, Chinese carmaker Shanghai Auto and Dongfeng Motor among its backers.

The automation of processes and procedures with cutting-edge technologies, such as self-driving, advanced robotics and AI has the potential to fundamentally change the global economy. From manufacturing to customer service, automation will transform overall economic productivity, but its emergence will have a seismic impact on the global labor force. As China looks to sustain economic growth, harnessing automation will be crucial to its long-term economic competitiveness. China's dwindling labor force is driving up the cost of doing business. Productivity, which measures economic output per hour worked, remains relatively low in China but automation is part of the solution.

Appendix 1: How Are Standards Created?

Technology standards are integral to modern life. Information and communication technology (ICT), particularly its ability to communicate with other devices, is reliant upon widely adopted and accepted standards. Amid numerous international standards institutions, two private regulatory networks – the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) – have produced around 85% of all known international standards, and they are the leading bodies for standards-setting in digital technologies The International Telecommunication Union (ITU), a treaty-based organization with member states, is influential in the developing world. Standards development also occurs through industry associations and consortia, which aim to develop identity authentication standards through non-password methods like facial recognition.

Standards serve as the unseen foundation for and international language of commerce. When applied and used well, standards and conformance provide the basis for interoperability of technologies, support innovation, and increase consumer trust and confidence; when misapplied, they can disrupt trade and create market barriers. When a country's standards and conformance differ too greatly from international best practices, foreign and domestic companies alike face greater barriers to accessing international markets.

Standards have been created by private companies who are industry leaders as well as by international industry associations. They are enforced either as a convention – a "best practice" – or as formal agreements, depending on the industry and product. We have seen some markets become increasingly shaped and defined by dominant US technology firms. Inevitably, company size equates to influence and although some standards are set through voluntary consensus and committee deliberations, others are determined by market competitiveness.

There are two ways to set global technology standards:

- **The first is a market access approach**, which broadly aligns with the goals of leading multinational corporations. Major influential producers who monopolize key technologies and consistently innovate tend to establish their own global standards and propagate these worldwide. For example, Intel's x86 processing technology, Huawei with its highly competitive 5G communication technologies and Microsoft's Windows software, which is used by most computers in the world.
- **The second is a conventional rule-based institutional approach** established by international organizations such as the ISO, its electronics counterpart – the IEC (International Electrotechnical Commission) whose product standards affect market access and the value of intellectual property rights, or the International Accounting Standards Board (IASB), whose financial reporting standards determine financing options and business practices.

