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The future of Asia

How Asia can boost growth through technological leapfrogging

Discussion paper
December 2020

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In brief

How Asia can boost growth through technological leapfrogging

Asia's initial response to the COVID-19 pandemic in 2020 was enabled by the technological foundation the region had developed long before the crisis. Asia has been building its technological capabilities and infrastructure at a rapid pace over the past decade, transforming economies and markets. There is more to come, given the potential to leapfrog in the region's technological development based on the scale of markets and investment and the speed of technology adoption, as well as through intellectual property creation. However, gaps in core capabilities still need to be addressed and the risk of disruption to technology flows needs to be monitored. The research focuses on Asian economies, describing growth in major technological indicators, exploring characteristics of growth in technological capabilities, and homing in on four major sector opportunities.

Asia has undergone a significant technology transformation over the past decade. Asia has rapidly enhanced its technological capabilities over the past ten years, although challenges remain. During that time, the region accounted for a large share of global growth in technology company revenue (52 percent), startup funding (43 percent), spending on research and development (51 percent), and number of patents filed (87 percent). Asia's highly adaptable digital consumers, who now account for half of global internet users, enabled this technology transformation. Asia is diverse with different gaps and challenges, but also complementary strengths. Advanced Asian economies and China have developed large technology companies and innovation capacity. However, Advanced Asia has relatively few unicorns, and China still relies on foreign imports for core technologies. It imports six times more intellectual property (IP) than it exports. The rest of Asia lags behind on the presence of technology firms, R&D innovation, and IP creation; nevertheless, markets and investment are growing rapidly.

Our assessment of emerging technologies suggests that Asia has varying degrees of development in terms of intellectual property (IP) creation and startup investment. Of 33 technologies analyzed, Asia has a strong presence in startup investment in 11 technologies and another ten in terms of IP creation. Asia has a solid position in four technologies on both dimensions, which are mobile services (including 5G), artificial intelligence and machine learning, manufacturing, and the Internet of Things. Asia accounts for 40 percent of global investment in startups and represented 38 percent of strong patents applied (with a strength index above 50) filed between 2016 and 2018. City-level analysis suggests that China and India are home to more than two-thirds of Asia's urban technology hot spots.

Potential disruptions to technology-related flows could impede the rate of innovation. Tariff and data flow barriers, standards, export controls and research barriers pose new risks.

Asia can capture four types of technological leapfrogging opportunities, if current challenges are tackled. First, accelerated digitization creates huge opportunities throughout the value chain. Asia's large-scale consumer demand and its widespread gaps in provision in consumer markets are enabling the region to leapfrog in consumer digital solutions. Second, Asia can turn manufacturing strengths into technology advances. Although the region still has some gaps in established core technologies such as semiconductors design, it could build on its robust manufacturing value chains to establish strong positions in new technologies such as mobile application processors, advanced displays, and next-generation electric vehicle batteries. Third, Asia's strong talent endowment can boost business technology services at a time when demand for digital services is soaring. Asia's share of global IT service revenue has increased over the past decade from 25 percent to 29 percent and that share could rise further due to the region's ample pool of talent. The region will need to continuously improve the quality of talent and enhance organizational agility to capture the growing global demand. Finally, energy sectors, notably renewables, are growing strongly because of active policy support. Installed renewable energy capacity increased at a compound annual growth rate of 12 percent between 2010 and 2019, double the rate in other parts of the world. Companies in the region can consider bold capital allocation to diversify portfolios and deploy technologies to remove carbon from the value chain.

Speed, collaboration, and resilience will be the key arbiters of corporate technological success. Innovation appears to have accelerated during the COVID-19 disruption, and companies need to ensure that they keep pace. They are more likely to be able to weather complex conditions if they work in partnership and within their ecosystems. Finally, in response to growing global risks, building resilience into supply chains and achieving scale through regional collaboration may be even greater priorities.

1. Asia has undergone a significant technological transformation

The battle to flatten the curve of COVID-19 infection caused by the novel coronavirus SARS-CoV-2 in 2020 has been—and continued to be at the time of writing this discussion paper in October 2020—a mammoth society-wide task across the globe. In Asia, prowess particularly in digital and mobile technologies played a major role in the region's early response to the virus. Those technology-enabled responses were rooted in capabilities developed prior to the pandemic.[1] The region had been developing and deepening its digital infrastructure for some time, its people have rapidly adapted to new technology solutions, and Asian firms are now among the largest technology companies in the world. Asia has undergone a significant technological transformation, which in turn has changed the region's technology marketplace.

This paper is part of a series focused on the future of Asia.[2] The aim of the research was to understand the region's technological development and opportunities for further technological progress that could help Asia maintain its growth momentum. Specifically, we look at Asia's rapid growth in major technology indicators, explore the characteristics of its growth and of particular technology hot spots, and investigate leapfrogging opportunities in different sectors, homing in on four specific opportunities. These include accelerated digitization, notably in consumer markets; turning manufacturing strength into technology advances; using Asia's strong endowment of talent to forge ahead in business technology services; and building on strength in renewable energy and strong policy support to play a key role in the global energy transition.[3]

Asia accounts for the largest regional share of growth in global technological capabilities over the past decade

Asia's global significance is reflected in key economic and demographic metrics. In 2019, the region was home to 47 percent of the world's population, a share that is expected to drop to 44 percent by 2040. In 2019, 42 percent of the world's middle-income earners were in Asia, more than in any other region, and that share is expected to rise to 54 percent by 2035. Almost half of the world's city dwellers, about 2.0 billion of 4.1 billion, lived in Asia in 2019. Asia accounted for 43 percent of global GDP in purchasing power parity terms, the highest of any region. In comparison, Europe's share was 22 percent, and North America's 18 percent. By 2040, Asia's share of global GDP is expected to increase to 52 percent. Asia accounted for 29 percent of real consumption spending in 2019, second to North America at 32 percent, and by 2040, the region's share is expected to grow to 39 percent, overtaking North America, at 28 percent, as the most significant driver of consumption worldwide.[4]

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1 Oliver Tonby, Jonathan Woetzel, Noshir Kaka, Wonsik Choi, Jeongmin Seong, Brant Carson, and Lily Ma, *How technology is safeguarding health and livelihoods in Asia,* McKinsey & Company, May 12, 2020.

2 We use the definition of Asia and four groups of Asian economies (the Four Asias) used throughout our series on the Future of Asia. See *The future of Asia: Asia's flows and networks are defining the next phase of globalization*, McKinsey Global Institute, September. We follow the approach of the United Nations (UN) that includes 83 countries in the Asia and Oceania region, but we have made some exceptions. For instance, we omit Iran and countries in the UN's Western Asia grouping that includes Saudi Arabia and the rest of the Middle East; this is because these economies are dissimilar to those of the rest of Asia and do not have strong economic ties with those economies. While we include Oceania in our analysis, available data are limited for many countries. We note that groupings and maps used in this paper are for illustration only.

3 *The future of Asia: Asia's flows and networks are defining the next phase of globalization*, McKinsey Global Institute, September 2019; and *The future of Asia: Decoding the value and performance of corporate Asia*, McKinsey Global Institute, May 2020.

4 Data on middle-income, urban, and total populations from Oxford Economics. Middle income is defined as $20,000 to $70,000 at constant 2015 prices; GDP and consumption data from the McKinsey Global Growth Model.

Asia has developed and deepened its technological capabilities and infrastructure rapidly over the past decade, accounting for the largest share of global growth in many technology metrics (Exhibit 1). We look in a little more detail at three aspects of Asia's technological development: (1) the presence of strong technology companies; (2) Asia's considerable investment in R&D and startups; and (3) the region's significant creation of knowledge as measured by IP and publications.

Corporate presence: Asia has built a strong base of technology companies

The confluence of several factors, including a rising number of middle-class citizens across the region, higher levels of education, and a startup culture taking root, means that Asia's technology companies have become increasingly active. As some Asian economies diversified to become knowledge- and innovation-focused, the regional share of global technology company revenue increased from 41 percent in 2006–08 to 45 percent in 2016–18, accounting for 52 percent of global growth.[5] In 2020, Asia was home to four of the world's top ten technology companies based on market capitalization; only ten years earlier, the region had no representatives in the top ten (Exhibit 2).

The number of unicorns (privately held startups—usually technology-based—valued at $1 billion or more) has grown as an increasing number of consumers became connected to the mobile internet, catalyzing growth in unicorns in financial technology (fintech), telecommunications, artificial intelligence (AI), and e-commerce. In 2012, Asia had only two unicorns.[6] Today, the region has 170 unicorns, accounting for 36 percent of the world's unicorns. Asia had particularly high growth in the number of unicorns between 2016 and 2018, accounting for 46 percent of new unicorns during this period. By July 2020, the region was home to 50 percent of the world's telecommunications unicorns, 53 percent of the total in transportation, 51 percent in e-commerce, 75 percent in Edtech, and 64 percent in travel. In the case of AI, the United States has the highest share of the world's unicorns at 48 percent, but Asia is not far behind with 39 percent.

Investment: Asia captures an increasingly large share of early-stage and R&D investment

Hot on the heels of economic development in large Asian economies like India and a burgeoning middle class in the rest of the region, there has been a gold rush of venture capital, especially from advanced Western economies, into Asia. Asia's share of startup investment, which includes venture capital investment and initial public offerings, increased from only 16 percent in 2006–08 to 40 percent in 2017–19, accounting for 43 percent of global growth. Although China accounts for a large share of investment, over the past decade venture capital has increasingly flowed to Southeast Asia, too.[7] Southeast Asia has become a target market for Chinese technology giants that have moved into the payments, gaming, cloud computing, and e-commerce sectors, investing heavily.[8] Investment in R&D has also surged. Asia's share of global R&D investment increased from 26 percent in 2006–08 to 34 percent in 2016–18, accounting for 51 percent of global growth.

IP creation: Asia surges ahead in patent filings

As an indication of the region's commitment to knowledge and innovation, Asia captured 87 percent of global growth in patent filings over the past decade; in the period from 2016 to 2018, China alone accounted for 45 percent of the world's patents. The surge can be attributed to the region's growing concentration of high-technology companies in, for instance, the consumer electronics, batteries, renewable energy, and automotive industries. China's overall filings increased 200-fold over the past 20 years.[9] The government has supported this growth by subsidizing patent filings.[10]

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5 Includes 3,122 technology companies with more than $1 million annual revenue between 2016 and 2018 from the McKinsey Corporate Performance Analytics database.

6 *The global unicorn club*, CB Insights, July 1, 2020.

7 Felicia Tjiasaka, *Indonesia – The Komodo – Time to monetise*, CLSA, December 16, 2019.

8 Clay Chandler and Eamon Barrett, "Alibaba v. Tencent: Taking the Fight to Southeast Asia," *Fortune*, June 12, 2018.

9 *China becomes top filer of international patents in 2019 amid robust growth for WIPO's IP services, treaties, and finances,* World Intellectual Property Organization press release, April 7, 2020.

10 Josh Ye, "Chinese government subsidies fuel surge in patents but experts warn it's quantity over quality," *South China Morning Post*, April 15, 2020.

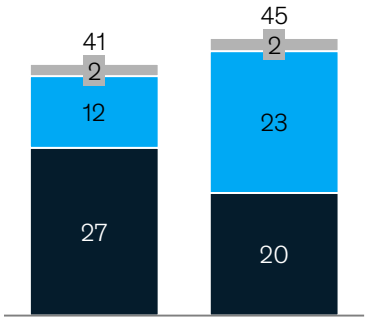
Exhibit 1

Asia has accounted for a large regional share of global growth in key technology metrics over the past decade.