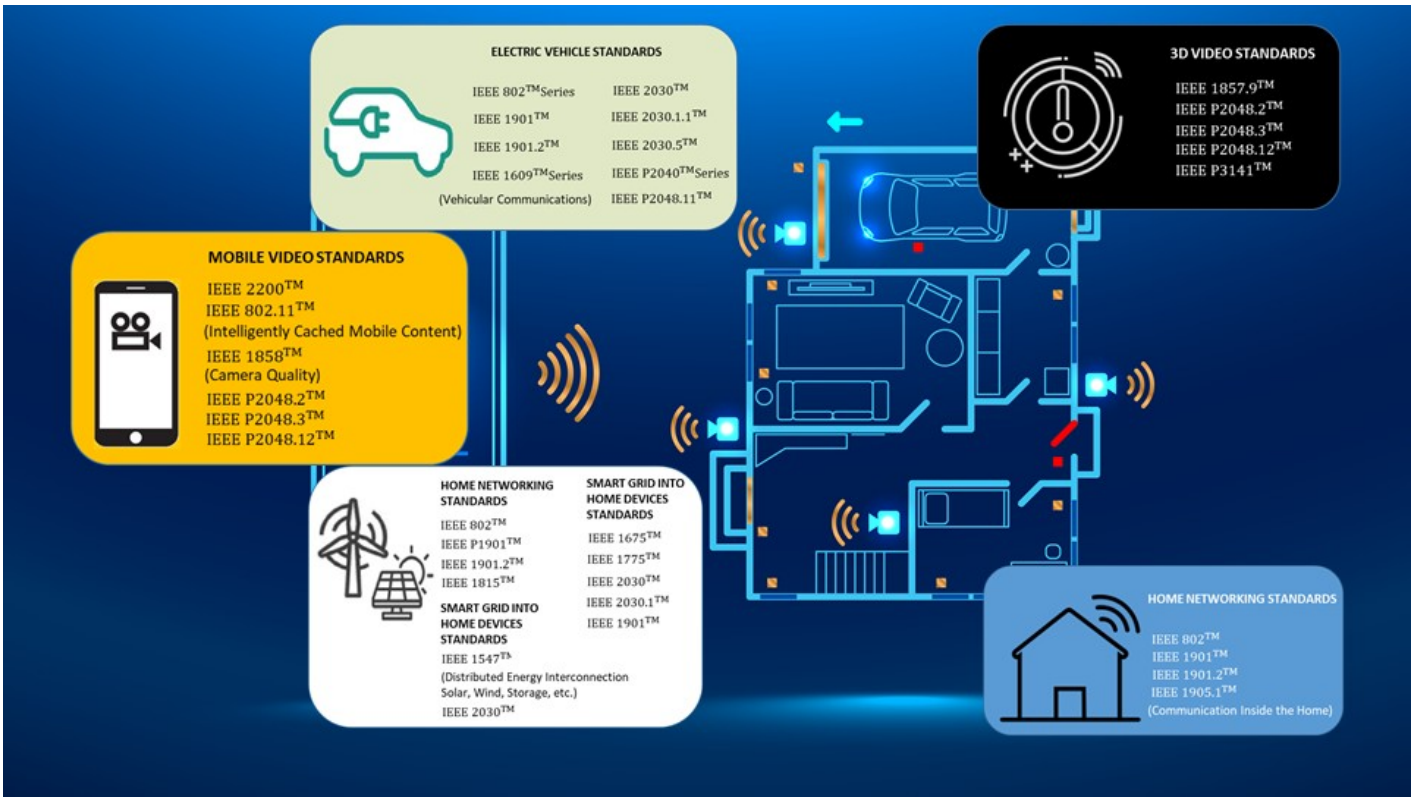
As an example, the bar code or QR (quick response) code today, which represents a global language of everything, is an amazing standard, humble but sensational thinking as it cuts human error, saves time and makes it easy for consumers to take action after scanning the codes with their phones.

How are standards created?

Nearly every aspect of our lives, work, and play relies on hundreds of technology standards. From the connection to a Wi-Fi network, Bluetooth earbuds, to a smartphone or tablet, these are all possible thanks to technology standards such as IEEE 802, which provides a framework that enables devices from different manufacturers to communicate with one another. Standards provide highly detailed information such as how devices identify one another, how data flows between them, and how those communications are kept secure.

Exhibit 28:

IEEE Standards Used in Everyday Life



Source: IEEE, Morgan Stanley Research

The IEEE Standards Association (SA) is a global standards development organization (SDO) that creates, publishes, updates, and maintains standards. The IEEE provides hardware manufacturers, software developers, service providers, and other businesses with the time-tested platforms, rules, governance, methodologies, and facilitation services they need to transform a concept into an industry standard.

The standards development process includes boards, committees, and professional staff who establish and maintain the policies, procedures, and guidelines that help ensure the integrity of the standards development process. Once a new standard is finalized, there are also frameworks for distributing it and continually updating it to meet evolving marketplace conditions and opportunities.

Exhibit 29:

IEEE Standards Making Process

Source: IEEE, Morgan Stanley Research

Agreeing on common standards is a simple coordination process. Standards are primarily a function of science and technical considerations as opposed to a function of the distribution of power between national, regional or non-state parties. Technical consensus is easy to achieve as scientific and technical knowledge is universal and uncontested. They are built on rational progress, universal and egalitarian. The principles of governance are typically based on equality and fairness. As such, the technological considerations trump state power and competition between nations or regions does not shape product standards. Technology standards are agreed-upon technology platforms for interconnection, operation, or function on which other applications, improvements, and innovations can be made. Like patents, the formal documentation for a standard consists of hundreds of pages of technical specifications defining terminology, outlining protocols and specifying the technologies necessary to make the protocols function.

Dominant voice in international standardization. As standards are globally adopted and applied in many markets, they also fuel international trade.

A highly participatory activity underpins standardization, as it involves not simply the standard makers but also the standard users and third parties. Standardization as a mode of regulation and coordination that may be comparatively flexible and open to change, but also requires constant work from a diverse group of actors to maintain the legitimacy of the standard in a highly dynamic environment.

In terms of the competitive advantages for particular companies, on some level the best technology usually wins out and the de facto standard in the market often becomes the codified standard in the international body. Regarding the regulatory effects of standards, observers note that since some standards organizations like the ISO are heavily dependent on industry stakeholders, the process often results in “modest, least-common-denominator” standards.

A bit of history

Before the 1980s, standard setting for firms was decided at the national level with little regard for others. International standards were few and very basic such as the thickness of credit cards, the dimensions of containers, just to name a few. ISO/IEC are responsible for the largest number of international standards covering a wide range of economic sectors and came to prominence when globalization took off. These are voluntary standards but adopted by many countries as part of their notional regulatory framework in addressing health, safety and the environment.

Standards present precise descriptions and terminology, and offer an objective and authoritative basis for organizations and consumers around the world to communicate and conduct business.

Product standards are technical specifications of design and performance characteristics on manufactured goods. The majority of standards start from the private sector and act as a global network consisting of numerous technical committees and experts representing industries. The institutional backbone of these networks is formed by the private sector at the national level, which eventually becomes part of the international institutional structure.

Significant economic and technical expertise are prerequisites in leading international standards. For example, when Microsoft set a de-facto standard for its software, others were faced with the choice of joining or challenging Microsoft in the marketplace with a superior standard.

Standards accelerate innovation. Open standards free the need for the development of internal systems and allow companies to devote resources to drive innovation. Standards are not about the technology – let the technology and computers do the repetitive work – but it is how one brings that project to life, how they solve problems, bring the craftsman, all actors, contractors together into the job – those are what matter most.

3G, 4G and 5G standards – breaking dominance

QCOM once monopolized global phones standards through its comm chips standards. It began to rule 3G and dominated 4G. Its 4G leadership has created millions of jobs and changed the course of the wireless industry's economic impact. In earlier mobile generations – 2G and 3G – European countries led the world in wireless and reaped the economic benefits that leadership entailed. But these countries did not maintain their wireless leadership as mobile generations evolved, and jobs were lost and economic momentum stalled. This demonstrates that the performance of a country in one generation is not a guarantee of success in the next generation. But Huawei broke that monopoly with 5G. It makes not only the products and the technology, but also the standards. Huawei's smartphone is the product; AI chips are the technology and Huawei's Polar Code is the 5G standard proposed by the company (Huawei is currently operating and planning its own AI standard).

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Equal-weight/Hold	1418	41%	373	42%	26%	649	42%
Not-Rated/Hold	4	0%	2	0%	50%	4	0%
Underweight/Sell	529	15%	95	11%	18%	210	14%
Total	3,468		883			1533	

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INDUSTRY COVERAGE: S. Korea Technology

COMPANY (TICKER)	RATING (AS OF)	PRICE* (05/06/2021)
Ryan Kim		
Advanced Process Systems Corp (265520.KQ)	O (04/09/2020)	W28,450
Duk San Neolux Co Ltd (213420.KQ)	O (04/09/2020)	W42,200
Ecopro Co Ltd (086520.KQ)	E (02/21/2019)	W74,800
Iljin Materials (020150.KS)	O (02/21/2019)	W67,700
L&F Co Ltd (066970.KQ)	O (12/17/2020)	W87,200
Posco Chemical Co Ltd. (003670.KS)	U (04/27/2021)	W149,500
Wonik IPS Co Ltd (240810.KQ)	O (09/07/2020)	W50,800
Shawn Kim		

LG Display (034220.KS)	E (03/19/2020)	W24,150
LG Electronics (066570.KS)	E (11/04/2020)	W151,500
LG Innotek (011070.KS)	U (01/22/2021)	W195,500
Samsung Electro-Mechanics (009150.KS)	O (10/06/2019)	W177,000
Samsung Electronics (005935.KS)	O (11/18/2019)	W74,500
Samsung Electronics (005930.KS)	O (11/18/2019)	W82,300
Samsung SDI (006400.KS)	E (01/22/2021)	W642,000
Samsung SDS (018260.KS)	E (06/23/2017)	W180,000
Seoul Semiconductor (046890.KQ)	U (04/04/2018)	W20,100
SK Hynix (000660.KS)	O (11/18/2019)	W129,000

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* Historical prices are not split adjusted.

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