Asia's share of global total, 3-year average, %[1]

Corporate presence

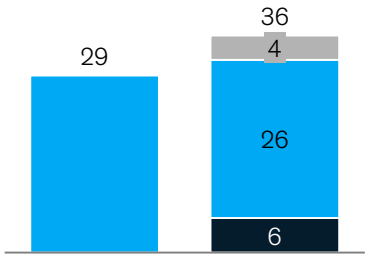
Technology-company revenue



Asia's share of global growth, %

52

Number of unicorns

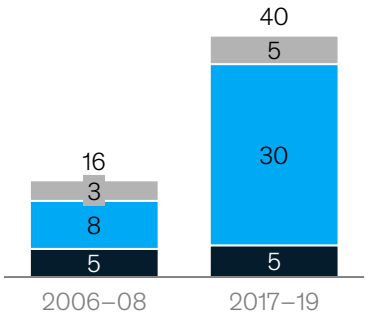


Asia's share of global growth, %

36

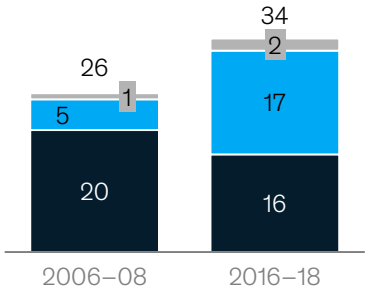
Investment

Startup investment (VC and IPO)



43

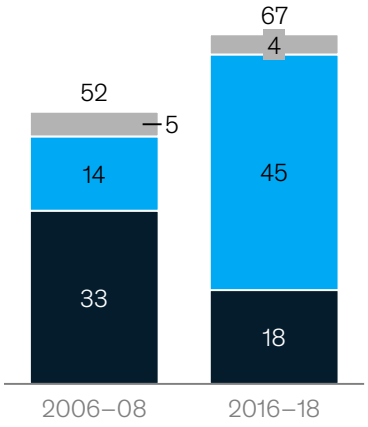
R&D expenditure



51

IP and publications

Number of patents



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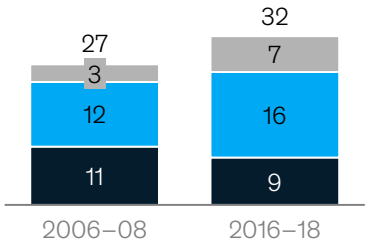
Science and engineering articles



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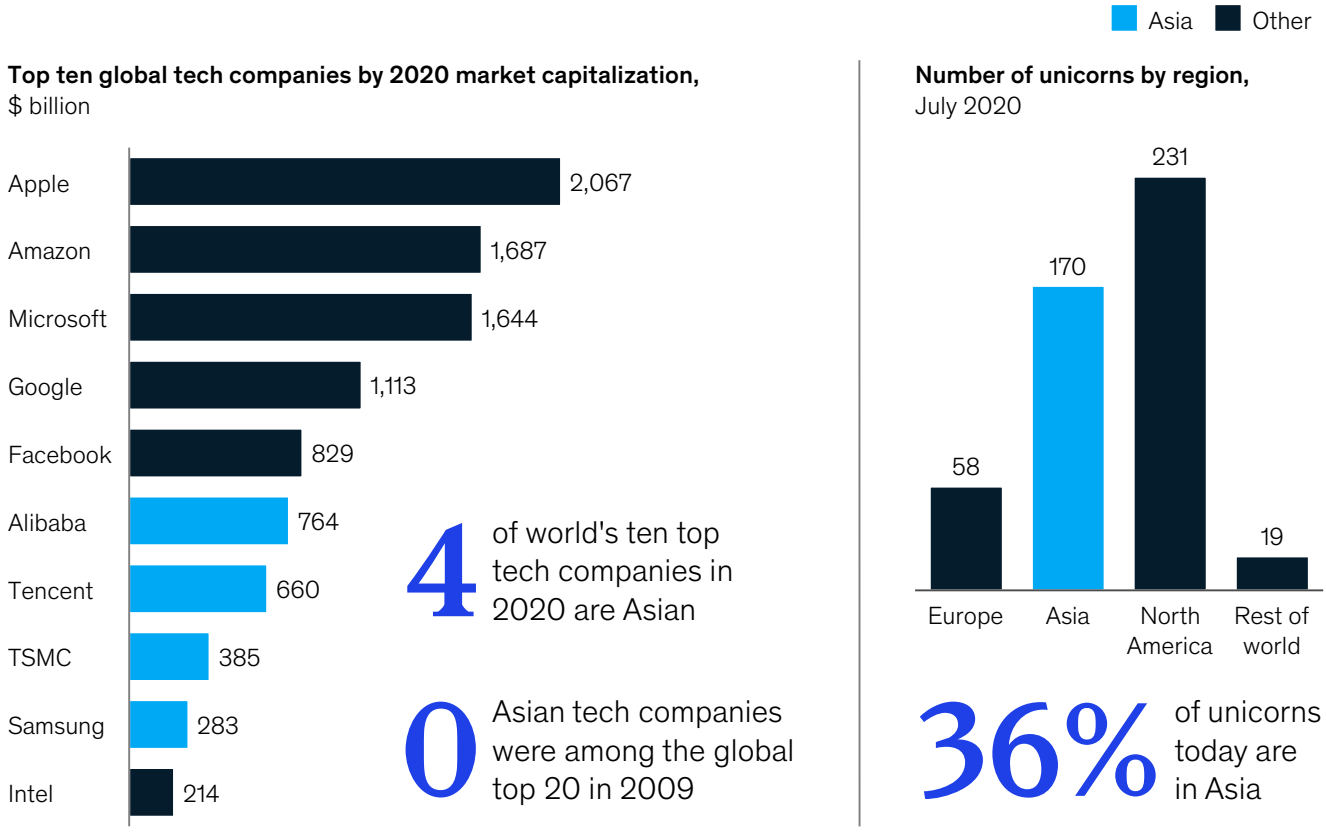
1. For technology-company revenue, data come from the McKinsey Corporate Performance Analytics database; includes 3,122 technology companies with more than $1 million annual revenue between 2016 and 2018. For the number of unicorns, data are from July 2020 and come from CB Insights. Data on startup investment come from PitchBook. Data on R&D expenditure are from the World Bank and include numbers on 91 economies where data is available for both 2006–08 and 2016–18. Data on patents come from WIPO. Data on articles come from the National Science Board.
2. Advanced Asia includes Australia, Japan, New Zealand, Singapore, and South Korea.

Note: Figures may not sum to 100% because of rounding.

Source: McKinsey Global Institute analysis

Exhibit 2

Asia is building a strong position in technology.



Source: Bloomberg; CB Insights; McKinsey Global Institute analysis

Asia's digitally adaptable populations are embracing technology

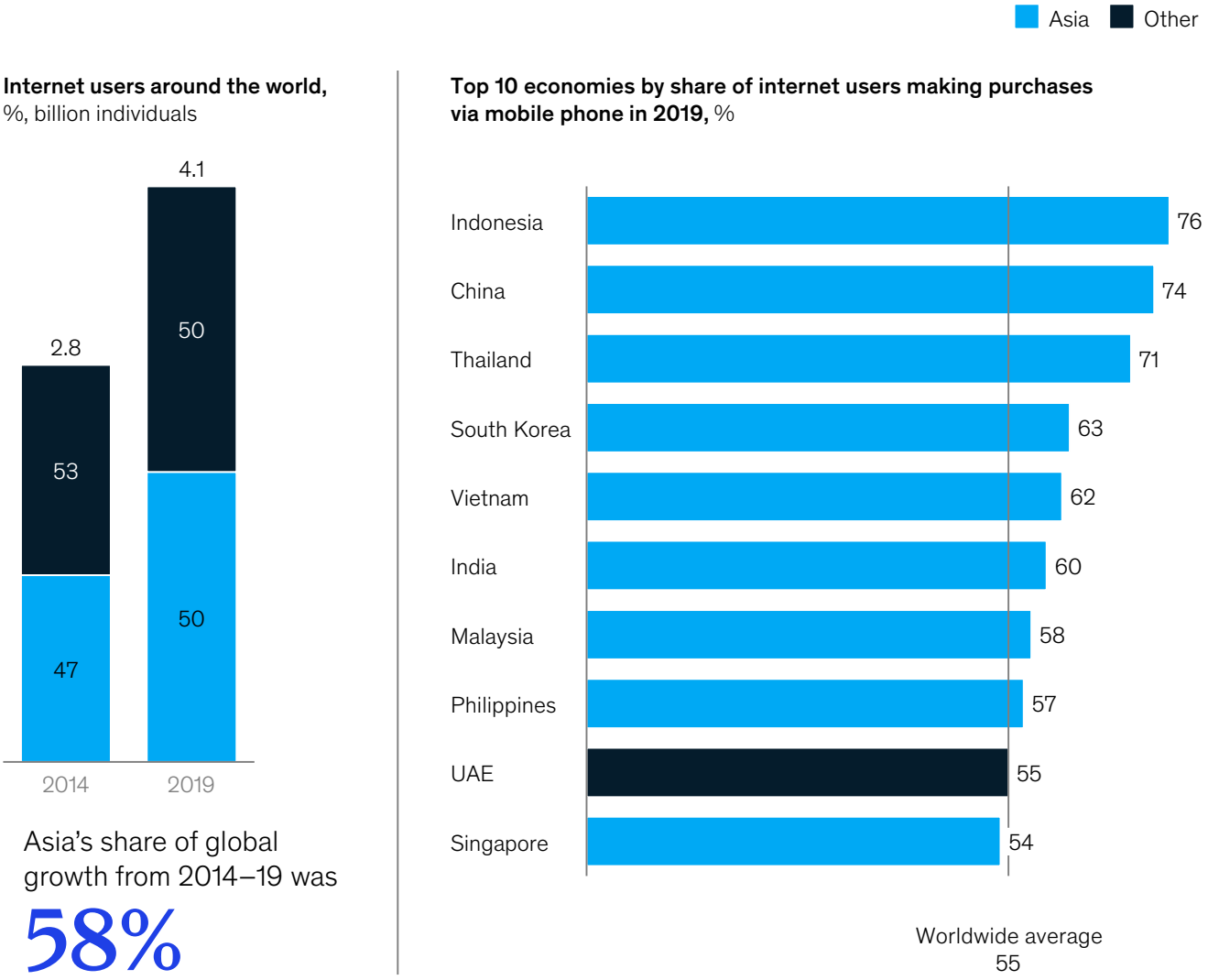
Over the past decade, Asia's populations have embraced technology more quickly and enthusiastically than in any other region of the world. Mobile messaging, online shopping, digital banking, and other applications have permeated daily life. Consumers' openness toward adopting technology has resulted in high engagement rates. To gauge the speed of adoption, we looked at the following three metrics:

— **Internet users.** The number of internet users in Asia has grown more than elsewhere (Exhibit 3). Asia is now home to half of global users.[11] The digitally savvy population has embraced technology across sectors, and user engagement is high. For much of Asia, especially Emerging Asia, mobile is the first (and often only) touchpoint with the internet, and it is how Asians access digital public services, news, commerce, banking, and social media.[12] Southeast Asia has more than 400 million internet users out of its total population of 670 million.[13] Within Asia, people in the Philippines (nine hours, 45 minutes), Thailand (nine hours, one minute), and Indonesia (seven hours, 59 minutes) spend the most time each day on the internet.[14]

[11] *Asia home to half of the world's internet users*, Data Center News, April 1, 2020.
[12] *Southeast Asia going digital: Connecting SMEs*, Organisation for Economic Co-operation and Development (OECD), 2019. MGI's Future of Asia research identifies Emerging Asia as Bhutan, Brunei, Cambodia, Indonesia, Laos, Malaysia, Mongolia, Myanmar, Nepal, the Philippines, Thailand, and Vietnam. See *The future of Asia: Asian flows and networks are defining the next phase of globalization*, McKinsey Global Institute, September 2019; and *The future of Asia: Decoding the value and performance of corporate Asia*, McKinsey Global Institute, May 2020.
[13] Simon Kemp and Sarah Moey, *Digital 2019 spotlight: Ecommerce in Southeast Asia*, DataReportal, September 18, 2019; and Worldometer, worldometers.info.
[14] Simon Kemp, *Digital 2020: Global digital overview*, DataReportal, January 30, 2020.

Exhibit 3

Asia is the region that is moving online fastest, with citizens becoming enthusiastic adopters of digital solutions.



Source: ITU World Telecommunication/ICT Indicators; We are Social database; McKinsey Global Institute analysis

— **E-commerce transactions.** E-commerce transactions are on the rise across Asia. By the end of 2019, e-commerce spending accounted for 3.3 percent of Asia–Pacific GDP.[15] The total e-commerce market is projected to reach $1.43 trillion in 2020, nearly triple the volume in the United States.[16] Growth in spending via e-commerce accelerated during the early months of the COVID-19 outbreak. Asia has relatively few big-box retailers to compete with e-commerce, compared with the United States and parts of Europe, and the ability of third-party logistics players to reach less connected and more remote populations also supports e-commerce. E-commerce transactions have grown more quickly as it has become the primary channel for consumers living outside densely packed urban centers. Mobile e-commerce spending accounts for 74 percent of total spending on e-commerce in Asia, compared with 37 percent in Europe and 31 percent in North America. Overall, e-commerce in Asia accounted for about 9 percent of all retail in 2019, a 2.6-fold increase from 2010, with large economies like China, India, Indonesia, and Vietnam experiencing the most growth.[17]

— **App downloads.** App downloads have grown more in the region than in the rest of the world, reflecting Asia's mobile-first approach to the internet. Asian consumers are more likely to spend more time on those devices. Asia accounted for 41 percent of all mobile app downloads in 2019.[18] App downloads grew by 190 percent in India, 80 percent in China, and 70 percent in Indonesia between 2016 and 2019; growth in app downloads in the United States was 5 percent over the same period.[19] China is also driving increased spending on apps, with a 190 percent increase between 2016 and 2019, compared with the worldwide average of 110 percent. Increased downloads also reflect the volume and variety of apps being developed for everyday uses such as personal finance, mobility, commerce, social media, and citizen services.

[15] Euromonitor International Limited, World Bank, and Statista.
[16] Statista.
[17] Euromonitor International Limited.
[18] Priori, data from 55 countries.
[19] Sarah Perez, "App stores saw record 204 app downloads in 2019, consumer spend of $120 billion," TechCrunch, January 15, 2020.

Asian governments play an important role in technology development with strong public-private collaboration

Some Asian governments have been vital catalysts to the development of technology in recent years, steering its commercialization and execution. To spur commercialization, governments have created a large market through procurement that, in turn, can facilitate long-term private-sector investment. Governments have also rolled out programs directly to increase adoption of new technologies. In this section, we describe examples from different parts of Asia.

In China, the government has worked closely with technology companies to steer the commercialization of AI. The government's stated aim is to develop a domestic AI industry worth nearly $150 billion by 2030.[20] The government more than doubled its spending on technology over the past ten years, from around $22 billion in 2009 to $51 billion in 2019.[21] It has used AI technology in many of its public services. The Ministry of Education introduced a "national internet cloud classroom" during the COVID-19 outbreak that aims to serve 50 million students, offering instruction in 12 subjects. The cloud classroom is powered by more than 7,000 servers.[22] Companies including Alibaba, Baidu, and Tencent have established AI research centers. The government has announced plans to increase investment in "new infrastructure," including 5G, new energy automobiles, and data management, to about $2.46 trillion from 2020 to 2025.[23]

In healthcare, the government of China has used incentives to promote telemedicine, and the online healthcare market increased in value from 25 billion renminbi ($3.6 billion) in 2013 to 120 billion renminbi ($17.5 billion) in 2019. On the environment, China has been using AI technologies as part of its drive to build zero-waste communities. One part of this effort was the installation in 33 cities of more than 10,000 AI-powered bins that sort waste automatically, which attracted over 2.6 million users on the app linked to the bins in 2019.[24] The government has also used AI and automation in transportation; 27 percent of China's airports had self-boarding gates using AI and automation in 2019, and the plan is to increase this share to 66 percent in three years.[25] China's Civil Aviation Administration opened the first test-flight base for civilian drones in Shanghai in 2017 for 500 drone manufacturers.[26]

India has put in place a "make in India" policy, which includes a strong technological component, to encourage multinational and domestic companies to manufacture products in India. The country has launched several programs that link technology and social development. One is the Digital India plan, which includes the opening of digital bank accounts and subsidy transfer schemes linked to the Aadhaar program that gives citizens unique biometric digital identities.[27] We acknowledge that there has been debate about the program centered on citizens' privacy and cybersecurity.[28] In the ten years ending in April 2020, more than 1.2 billion people registered with the Aadhaar program.[29] India considers digital ID to be a strategic tool for delivering government services, managing budgets, and increasing financial inclusion. The number of bank accounts linked to Aadhaar rose from 56 million in 2014 to 870 million in 2018. E-governance has become a much more prominent feature of India's public life in recent years as digitization has taken hold.

[20] "National AI plan to drive development," *China Daily*, October 22, 2019; *A next generation artificial intelligence development plan*, China State Council, 2017, gov.cn.
[21] Technology spending defined as spending to enhance the country's ability in technology and to accelerate important technology projects, see gov.cn.
[22] Anna Fifield, "In China, 200 million kids have gone back to school. Online." *The Washington Post*, February 17, 2020.
[23] "Economic watch: China steps up new infrastructure investment to empower cities of the future," *Xinhua*, June 3, 2020.
[24] "AI-powered waste management underway in China," *People's Daily Online*, February 26, 2019.
[25] *Chinese airports are embracing AI and automation*, International Airport Review, November 28,2019, internationalairportreview.com.
[26] *China Opens First Civilian Drone Base in Shanghai*, NDTV, September 2, 2017, ndtv.com.
[27] *Digital Identification: A key to inclusive growth*, McKinsey Global Institute, April 2019.
[28] Mardav Jain, *The Aadhaar Card: Cybersecurity issues with India's biometric experiment*, The Henry M. Jackson School of International Studies, University of Washington, May 9, 2019.
[29] Unique Identification Authority of India, uidai.gov.in. Also see *Digital India: Technology to transform a connected nation*, McKinsey Global Institute, March 2019; and *Digital identification: A key to inclusive growth*, McKinsey Global Institute, April 2019.

For instance, by November 2017, 31 states and union territories had installed a modern land records management system, and 30 states and union territories had completely computerized property registration. A large share of subsidies and benefits are now disbursed electronically directly into bank accounts—an estimated $70 billion from 56 ministries. Digital technologies are also being more widely used in education and healthcare. The Indian government has integrated its national digital library, which contains 70,000 books and more than 18,000 video lectures, into a single web portal. The government-backed SWAYAM web portal gives access to more than 1,000 massive open online courses. E-hospitals that use digital workflow-based management systems are becoming more widespread. Since 2015, 47 million transactions have been made in inpatient departments, in labs, and during registration at more than 300 hospitals.[30] The government has also supported digital channels in agriculture, such as the mKisan portal, to provide crucial information and services to farmers in their own languages and dialects.[31] Since May 2013, 22 billion text messages have been sent, and mKisan call centers have answered farmers' queries in 22 languages.[32]

The governments of Japan and South Korea are planning to forge ahead with the hydrogen economy (see section 3.4 for a discussion of Asia's significant role in the global energy transition). South Korea is working on developing its data economy and has put in place the legal foundations by amending its three major data privacy laws to ease regulation of data use, including personal and credit information. Revisions in these laws are expected to facilitate the compilation of statistics, data research, and customized recommendations of products, all of which were previously somewhat restricted.

Asian governments are also supporting the development of other advanced technologies. For example, the government of South Korea plans to invest $95 billion over the next five years in a post-pandemic "Korean new deal" that aims to lay the foundations for economic growth driven by digital and green and clean technologies. The program includes a plan to train 100,00 people in AI, establish 230,000 energy-saving homes and public buildings, produce 1.13 million electric cars, and build nationwide 5G networks.[33]

Innovation and change are occurring beyond Asia's advanced economies, China, and India. Southeast Asian governments are actively promoting the digitization of their economies. For example, Malaysia has formed digital free trade zones through which $65 billion worth of goods and services are expected to flow in the period to 2025. The Philippines has a $29 million plan to provide free Wi-Fi in public spaces and educational institutes, and is investing $4.5 billion in improving internet quality and speed. The government of Singapore has already invested in building robust digital infrastructure, and it is devoting $19 billion to a research and innovation enterprise plan that will accelerate digital innovation in healthcare and manufacturing.[34]

[30] *India's Trillion-Dollar Digital Opportunity*, Ministry of Electronics and Information Technology, Government of India, February 2019, www.meity.gov.in.
[31] "Brief overview of the mKisan Portal," Department of Agriculture & Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, www.mkisan.gov.in.
[32] Kisan Call Centre dashboard, mKisan, Government of India; *Digital India: Technology to transform a connected nation*, McKinsey Global Institute, March 2019.
[33] Donald Kirk, "Korea reveals 'new deal' designed to boost jobs, revive sagging economy," *Forbes*, July 14, 2020.
[34] *Government initiatives to drive digitalization in ASEAN*, Asia IoT Business Platform, iotbusiness-platform.com.

The Four Asias are at different stages of technology development, face various challenges, and offer complementary strengths

Asia is a diverse region. We use MGI's Four Asias categorization to understand different stages of technology development in different parts of the region and how their strengths complement one another (Exhibit 4).[35]

Exhibit 4

The Four Asias are at different stages of their technological development, but complement each other with different strengths and gaps.

Concentration Asia Other

Dimensions	Metrics[1]	United States	Europe	Advanced Asia	China	Emerging Asia	Frontier Asia and India
IP and paper	Patents by origin, 2016–18 average, thousand	304	122	206	1,631	<1	<1
	Number of scientific and technical articles, 2019, thousand	215	207	146	301	22	68
Firm	Revenue of tech incumbents, 2016–18 average, $ billion	2,812	1,240	1,605	1,860	63	107
	Number of unicorns, July 2020	228	58	19	124	6	21
Market	Number of internet users, January 2020, million	288	711	198	882	443	889
	Number of mobile users, January 2020, million	353	1,090	300	1,654	935	1,524
Investment	Startup investment (including VC and IPO), 2017–19, $ billion	1,197	399	151	867	30	105
	R&D spending, 2016–18 average, $ billion	543	412	260	267	12	19

1. Patents data come from WIPO. Data on articles are from the National Science Board. For technology company revenue, data come from the McKinsey Corporate Performance Analytics database; includes 3,122 technology companies with more than $1 million annual revenue between 2016 and 2018. CB Insights provides data on unicorns. Statistics on internet and mobile users come from Digital 2020 Global Digital Overview. Data on startup investment come from PitchBook. Data on R&D expenditure are from the World Bank and include numbers on 91 economies where data is available for both 2006–08 and 2016–18.

Note: MGI identifies four Asias, distinct groups of economies based on scale, economic development, interactions with one another, and connectedness to the world. Advanced Asia includes Australia, Japan, New Zealand, Singapore, and South Korea; China has the scale to stand in its own category. Emerging Asia includes all Association of Southeast Asian Nations (ASEAN) countries except Singapore. India and Frontier Asia comprises the rest of the region's economies.

Source: McKinsey Global Institute analysis

[35] *The future of Asia: Asia's flows and networks are defining the next phase of globalization*, McKinsey Global Institute, September 2019; and *The future of Asia: Decoding the value and performance of corporate Asia*, McKinsey Global Institute, May 2020.

Each of the four Asias has strengths and challenges. Advanced Asia has strength and depth in technology companies, but has far fewer unicorns than other major economies, and economic growth is slowing. China has a rich ecosystem of startups, being home to 26 percent of all the world's unicorns, and has increased IP creation rapidly; however, it continues to rely on imports of key specific technologies and, more broadly, of IP. Emerging Asia has relatively low investment in technology and is not richly endowed with significant technology players. India, too, has fewer large technology companies than other major economies, and business dynamism is relatively constrained by some weaknesses in physical infrastructure.

However, strengths in some parts of Asia can compensate for gaps in others: the four Asias complement each other. For instance, the working-age populations of Advanced Asia and China are declining, but economies in the rest of Asia are projected to add 412 million people to their combined labor pool by 2040. Advanced Asia and China can offer funding and knowledge to their neighbors, and the rest of Asia can offer massive deployment and commercialization opportunities. The region as a whole can take advantage of these complementary factors to build resilience in the face of short-term volatility.

— **Advanced Asia.** This group includes Australia, Japan, New Zealand, Singapore, and South Korea. These countries have achieved high levels of economic development, with per capita GDP of $30,000 to $60,000, and have established robust capabilities for developing technology. They are a strong source of IP creation in the region, accounting for 18 percent of global patents issued in 2016–18 and 15 percent of R&D spending in 2016–18. These countries accounted for 20 percent of global technology company revenue in 2016–18. These economies have some gaps. In 2020, they are home to only 6 percent of the world's unicorns. Successful unicorns can grow into large companies and create virtuous cycles that build broader and more vibrant ecosystems, train talent, and fund other innovative business models. The relatively weak presence of unicorns may imply that these economies may face gaps in growing next-generation technology leaders in the medium to long term. Slower annual GDP growth of 1 to 2 percent could also limit opportunities to commercialize innovation.

— **China.** China is large enough and sufficiently distinct from other Asian economies to stand in its own category. It is an increasingly significant regional and global technology powerhouse and accounts for 45 percent of global patents and 17 percent of R&D expenditure, more than the Advanced Asia economies combined.[36] Chinese corporations generate 23 percent of global technology company revenue. Alibaba and Tencent are well-known Chinese technology conglomerates that are now among the top ten global technology companies by market capitalization. Moreover, China has developed strong startups, fueled by significant investment in these companies. In 2017–19, China accounted for 30 percent of global startup investment. Today, it is home to 26 percent of the world's unicorns. China has risen to become a global innovation powerhouse, but not in every technology. In robotics, for instance, China is the largest market in the world for leading-edge technology in core components such as servo motors and control systems, and relies on foreign production and imports. China continues to depend on imports of core technologies such as semiconductors and optical devices, as well as intellectual property (IP). China's IP imports are still six times larger than exports. More than half China's technology imports come from only three countries. China imports more integrated circuits than crude oil. Its cross-border data flows are still relatively small given the size of its digital economy at only about 20 percent of the global benchmark.[37]

[36] *The China effect on global innovation*, McKinsey Global Institute, October 2015; and *Digital China: Powering the economy to global competitiveness*, McKinsey Global Institute, December 2017.
[37] *China and the world: Inside the dynamics of a changing relationship*, McKinsey Global Institute, July 2019.

— **Emerging Asia.** This group consists of 12 countries: the members of the Association of Southeast Asian Nations (ASEAN) other than ASEAN member Singapore (which we include in Advanced Asia), and Bhutan, Nepal, and Mongolia. Emerging Asia is relatively diverse but tends to be characterized by small, fast-growing economies that are highly connected to one another. These countries offer Asia new sources of growth. Many of these economies grew at more than 6 percent between 2013 and 2017, and they are expected to continue to exceed global average GDP growth of 2.7 percent between 2017 and 2040. These economies also have fast-growing numbers of internet users, and their populations are digitizing rapidly. In previous research, MGI identified Indonesia as the fastest digital adopter among major digital economies.[38] These economies are at a relatively early stage in their technology development, with less IP creation, technology investment, and tech firm representation. On unicorns, for instance, these economies had six in July 2020, compared with 124 in China and 228 in the United States.

— **Frontier Asia and India.** These 12 economies are urbanizing, have large and young labor forces, and are major producers of business services.[39] India's median age was 27 in 2015 and is expected to be only 38 in 2050; 53 percent of GDP in India comes from the services sector, and the nation also has the world's second-highest number of science, technology, engineering, and math (STEM) graduates, after China. This group of economies had the highest average GDP growth in 2013–17 of any of the Four Asias at 6.8 percent, and it offers opportunities for investment in many sectors. These economies also tend to have low levels of regional integration and a more diverse global base of trading partners and investors. India, for instance, is less well represented by large technology firms than leading economies. Average revenue among Indian technology incumbents in 2016-18 averaged $107 billion, compared with $1,860 billion in China and $2,812 billion in the United States. India's technology firms also are constrained by relatively underdeveloped physical infrastructure, including transportation networks and manufacturing ecosystem. The quality of its large population of STEM graduates also needs to improve.

Because the Four Asias have characteristics that complement one another, we are seeing the formation of "multilocal innovation networks" in which solutions offered in each local market are tailored to their own consumers and regulations and managed by local entrepreneurs, but can share similar business models and be funded with regional capital. For example, Tokopedia, Indonesia's second-largest unicorn, raised funding led by Softbank (Japan) and Alibaba Group (China), while India's BYJU is backed by Tencent (China).

Asia's growth in technological capabilities, enabled by its digitally adaptable population and the role of government in catalyzing commercialization and implementation of new technologies, creates opportunities not only for Asian companies but for firms around the world. Over the past five years, global companies have been rapidly expanding into the region. China and India accounted for 49 percent of the expansion, but the scope extends beyond them (see Box 1, "Global companies are expanding into Asia to capture new opportunities").

In this section, we have examined Asia's increasing technological capabilities over the past decade, and some of the challenges that remain to be tackled. We now explore the region's potential to build on that foundation over the coming decade with analysis of specific technologies where the potential may be greatest if the region can address current gaps.

[38] *Digital India: Technology to transform a connected nation*, McKinsey Global Institute, March 2019.
[39] Frontier Asia and India comprises Afghanistan, Bangladesh, Fiji, India, Kazakhstan, Kyrgyzstan, Maldives, Pakistan, Sri Lanka, Tajikistan, Turkmenistan, and Uzbekistan.

Box 1

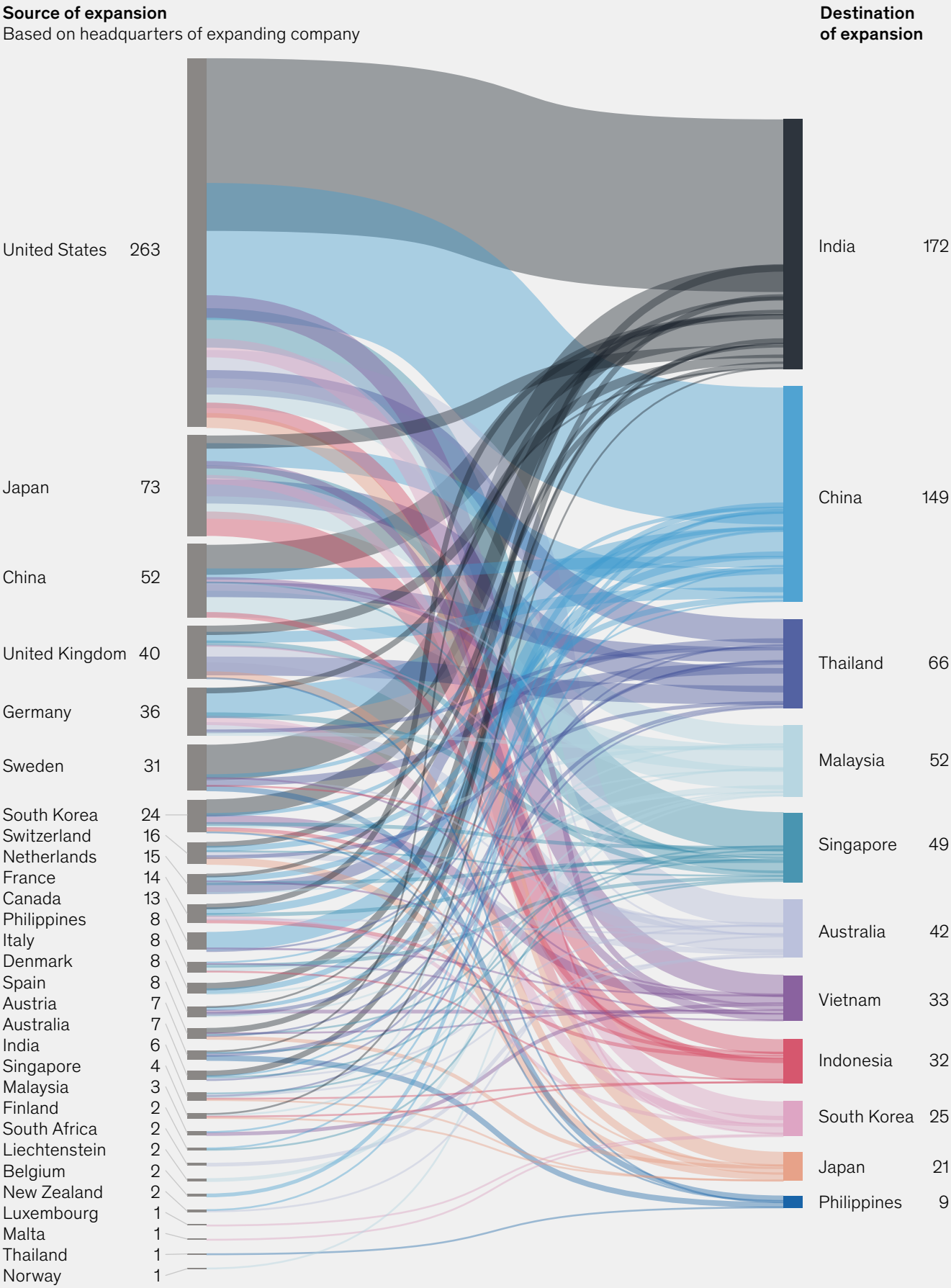
Global companies are expanding into Asia to capture new opportunities

Leveraging natural language processing capabilities by SparkBeyond, we analyzed two billion articles from 2016 to August 2020 (Exhibit 5). We found that China and India are the top destinations for companies expanding into Asia, together accounting for 49 percent of the total. But expansion goes beyond China and India; Thailand, Malaysia, and Singapore are the next three top destinations. The United States is the top source of companies expanding into Asia, accounting for 40 percent of the total. Japan and China are the second and third sources, accounting for an additional 19 percent, which points to strong intraregional expansion in business activity. Of the 650 companies studied, the top motivation for expansion was access to the Asian market, accounting for 52 percent of all expansions. The second most important reason was production and sourcing, with 42 percent. Only 6 percent of expansions into Asia were motivated by a desire to expand R&D.

Exhibit 5

Global companies are expanding into Asia to capture new opportunities.

Number of companies, 2016–August 2020



Source: SparkBeyond, based on two billion public articles from 2016 to August 2020; McKinsey Global Institute analysis

2. Where does Asia stand on emerging technologies?

Technology has been an important driver of economic growth in Asia and around the world. Economists broadly take total factor productivity (TFP) as the contribution of technology and innovation to the economy. Between 2010 and 2020, about 50 percent of Asia's GDP growth, equivalent to $6 trillion, came from total factor productivity, a broad measure of the contribution to the economy of technology and innovation, according to the McKinsey Global Growth Model. Over the coming decade, in order for Asia to maintain about 4 percent growth, technology needs to contribute 43 percent of expected total growth in GDP in the period to 2030—$7 trillion.[40] We see significant opportunities for Asia to continue to drive IP creation and investment and to make progress in technology development and innovation such as mobile services, AI/machine learning, and Internet of Things (IoT). At the same time, we also observe gaps in some technologies that need to be overcome. For instance, the region has relatively low startup investment and IP creation in some categories, including biotech and pharmaceuticals, oncology, and oil and gas technology. Asia has many technological hot spot cities, but they are heavily concentrated in China and India. Although China has been rapidly improving IP creation and growing global technology firms, it still has gaps in core technologies, including semiconductors and optical devices. Moreover, there are risks that we cannot overlook, including potential disruptions to global flows of technology that could compromise the trajectory of GDP growth.

In this section, we look at technologies in which Asia has an opportunity to carve out a strong position, others where gaps in startup investment and knowledge creation need to be overcome, uncertainties associated with potential disruptions to global flows of technology that may pose a risk to technological development specifically and to economic growth more broadly, and the technology hot spot cities in the region where innovation is already happening.

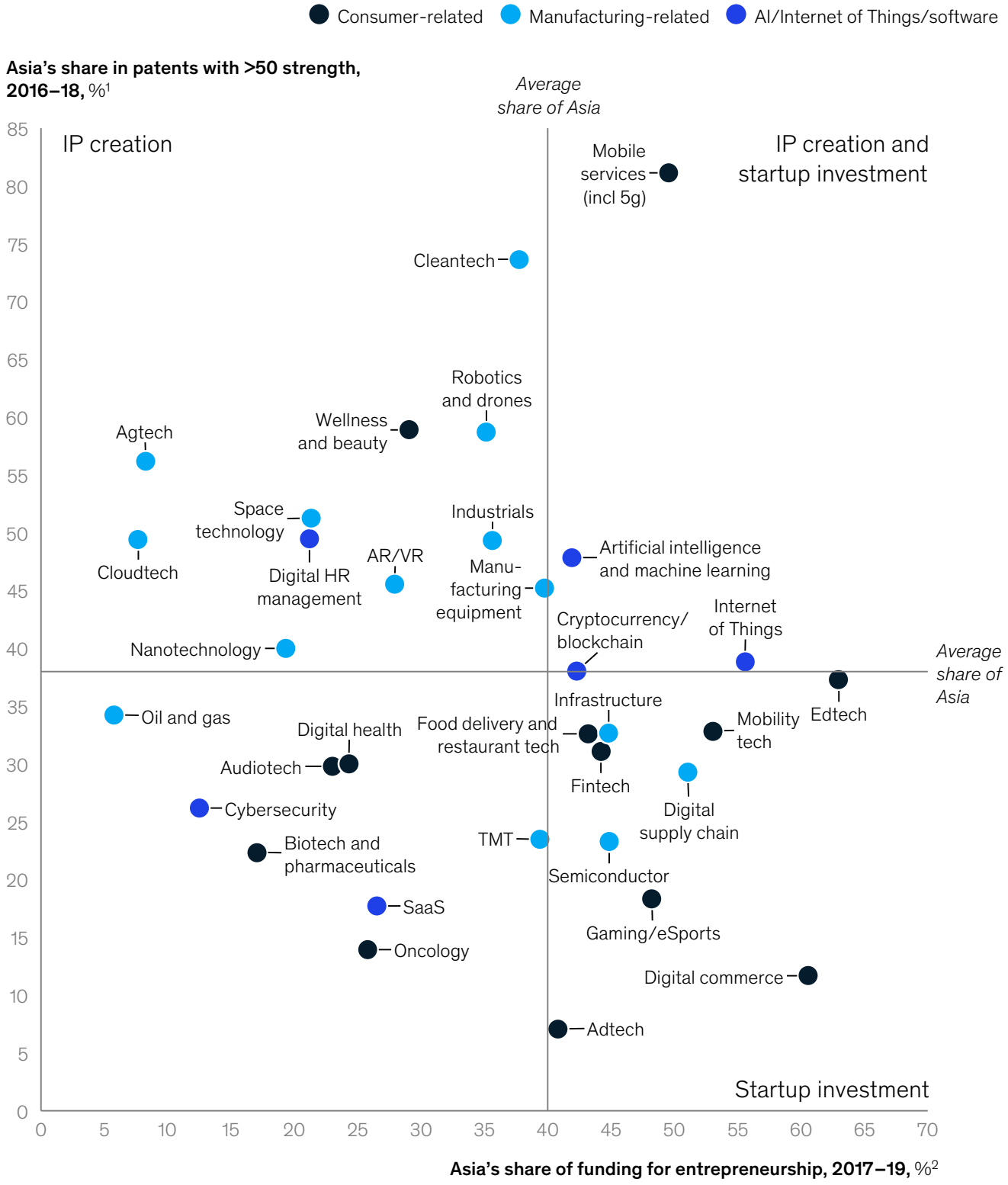
To develop a view of technologies in which Asia can establish further strength, we looked at a broad range of factors to assess 33 technologies, drawing on databases on startup investment as well as patent application statistics (Exhibit 6).[41]

[40] Calculated using real GDP based on 2019 prices from McKinsey's Global Growth Model.

[41] We chose the 33 technologies from a list of technologies compiled by PitchBook and made some modifications (such as grouping similar technologies) to make technologies comparable. We note that the data and analysis have not been reviewed by PitchBook analysts. For a detailed description of technologies, refer to https://pitchbook.com/what-are-industry-verticals#lohas. For patents, we used keyword-based data from Innography.

Exhibit 6

Asia has a strong presence in 11 technologies in startup investment, ten in IP creation, and four in both.



1. Based on filing office. PatentStrength is a normalized measure (0 to 100) calculated using Clarivate's proprietary algorithm. PatentStrength considers 30 different attributes determined to have a statistically significant correlation to patent value. CPA Global, Innography, and PatentStrength are trademarks of Clarivate and its affiliated companies.
2. Based on destination of investment; includes VC and IPO.

Note: TMT (technology, media, and telecommunications) includes technology to provide network infrastructure, utilize networks, and distribute digital content. Manufacturing equipment includes technology to produce electrical machinery, apparatus, and thermal processes. Infrastructure includes technology to build physical assets necessary for transporting goods, multimodal commerce, or generating power. Industrial includes technology in chemical engineering, materials, metallurgy, and optics.

Source: Innography; PitchBook; WIPO; McKinsey Global Institute analysis

To gauge Asia's potential to establish a strong position on technologies, we assessed two elements: (1) startup investment based on funding for entrepreneurship (including both venture capital investment and initial public offerings); this metric is an indicator of the level of interest in, and the commercialization of, each technology; and (2) IP creation using strong patents (with a strength index above 50) as our key metric; this metric indicates ownership of cutting-edge knowledge for a particular technology.[42]

Given that patent offices may have different standards for patent filing, the threshold for patent strength is intended to filter for higher-quality patents. As discussed in section 1, Asia is becoming a knowledge powerhouse, accounting for 67 percent of patents filed globally between 2016 and 2018. After filtering for patents with a strength index above 50, Asia's share falls, but it remains significant at 38 percent. Asia has a high share of patents and startup investments in four technologies: mobile services (including 5G), AI and machine learning, manufacturing, and the IoT. Because we discuss manufacturing in detail in section 3 of this paper, here we highlight the other three:

— **Mobile services.** Asia has 81 percent of the world's strong patents and half of venture capital and IPO funding for this sector, and is therefore leading global growth in mobile and telecom services. Use of mobile, data, and other telecom services is growing at an unprecedented rate in the region. The global mobile applications market is expected to grow at an 18 percent compound annual rate from 2019 to 2024. In Asia, 20 percent growth is expected in "super apps"—such as WeChat, multiservice platform Go-Jek, and ridesharing company Grab—that offer multiple services on one platform. Asia is home to some of the world's largest telecom operators. China's mobile communications corporations have the largest subscriber base, with more than 900 million customers.[43] Indian company Reliance Jio Platforms, one of the world's largest telecom operators, has expanded very quickly. The company led the 4G revolution in India by launching affordable 4G-enabled smartphones and free 4G SIM cards through an Aadhaar-based paperless activation model, enabling it to accumulate more than 380 million customers in only three to four years of operations. The company says it has reduced mobile data costs in India by more than 90 percent.[44] Jio is now developing its own lower-cost 5G technology and plans to deploy it in India and around the world in 2021.[45]

— **AI.** Asia has a 48 percent share of AI strong patents and accounts for 42 percent of global startup investment in AI technologies. Companies in China, Japan, and South Korea hold the most AI patents. Given high R&D spending by China, Japan, Singapore, and South Korea, and the fact that most R&D sectors such as biotech, materials, and computer sciences are driven by such technologies, use of AI is expected to increase.[46] Moreover, India and China produce the most computer science graduates in the world each year, and they are training these graduates to become data scientists and machine learning specialists.[47] India's AI workforce nearly doubled from 40,000 in 2018 to 72,000 in 2019.[48] Many global research companies have set up AI research centers in Bengaluru. Overall, Asia stands to gain from, and contribute to, the AI revolution.

[42] PatentStrength is a normalized measure (0 to 100) calculated using Clarivate's proprietary algorithm. PatentStrength considers 30 different attributes determined to have a statistically significant correlation to patent value. CPA Global, Innography and PatentStrength are trademarks of Clarivate and its affiliated companies.
[43] *China Mobile confirms 6.7m 5G subscriber base*, Comms Update, TeleGeography, February 20, 2020.
[44] "Jio brought down data costs from Rs 500 to Rs 12: Mukesh Ambani," *Business Today*, August 24, 2020.
[45] Danish Khan, "Inside Reliance Jio's Make in India strategy for 5G, IoT to cut dependence on foreign gear," *Economic Times*, July 31, 2020.
[46] Ayesha Khanna and Parag Khanna, "Where Asia is taking the world with AI," *Forbes*, May 2, 2020.
[47] G. S. Mudur, "Computer science skill wake-up call in study," *Telegraph India*, March 18, 2019.
[48] "India doubles its AI workforce in 2019, but faces a talent shortage: Great Learning," *Economic Times*, December 27, 2019.

— **IoT.** Asia has 39 percent of global strong patents and 56 percent of the investment in IoT technologies. The global IoT market is expected to grow significantly. In 2019, the market was valued at $465 billion; in 2030, the value is expected to be $1.5 trillion. In 2019, there were 7.6 billion active connected devices, and that is seen rising to 24.1 billion active devices in 2030. China currently has the largest market share at 26 percent, followed by North America and Europe at 24 and 23 percent, respectively.[49] Telecommunications companies such as M1 and SingTel in Singapore have launched narrowband IoT networks, a wireless communications standard for IoT that enables devices to be connected with only a small amount of data and low bandwidth with long battery life. Singapore is now ready to use IoT on a commercial and nationwide scale on the basis of its narrowband network.

Beyond these four technologies, Asia has an above-average share of startup investment in a dozen other technologies. Seven of these technologies are consumer facing, and Asia accounts for 51 percent of total investment in them. Powered by growing consumer demand, Asia has continued to increase investment in such technologies. The seven consumer-facing technologies are educational technology (edtech), digital commerce, mobility tech, fintech, food delivery and restaurant tech, gaming and e-sports, and advertising technology (adtech). We discuss digital commerce, mobility tech, fintech, and food delivery and restaurant tech in detail in section 3 of this discussion paper. On the other three, we find:

— **Edtech.** Asia accounts for 63 percent of startup investment and 37 percent of strong patents in edtech. In India, online education platform BYJU's valuation rose from $1 billion to $10.5 billion between 2018 and 2020 on the back of about $1.5 billion in investment.[50] BYJU spent $300 million to acquire online coding training school White Hat Jr. In China, Yuanfudao received $1.5 billion in funding, driving its valuation to about $8 billion. Indonesian company Ruangguru raised $150 million in 2019 to drive its expansion into other Asian economies. Edtech products are incorporating new technologies to improve learning outcomes. For instance, Tangyuan, an English language learning app, uses AI to analyze and grade learners' abilities.[51]

— **Gaming and e-sports.** Asia accounts for 48 percent of startup investment and 18 percent of strong patents in gaming and e-sports. Online and mobile gaming in Southeast Asia is predicted to grow to have 400 million users by 2021.[52] Asia accounts for the majority of global gamers in the world (55 percent) and is the fastest-growing region for gaming, with year-on-year growth of 7.7 percent in 2020.[53] This growth is driven by rising penetration of high-speed internet and by growth in the number of publishers as well as the quality of the content they produce. Douyu and Huya, the top video-steaming sites in China, have developed a community of e-sports enthusiasts and gamers. Kuaishou reports 35 million daily active users.[54] In revenue, Southeast Asia is the fastest-growing games market in the world, with publishers like GungHo, Sea Group, and Betsoft promoting gaming heavily to audiences.[55]

[49] Anasia D'mello, *Global IoT market to grow to $1.5trn annual revenue by 2030*, IoT Now, May 20, 2020; and Jeremy Coward, "Asia IoT: How Asia-Pacific can become the world's biggest IoT market," *IoT World Today*, September 3, 2017.
[50] Salman S.H., *Fresh funding round values Byju's at $10.5 billion*, Mint, August 5, 2020.
[51] Tony Xu, *Bytedance tests online learning app "Tangyuan English,"* TechNode, July 9, 2019.
[52] *Online and mobile gaming in Southeast Asia poised to hit $4.4 billion*, Niko, November 7, 2017.
[53] *Key numbers*, Newzoo, newzoo.com.
[54] James Chan, "Chinese video game livestreaming platforms set to challenge Twitch," KrASIA, April 27, 2020.
[55] *Global gaming market to witness a CAGR of 12% during 2020–2025 – players will spend $4.5 billion on immersive gaming in 2020*, Research and Markets, April 16, 2020.

— **Adtech.** Asia accounts for 40 percent of startup investment and 7 percent of strong patents in adtech. This technology essentially encompasses the software and tools that help brands target, deliver, and analyze digital advertising and digital technology that automates and simplifies the marketing process. Digital advertising accounted for 49 percent of all spending on advertising in Asia in 2019, an all-time high. China is home to Panshi, a unicorn that focuses on adtech for small and medium-size enterprises (SMEs). Other innovative companies in Asia include Primo in Thailand, which focuses on cross-promotion and redemption analytics, and Near in Singapore, which raised $100 million for an AI tool that merges online and offline behavior.[56]

On IP creation, Asia has a higher-than-average share of patents in ten technologies: cleantech, robotics and drones, wellness and beauty, agriculture technology (agtech), space technology, digital human resources management, augmented reality (AR), virtual reality (VR), industrial cloud-computing technology, and nanotechnology. Most of these are manufacturing related, emphasizing Asia's rising innovation capabilities in manufacturing sectors. We elaborate further on cleantech in section 3 of this discussion paper; the following are two other technologies in which Asia has the highest share of strong patents:

— **Robotics and drones.** Asia has a 59 percent share in patents and 35 percent share in investment in these technologies. Five economies—China, Japan, South Korea, the United States, and Germany (listed from largest to smallest share)—accounted for more than 70 percent of the global industrial robotics market in 2018. China had a 36 percent share, and Japan 13 percent.[57] The Chinese government has been actively promoting the development of the robotics industry by recognizing it as a strategically important sector and stating its ambition to transform China into a world leader. China is also home to the world's largest drone manufacturers; DJI, a Chinese consumer drone manufacturer, alone holds about 70 percent of the global market.[58] With respect to robotics, the top five companies based on 2017 revenue are all Asian: ABB, Omron, Fanuc, Kawasaki Robotics, and KUKA.

— **Agtech.** Asia has a 56 percent share of global patents in this sector and an 8 percent share of investment (which is highest in North America and Europe). Prospects for Asian agtech are promising. Although current production systems and logistics lag behind those in advanced economies, Asia has a high need for food, including protein, for its large and growing population. India, where agriculture contributes 18 percent of GDP and employs 55 percent of the population, is becoming a hub for agtech startups, with more than 450 companies already operating. One of every nine agtech startups in the world is an Indian company. The Indian government has encouraged and enabled the development of agtech, and the sector is expected to grow even further with advances in 5G, AI, and IoT.[59]

Asia has yet to build presence in startup investment or IP creation in eight other technologies we analyzed: oil and gas; cybersecurity; biotech and pharmaceuticals; audiotech; digital health; technology, media, and telecom (TMT); software-as-a-service (SaaS); and oncology. In most of these technologies, the United States and Europe still account for the majority of IP creation and startup investment. In biotech and pharmaceuticals, for example, Asia accounted for 22 percent of strong patents in 2016-18 and 17 percent of startup investment in 2017-19. In comparison, US and Europe combined accounted for 77 percent of strong patents and 79 percent of startup investment. Asian pharmaceutical companies have yet to catch up in terms of development capabilities. In many parts of Asia, treatment standards still lag behind those in the West; providers rely on previous generations of drugs. For example, a high share of diabetes patients in the United States are treated with innovative oral drugs

[56] Ingrid Lunden, "Near raises $100m for an AI that merges online and offline behavior to build consumer profiles," TechCrunch, July 16, 2019, Kristie Neo, "After $100m fundraise, SG-headquartered Near on the prowl for acquisitions in US," *DealStreetAsia*, August 6, 2019.
[57] IRF World Robotics 2019 ifr.org.
[58] Patrick McGee, "How the commercial drone market became big business," Nov. 26, 2019, ft.com.
[59] Supriya Modi and Swani Ramchandani, *The emerging scope of agri-tech in India*, Team India blogs, Invest India, January 14, 2020.

but older protocols are still common in China. It remains to be seen if Asia can catch up in these technologies.

Disruptions to technology-related flows could impact the pace of innovation in Asia and the world

Collaboration on technology can improve TFP because it facilitates knowledge flows and the adoption of competitive solutions. Although Asia is well positioned to benefit from deepening domestic technological capabilities, rising risks of potential disruptions to global technology-related flows could be a drag on the pace of innovation and GDP growth.

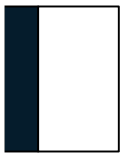
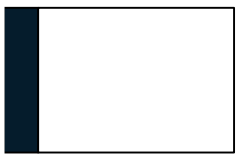
Many companies have been expanding in Asia over the past decade, but concern about rising barriers among trading partners has recently come into sharp focus (see Box 2, "Industry sentiment on potential disruption to technology-related flows"). Within Asia, restrictions by one country on exports to a neighboring economy of critical components of LCD and OLED displays and flash memory triggered tensions.[60] The risk exists that technology-related flows between nations could slow, which would be a change from the previous era of open collaboration. The world appears to be shifting toward digital barriers, localization, and protecting intellectual and technological capabilities from other nations at a faster pace than before. In a world so deeply networked and connected, the implications of potential disruptions to technology-related flows are significant.

We note that there is a wide range of views on the potential economic impact of these disruptions and many of the potential effects are not quantifiable. We have not modeled the impact of potential disruptions ourselves, but rely on a considerable body of academic literature and third-party research for estimates of the potential disruption and ranges of negative impact on global GDP if these disruptions were to occur (Exhibit 7). We summarized them into seven types of potential disruptions to technology-related flows. The value at stake figures are largely a collection of existing views by authoritative third parties such as the IMF, the OECD, academic studies, and estimates from prior MGI research that could change over time; these figures are given as a range and should not be taken as a forecast or estimate of future scenarios. There could be also overlap across dimensions, so figures are not additive. For example, data-flow interruption could affect research collaboration. Export controls can be also related to measures such as tariffs. We do not make any recommendations on scenarios, and do not make comparisons between them. (Please see the technical appendix for more detail on the approach used for collecting figures on potential value at stake.)

[60] Kenichi Yamada, "Samsung tests non-Japan materials as Asia trade war deepens," *Nikkei Asian Review*, July 17, 2019.

Exhibit 7

Seven types of disruption to technology-related flows may reduce global innovation.

Dimensions	Potential value at stake,[1] % of global GDP	Description
Interrupting data flows	 0.3–1.0	Data localization causes latency in data transfers and reduces the value of insights that can be extracted from data, in addition to product market impact caused by cost of implementing regulations (eg, localization requirements)
Increasing cost due to tariffs	 0.6–2.5	Tariffs increasing cost of goods, driving down demand for most goods and thus reducing the market for innovation
Divergence in standards	 0.2–1.0	Duplicated efforts in technology standards reduce scale effects; productivity is reduced without uniform technology standard
Establishing export controls[2]	 0.3–2.0	Export controls reduce market for goods; supply chain interruptions and switching cost decrease productivity
Banning collaboration on research	 0.1–0.2	Reduction may result in shrunken funding and opportunities for researchers and may reduce scope of shared knowledge creation
Forced technology transfer	Subject to individual cases	If extended globally, countries may not fully leverage comparative advantages as multinational companies may not be willing to expand global R&D and manufacturing footprint
Non-tariff barriers to market access	Subject to individual cases	Potential loss of consumer welfare due to limited competition and choice in domestic markets

1. Reduction in GDP in any given year.
2. Export controls of strategically important goods and services controlled for reasons of national security; range of impact takes into account direct effects of export control rule (loss in revenue of affected component or service); does not take into account effects of export control restriction on entire supply chain.

Note: Figures on potential value at stake are derived largely from the view of authoritative third parties, academic studies, and estimates from prior MGI research that could change over time; these figures are given as a range and should not be taken as a forecast or estimate of future scenarios. There could also be overlap across dimensions; figures are not additive.

Source: Literature review; McKinsey Global Institute analysis

The potential disruptions are as follows:

1. **Interrupting data flows (minus 0.3–1.0 percent of GDP).** The number of nations enacting some degree of data protectionism—blocking personal, digital service, and telecom data—is already rising.[61] In this scenario, data ownership becomes decentralized as further limitations are placed on cross-border transfers. Localization rules are imposed by data regulators requiring the use of local data centers. Transferring data across borders becomes increasingly cumbersome and costly. The calculation includes GDP losses in the range of 0.8 percent to 1.7 percent from data localization in seven territories: China, Brazil, the European Union (EU), India, Indonesia, South Korea, and Vietnam.[62]

2. **Increasing cost due to tariffs (minus 0.6–2.5 percent of GDP).** In this scenario, tariffs are imposed on goods and services. For example, tariffs may be imposed on goods coming from export-reliant nations, making products originating in those countries less competitive, or may be imposed on components critical to the production of technology-related goods or services, which may reduce the overall quality of products. The higher cost may also reduce demand in the global economy. In 2019, the Organisation for Economic Co-operation and Development (OECD) estimated that trade disputes could lower global GDP by 0.6 percent by the end of 2021; we took this figure as the lower end of the range.[63] The higher end of the range of the impact is based on a scenario of a 10 percent increase in tariffs on imports by all countries, and includes both direct and indirect impacts on GDP.[64]

3. **Divergence in standards (minus 0.2–1.0 percent of GDP).** In this scenario, companies and countries opt to use diverging standards for technologies, reducing interoperability. Competition over standardization may generate duplication and delay in R&D with an impact on GDP. On the basis of published studies, this may lead the negative impact on GDP of a divergence in standards of between 0.2 percent and 1 percent.[65]

4. **Establishing export controls (minus 0.3–2.0 percent of GDP).** In this scenario, nations limit or ban the export of key strategic technologies (for example, in communications and defense) as well as frontier technologies. Nations also limit the use of foreign-made software, services, and technology or manufacturing equipment. For example, they may impose restrictions on exports of certain key emerging or frontier technologies such as AI and robotics. Depending on substitutability, such export controls can cause supply chain disruption globally. MGI research on value chains in 2020 simulates that losses due to disruption in global supply chains over a decade are equal to about 7 percent of annual company profits.[66]

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[61] Nigel Cory, *Cross-border data flows: Where are the barriers, and what do they cost?* Information Technology & Innovation Foundation, May 1, 2017; and Martina F. Ferracane, *Restrictions on cross-border data flows: a taxonomy*, ECIPE working paper number 1/2017, European Centre for International Political Economy, 2017.

[62] Sources used for this analysis were *Digital globalization: The new era of global flows*, McKinsey Global Institute, March 2016; and Erik van der Marel, Hosuk Lee-Makiyama, and Matthias Bauer, *The costs of data localization: A friendly fire on economic recovery,* European Centre for International Political Economy, May 2014.

[63] *OECD Economic Outlook, Interim Report*, OECD, September 2019.

[64] For a reference, see Antoine Berthou et al., "Costs and consequences of a trade war: A structural analysis," *Rue de la Banque*, Banque de France, December 2018, Issue 72.

[65] Three studies formed the basis for our analysis. See Justus Baron and Tim Pohlmann, "Who cooperates in standards consortia—rivals or competitors?" *Journal of Competition Law & Economics*, December 2013, Volume 9, Issue 4; G. M. Peter Swann, *The economics of standardization: An update*, Report for the UK Department of Business, Innovation and Skills Innovative Economics Limited, 2010; and Nizar Abdelkafi et al., *Understanding ICT Standardization: Principles and Practice*, Hamburg, Germany: Tredition, 2019.

[66] *Risk, resilience, and rebalancing in global value chains*, McKinsey Global Institute, August 2020.

5. **Banning research collaborations (minus 0.1–0.2 percent of GDP).** In this scenario, research collaborations between nationals of specific countries at academic institutions such as universities, think tanks, and nongovernmental bodies and in the private sector are constrained. Academic institutions have faced a growing number of restrictions on research collaboration.[67] Limiting collaboration or a global ban on all cross-border R&D collaborations could in turn impact TFP, which typically account for 30 percent of GDP growth.

6. **Forced technology transfer.** In this scenario, countries arrange technology transfers to local partners. This could happen through various channels such as joint venture requirement for foreign companies, IP transfer requirements, or theft of trade secrets. Such concerns could create disincentives for multinational companies to optimize their global R&D footprint and production base. This would mean that countries cannot fully leverage their comparative advantage, whether developing or advanced nations.[68] It could result in higher costs of production and slower rates of innovation at a global level. The economic impact of forced technology transfer is highly dependent on cases and context, and we have not quantified the magnitude of the potential impact.

7. **Non-tariff barriers (NTB) to market access.** In this scenario, countries deploy series of non-tariff measures such as restrictive licenses, state subsidies, public procurement of localized products, and local compliance requirements. One example is the requirement for foreign companies to form joint ventures with domestic companies, as observed, for instance, in China and Japan. These measures often limit foreign competition and favor domestic players. This can limit competition, increase prices, and reduce welfare for consumers, and, as a result, lead to lower productivity growth. The economic impact of NTB is subject to individual cases and context, and we have not quantified the magnitude of the potential impact.[69]

Our examination of the third-party research suggests that disruptions could result in short-, medium-, and long-term consequences for global GDP. In the short term, reduction in technology-related flows could affect the efficiency of global supply chains and potentially raise transaction costs. Disruption could take several forms, including a need to switch trading partners, set up new bases of intellectual capital, and develop technology that can no longer be readily obtained from a primary export partner. In the medium term, a partial mitigation of risk might be expected. Potential mitigation factors include the creation of compliance-related services and businesses and reduced risk of financial losses from data breaches; the diversion of trade to domestic or alternative sources of imports, which may accelerate the development of industry and productivity in new regions around the world; increased innovation and competitiveness in submissions to international standards organizations; the diversification of supply chains to replace essential components where substitutes exist; the creation of export-control compliance services (for instance, licensing); and an increase in investment in research both domestically and in international collaboration with others that creates value that can be commercialized.

[67] For this reference, see Jenny J. Lee and John P. Haupt, "Winners and losers in US–China scientific research collaborations," *Higher Education*, 2020, Volume 80.

[68] For related literature, see Lee Branstetter and Kamal Saggi, "Intellectual property rights, foreign direct investment, and industrial development," *The Economic Journal*, Volume 121, Issue 555, September 2011; Gene M. Grossman and Elhanan Helpman, "Comparative Advantage and Long-Run Growth," *The American Economic Review*, Volume 80, Number 4, September 1990; Peter Gustafsson and Paul S. Segerstrom, "North–south trade with multinational firms and increasing product variety," *International Economic Review*, 2011, Volume 52, Issue 4.

[69] For more information on impact, see Mike Webb, John Gibson, and Anna Strutt, "Market access implications of non-tariff measures: Estimates for four developed country markets," *The World Economy*, Volume 42, Issue 2, February 2019; Luisa Kinzius, Alexander Sandkamp, and Erdal Yalcin, *Global trade protection and the role of non-tariff barriers*, VoxEU, September 16, 2019.

The magnitude of mitigation of risks will depend on several factors, including the restoration of existing relationships and the creation of new ones; whether countries are heading for a long period of technological stasis or whether technological innovation and flows will revive; and the extent to which new partnerships may be able to boost productivity, inspire new innovation, and capture the consumer surplus that results. For example, in some scenarios the curtailment of apps' access to key markets could enable new companies to innovate in the social media segment.

In the longer term, a new compact in international technology flows could be brokered with new trading blocs, redefined supply chains, and a different pattern of trade flows. However, this new equilibrium would come at the cost of market forces being redirected to get around barriers to technology-related flows.

A more enduring shock could affect certain industries that rely on close global interconnections, including, for instance, automotive and semiconductors, which cannot easily use import substitution strategies as a counterbalance. For example, restrictions on the export of chemicals by one Asian economy to a neighbor triggered an intense debate on the disruption of global supply chains at the latter's high-tech companies.[70]

If negative shocks were to be felt by the world's economies over a long period, global productivity, innovation, and competition could diminish. Further impediments on flows of technology could alter GDP growth. Such impediments include a decline in the commercial value and robustness of data as data flows are reduced; potential retaliatory effects of tariff barriers; a decline in interoperability and productivity as a result of duplicative standards in advanced technologies; disruption to supply chains needed for key technologies as a result of market access limits arising from export control laws; and a slowing pace of scientific advancement and impaired innovation in research.

Looking at countries and regions, mitigation may be uneven, with some nations better positioned to benefit from the loss of technology-related flows than others. Broadly, the potential mitigation could be focused on countries with sufficiently large domestic markets for internal trade to flourish, self-sustaining ecosystems, and the technological capabilities and diplomatic expertise and clout to replace some of the lost links. Large countries could turn global disruptions in technology-related flows into opportunities to close gaps in technological leadership. Some nations may be positioned better than others to capture opportunities, including some of the emerging economies of Southeast Asia that may be attractive "safe harbors" from geopolitical tensions elsewhere.[71] However, as trading blocs reorganize and investment is redirected, some countries may not have the scale or agility to take advantage of the flux in global technology patterns. Others may be unable to take advantage because of treaty obligations and security concerns, for instance.

[70] Pushan Dutt, *The global impact of the trade stand-off between Japan and South Korea*, INSEAD blog, September 27, 2019.
[71] *China and the world: Inside the dynamics of a changing relationship*, McKinsey Global Institute, July 2019.

Box 2

Industry sentiment on potential disruptions to technology-related flows

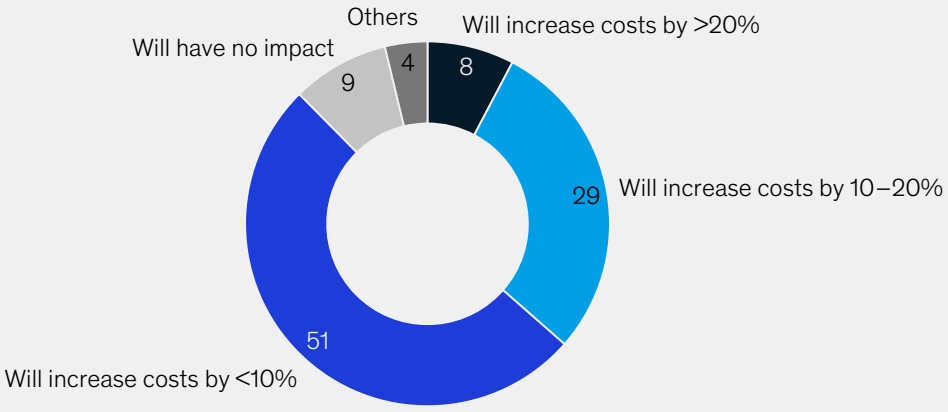
Concern about potential disruption to technology-related flows as a result of trade and other tensions is increasing around the world. One McKinsey survey indicated that 65 percent of technology industry leaders believe some degree of such disruption, sometimes referred to as "decoupling" between the United States and China, is likely in the global technology industry in the next ten years. If this were to occur, most respondents said that it would increase the total cost of goods and cut profit (Exhibit 8).[72]

Exhibit 8

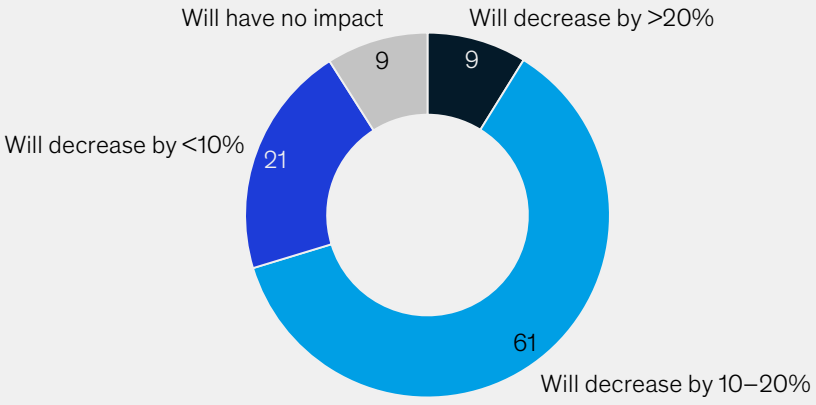
Survey results suggest that technology industry leaders believe potential disruption to technology-related flows may lead to decline in profit.

% of respondents (n = 532)

88% believe "decoupling" between the United States and China will increase delivered cost of systems and applications in 5 years …[1]



… leading to lower profit



1. Examples of systems and applications: PCs, servers, base stations, and data centers.

Source: McKinsey survey, February 2020; McKinsey Global Institute analysis

[72] McKinsey US–China decoupling survey conducted in February 2020.

China and India account for two-thirds of Asia's urban tech hot spots

Where do the four Asias stand in the technology landcape? We analyzed the share of different Asias on two dimensions: IP creation and startup investment. Within Asia, Advanced Asia and China account for the majority of the region's share. China, in particular, stands out given its sheer scale in the region. Looking at this closer and observing global comparisons, we observed both strengths and gaps in Asia versus other major economies. On IP creation, China has a higher share than Western economies in mobile services and clean tech, for example. However, in other technologies such as semiconductors, advertising tech, gaming and e-sports, and mobility tech, China is still behind the global benchmark. In terms of startup investment, China is strong in IoT and education technology, for example. The whole Asia region has gaps in cloud computing and space technology (Exhibit 9).

We also took a city-level view to assess which Asian cities are rising fast as technology hot spots in the region. For this paper, we identified 50 of these cities by creating a technology output index based on three dimensions: technology company revenue, number of unicorns, and number of patents applied (Exhibit 10). China and India account for 68 percent of the 50 hot spots. The majority of the rest are capital cities such as Jakarta and Kuala Lumpur. In our assessment of cities with the fastest growth in technology output over the past decade, we found that 80 percent of them are the same as cities that had the highest technology output in 2019. This suggests that technological ecosystem strength is rather concentrated in Asia.

Exhibit 9

China and, to a lesser extent, Advanced Asia account for the majority of the region's new patents …

Low High

Where Asia has a strong position	Technology	Patent distribution (strength index >50), 2016–18, %[1] United States	Europe	Advanced Asia	China	Rest of Asia
IP creation and startup investment	AI/machine learning					
	Internet of Things					
	Manufacturing equipment					
	Mobile services (incl 5G)					
Startup investment	Advertising tech					
	Cryptocurrency/blockchain					
	Digital commerce					
	Digital supply chain					
	Edtech					
	Fintech					
	Food delivery and restaurant tech					
	Gaming/e-sports					
	Infrastructure					
	Mobility tech					
	Semiconductors					
IP creation	Agtech					
	AR/VR					
	Cleantech					
	Cloud computing					
	Digital HR management					
	Industrials					
	Nanotechnology					
	Robotics/drones					
	Space technology					
	Wellness and beauty					
	Total					

1. Based on patent filing office. Patent strength index is a normalized measure (0 to 100) based on patent claims, references, citations, litigation, and expiration. PatentStrength is a normalized measure (0 to 100) calculated using Clarivate's proprietary algorithm. PatentStrength considers 30 different attributes determined to have a statistically significant correlation to patent value. CPA Global, Innography, and PatentStrength are trademarks of Clarivate and its affiliated companies.

Source: Innography; PitchBook; WIPO; McKinsey Global Institute analysis

Exhibit 9 (continued)

… while the rest of Asia has pockets of excellence in startup activity.

Low High

Where Asia has a strong position	Technology	Startup investment distribution (incl VC and IPO), 2017–19, %[1]				
		United States	Europe	Advanced Asia	China	Rest of Asia
IP creation and startup investment	AI/machine learning					
	Internet of Things					
	Manufacturing equipment					
	Mobile services (incl 5G)					
Startup investment	Advertising tech					
	Cryptocurrency/blockchain					
	Digital commerce					
	Digital supply chain					
	Edtech					
	Fintech					
	Food delivery and restaurant tech					
	Gaming/e-sports					
	Infrastructure					
	Mobility tech					
	Semiconductors					
Knowledge creation	Agtech					
	AR/VR					
	Cleantech					
	Cloud computing					
	Digital HR management					
	Industrials					
	Nanotechnology					
	Robotics/drones					
	Space technology					
	Wellness and beauty					
	Total					

1. Based on destination of investment.

Source: Innography; PitchBook; McKinsey Global Institute analysis

Exhibit 10

MGI mapped 50 Asian technology hot spot cities that had the highest technology output in 2019.

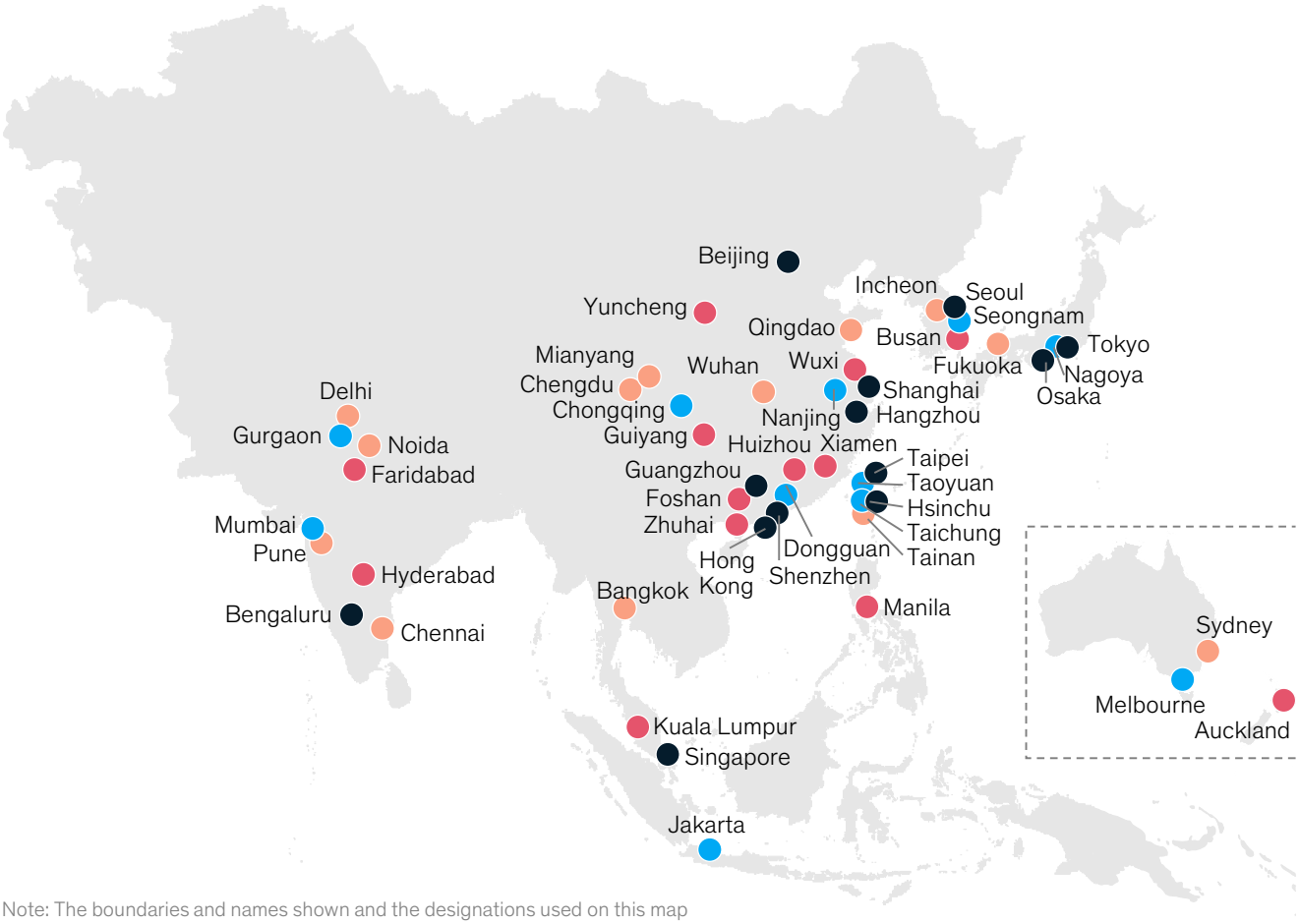
2019 or closest available year

Metrics analyzed

- Number of patents applied
- Technology revenue
- Number of unicorns

Overall technology output index

Low High



Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by McKinsey & Company.

Source: CB Insights; Clarivate Analytics; McKinsey Corporate Performance Analytics; McKinsey Global Institute analysis

We studied the correlation between the environment and the technology output index of cities, and we found that infrastructure, talent, and corporate ecosystems have a high correlation with technology output. In contrast, greenfield investment is not significantly correlated with the index, indicating that investment alone appears to be insufficient to create technology hot spot cities.

Based on an analysis of what is driving a city's technology output index, we identified four types of technology hot spot cities: (1) megacities, which are in the top quartile on at least two dimensions of the three analyzed in creating the technology output index; (2) technology-enterprise driven (high presence of technology companies); (3) unicorn-activity driven; and (4) IP-driven (active patent generation). We applied a general rule that the "technology-driven", "unicorn-activity driven" and "IP-driven" cities are above median on one dimension (for instance, technology company revenue in the case of technology-enterprise driven cities) and below median for the other two (Exhibit 11).

— **Megacities.** Asia has 13 megacities that are technology hot spots, of which eight are in China, two in Japan, and one each in India, Singapore, and South Korea. These cities are all widely known Asian "Silicon Valleys," such as Shenzhen in China and Bengaluru in India. Each of them has developed a robust pipeline of technological developments enabled by a significant presence of educational institutions and large technology companies.

— **Technology-enterprise driven.** In these cities, there is a higher concentration of technology companies with significant operations. Asia has eleven technology hot spot cities in this category, three in China, three in India, two in South Korea, and one each in Australia, Thailand, and Malaysia. Noida in India and Seongnam in South Korea are two examples. Noida, situated close to India's capital, Delhi, was developed as an industrial hub beginning in the late 1970s; its success reflects its proximity to the capital, access to quality talent, and the greater availability of land—and therefore lower rental prices—than in Delhi. Noida is home to several major technology companies, including Accenture, Ericsson, IBM, and TCS. Microsoft plans to build a new hub employing 4,000 people. Noida is also a low-cost manufacturing center that has more than 80 mobile manufacturing factories and manufactures 40 percent of all cellphones made in India.[73] Pangyo Techno Valley in Seongnam, near Seoul, is known as the rising technology hub of South Korea. Established in 2004, it has become a thriving area with more than 1,300 tech companies. The government enabled its development, providing a large parcel of land near the capital and building transportation infrastructure including roads and subways connecting the hub to Seoul and Incheon international airport. Seongnam aims to be a model for smart-city development, an effort that has attracted 35 partner cities and organizations.[74]

[73] Amit Raja Naik, *Noid 'Make in India' hub to manufacture 30% of the world's mobile phones by 2025*, Inc 42, November 17, 2019; and Sanjeev K Jha, "Noida mobile makers get nod to start factories, 50k workers to benefit," *Hindustan Times*, May 6, 2020.

[74] Mike Hibberd, *SynchroniCity builds smart city IoT data marketplace*, Inform, January 2019.

— **Unicorn-activity driven.** Asia has 13 technology hot spot cities in this category: eight in China; two in India; and one each in Australia, Indonesia, and the Philippines. Gurugram (the official name of the city better known as Gurgaon) in India and Jakarta in Indonesia are two examples. Gurugram is home to six of India's 21 unicorns (only Bengaluru has more, with eight).[75] Although Bengaluru is the startup capital of India, Gurugram is popular because it is close to Delhi and 250 of the Fortune 500 firms have an office in the city.[76] Gurugram is also home to consumer-market unicorns such as Oyo Rooms and Zomato. Jakarta, Indonesia's capital, is at the heart of Southeast Asia's internet and digital economy boom, hosting thousands of startups and all four of the country's unicorns. Indonesia is forecast to contribute $133 billion of the expected $300 billion value of Southeast Asia's internet economy in 2025 (including e-commerce goods and online vehicle services, media, and travel).[77] Indonesia ranks fourth in the world in number of internet users, and this is expected to continue to drive internet commerce and trade in the city.[78]

— **IP-driven.** Asia has nine technology hot spot cities in this category: six in China, three in India, two in Japan, and one each in New Zealand and South Korea. Hyderabad in India and Wuhan in China are two examples. Hyderabad is India's largest hub for pharmaceuticals and life sciences, sectors that have high levels of R&D. Hyderabad is sometimes dubbed the vaccine capital of the world, producing two billion doses a year—one-third of all vaccines produced globally—as well as 35 percent of India's pharmaceuticals. The city serves more than 1,000 innovative companies from around the world that are developing various pharmaceuticals.[79] Novartis, Dr. Reddy's Laboratory, GVK Bio, and Sai Life Sciences all have a significant presence in the city, and the medical technology company Medtronic is investing $161 million (1,200 crore rupees) to expand its R&D center.[80] In China, Wuhan has been in the spotlight for being where COVID-19 first came to the world's notice, but the city is also a booming technology hub. It has three national development zones, four scientific and technologic development parks, more than 350 research institutes, 1,656 high-tech enterprises, numerous enterprise incubators, and investment from 230 Fortune Global 500 firms. The city offers globally competitive strengths in many business fields.[81] An AI science and technology park that will focus on innovation of next-generation automobiles is being built there that is expected to attract 400 businesses with annual output of 50 billion renminbi.[82] In 2019, electronics company Xiaomi opened its headquarter in Wuhan, where it plans to build an AI innovation center.[83]

In this section, we analyzed the overall technology landscape of Asia, discussing in some detail the technologies in which the region has potential for further progress—in some cases reflecting current gaps—together with a survey of Asia's urban technology hot spots and the possible impact of disruptions to technology-related flows on costs and economic growth. In the next section, we turn to an analysis of sector-specific opportunities.

[75] "India is home to 21 unicorns, collectively valued at $73.2 billion: Hurun Global Unicorn List 2020," CNBC, August 4, 2020.
[76] *Gurgaon, Current openings*, Nielsen, careers.nielsen.com.
[77] *Indonesia leads Southeast Asia internet economy in 2025*, The Insider Stories, October 7, 2019.
[78] J. Clement, *Countries with the highest number of internet users 2019*, Statista, June 25, 2020.
[79] "Hyderabad's life sciences sector to get major boost," *Telangana Today*, February 18, 2020; V Rishi Kumar, "20 more firms to set up R&D centres in Telangana: KT Rama Rao," *Hindu BusinessLine*, February 17, 2020.
[80] *Hyderabad to host Medtronic's largest global R&D centre outside US*, Mint, August 12, 2020.
[81] *Focus on Wuhan*, Government of Canada, tradecommissioner.gc.ca.
[82] Arjan Kharpal, "China is building a giant $2.1 billion research park dedicated to developing A.I.," CNBC, January 3, 2018.
[83] *Xiaomi Wuhan headquarters officially opened in just 2 years*, GizmoChina, December 18, 2019.

Exhibit 11

There are four types of technology hot spot cities.

Asian cities with top technology output indexes, 2019 or latest available year

	Type			
	Megacity	**Technology-enterprise driven**	**Unicorn-activity driven**	**IP-driven**
Regions and cities	China • Beijing • Guangzhou • Hangzhou • Hong Kong • Hsinchu • Shanghai • Shenzhen • Taipei India • Bengaluru Japan • Osaka • Tokyo Singapore • Singapore South Korea • Seoul	Australia • Melbourne China • Huizhou • Mianyang • Taoyuan India • Chennai • Delhi • Noida • Mumbai • Pune Malaysia • Kuala Lumpur South Korea • Incheon • Seongnam Thailand • Bangkok	Australia • Sydney China • Chengdu • Chongqing • Guiyang • Nanjing • Qingdao • Wuxi • Xiamen • Yuncheng • Zhuhai India • Faridabad • Gurgaon Indonesia • Jakarta Philippines • Manila	China • Dongguan • Foshan • Taichung • Tainan • Wuhan India • Hyderabad Japan • Fukuoka • Nagoya New Zealand • Auckland South Korea • Busan

Source: CB Insights; Clarivate Analytics; McKinsey Corporate Performance Analytics; McKinsey Global Institute analysis

3. Asia has leapfrogging opportunities if it overcomes its challenges

Asia's strong position on four elements—consumer demand, growth of large manufacturing companies with a high share of global revenue, labor endowment, and active policy support—has been a catalyst for advances in technology in relevant sectors, and has enabled a decline in technology costs over time. There are bottlenecks, quality gaps, or other types of challenges in each of these areas, too, suggesting that, if they can be overcome, there is an opportunity for further growth. In this section, we discuss opportunities in four groups of sectors (Exhibit 12):

— **Accelerated consumer digitization creates huge opportunities throughout the value chain.** Asia accounted for 41 percent of global consumer demand in 2018. Moreover, the region is expected to represent the majority of the increase in that demand worldwide, with a share of 56 percent between 2018 and 2030. Asia's high share of global growth has facilitated digitization particularly well in consumer-facing sectors such as consumer goods and services, financial services, and healthcare. There are still substantial gaps in provision of goods and services to consumers in Asia (access to healthcare being an example), instances of low quality, and inefficiencies that, if tackled using digital technologies, could offer further opportunities for growth. In section 3.1, we look at the steps that can be taken to reimagine the consumer experience by creating an integrated digital model. The digital interface with consumers is the first step in that transformation, followed by the creation of cross-sector platforms, and digital enabling of every aspect of the value chain so that individual companies are part of a digital ecosystem.

— **Manufacturing potential is significant on the back of strong large companies.** On average, Asian companies contributed 41 percent of the revenue of the world's top 5,000 companies—the G5000—between 2016 and 2018.[84] In sectors including capital goods, information technology (IT), and energy and infrastructure, the share of global G5000 revenue coming from Asian companies was even higher. However, in some types of core technology, Asia has yet to catch up with other regions, and may find it hard to compete with leading players; examples of relative gaps in technology include semiconductor chips, operating system software, and solutions design. To catch up with the world's leaders, Asia may consider strengthening its development of intangible assets, develop strength in being a provider of solutions rather than only hardware, and accelerate the digitization of operations. In section 3.2, we look at how high demand, a strong manufacturing ecosystem, and resilient supply chains give Asia a platform that could build even more momentum toward further advances in technology.

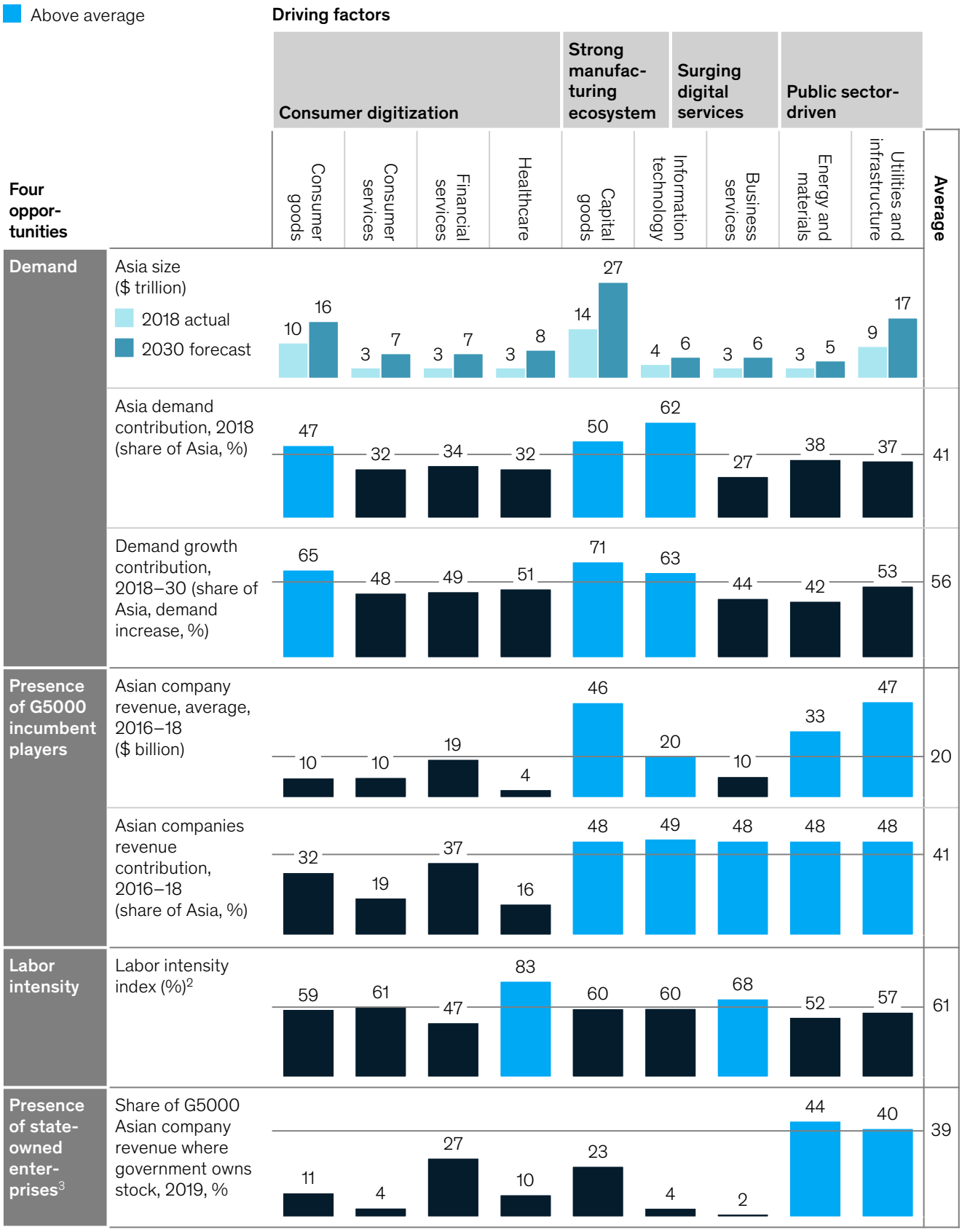
[84] *The future of Asia: Decoding the value and performance of corporate Asia*, McKinsey Global Institute, May 2020.

— **Business technology services are enabled by Asia's strong endowment of labor and talent.** The labor intensity index for IT is high, at 61 percent, and is even higher for business services at 68 percent. So far, Asian firms have demonstrated moderate performance in the IT services segment, accounting for about 29 percent of the global market. Asia accounts for relatively low shares of IT services demand, and has fewer global firms overall than others to meet worldwide demand. Moreover, many firms still have traditional organizational models and the quality of talent has room for improvement. There is considerable scope to raise efficiency and participate in global growth. In section 3.3, we discuss soaring demand for business technology services—IT and digital—and the fact that Asia's strong talent base could make the region the key to the supply of tech talent globally.

— **Energy sectors, notably renewables, are growing strongly because of active policy support.** Governments in Asia have been more active in fueling investment in heavy energy and infrastructure-related sectors than their counterparts in other parts of the world. For example, in in the energy and material, utilities, and infrastructure sectors, 42 percent of the revenue of Asian companies in the G5000 (the world's 5,000 largest companies) are generated by companies in which governments owned significant equity, compared with the global average of 31 percent. The imperative to play an active role in the world's energy transition is high in Asia, which arguably is more exposed to climate risk than any other region in the world. Making the energy transition will require massive portfolio reallocations by companies and countries, promising an era of disruption for energy companies and necessitating very significant investment. In section 3.4, we discuss how the role of policy has been a catalyst to the adoption of technology, how Asia has a strong position in a range of renewable energy sources, and the opportunity for companies to shift their energy portfolios through capital reallocation.

Exhibit 12

Asia can seize four opportunities to leapfrog in its technological development.



1. Asian companies in G5000 by average 2016–18 revenue.
2. Weighted average of labor compensation/gross value added across sectors.
3. Share calculated as revenue of Asian G5000 companies where government owns large stock as percent of total Asian G5000 companies' revenue.

Note: Not to scale. Figures may not sum to 100% because of rounding.

Source: IHS Markit; PitchBook; WIPO; McKinsey Corporate Performance Analytics; McKinsey Global Institute analysis

3.1 Reimagining the consumer experience

Across Asia, consumer adoption of digital technologies is accelerating at a sufficient pace for digitization to enable a jump or leapfrog from old to frontier technologies—in payments, for instance, skipping the credit-card ownership stage and going straight to e-wallets. Because consumers are so open to, and enthusiastic about, these technologies, the region still has a considerable opportunity to reimagine the entire consumer experience.[85] Nevertheless, across consumer markets, there are gaps in provision, access, and quality. Digital technologies can help to overcome these challenges. If Asia deploys digital to help reimagine the consumer experience, then there is scope for further progress. We see three steps in this reimagining: (1) digitizing the consumer experience; (2) creating cross-sector buying platforms; and (3) digitally enabling the entire value chain.

Asia has leapfrogged in consumer digital technologies

Asia has leapfrogged technology cycles in the past ten to 15 years. Consumer markets, particularly in the region's emerging economies, are already using digitization to leapfrog to frontier digital solutions. This has partly been enabled by an absence of legacy infrastructure or services in some markets. Many consumers in Asia do not need to unlearn old patterns of consumption, and companies have not had to invest capital in upgrading legacy systems, advertising, or persuading consumers to use new channels or devices.

— **China already has strength in the consumer-facing digital economy.** China has more than 900 million internet users, larger than the United States and the EU combined. Over 95 percent of them are on mobile platforms. Penetration of mobile payment is three times higher than that of the United States. Digital champions and start-ups constantly experiment with new types of services touching every aspect of consumers' daily life.[86]

— **Advanced Asia already has a mature digital market and is now pushing forward on innovation.** These economies are finding new avenues to connect with consumers and increasing the breadth of services as their businesses mature. COVID-19 has given a second wind to established businesses in mature digital markets; by imposing pressure on business models, the pandemic has been an opportunity to use their developed technology ecosystems to deploy new solutions rapidly. Delivery models continue to evolve by differentiating and discovering new customer needs within existing services. For instance, Market Kurly, a leading grocery e-commerce player in South Korea, pioneered "dawn delivery" of fresh produce ordered hours before, igniting similar efforts by Coupang.[87] Moreover, the consumer product landscape is shifting as the digital market—including app ecosystems, connected devices, and high internet speeds—provides fertile conditions for new consumer experiences. Countries like Japan and South Korea are world leaders in 5G speeds and network experience.[88] They are therefore able to tap into new consumer uses and launch products in areas such as AI-connected devices for coaching of at-home physical fitness classes, AR devices for virtual library exploration, and smart glasses for holographic conferencing.[89]

[85] China is one of the largest consumers of technology in the world—for instance, accounting for 40 percent of global sales of mobile phones in 2017, more than any other country. In 2018, China had more than 800 million internet users, more than the EU and the United States combined, and 95 percent of users accessed the internet via mobile. See *Digital China: Powering the economy to global competitiveness*, McKinsey Global Institute, December 2017; and *China and the world: Inside the dynamics of a changing relationship*, McKinsey Global Institute, July 2019.

[86] *Digital China: Powering the economy to global competitiveness*, McKinsey Global Institute, December 2017.

[87] *Dawn delivery takes retail industry by storm*, The Investor, January 13, 2019.

[88] Joe Devanesan, *South Korea and Japan surge ahead in 5G speed – report*, Techwire Asia, August 10, 2020.

[89] *5G launches in Korea: Get a taste of the future*, Samsung case study, 2019; *Key drivers for Korea's 5G success: Exploring compelling 5G services*, Samsung Newsroom U.S., July 8, 2020.

— **Emerging Asia and Frontier Asia and India, in particular, have an opportunity to leapfrog linear technology cycles with the advent of mobile-first technologies.** Digital adoption in Emerging Asia and India is growing rapidly. Today, India and Indonesia rank low on the World Bank's Digital Adoption Index.[90] However, they have among the highest rates of growth in adoption as investment pours into their economies and governments establish substantial programs to encourage digitization. Indonesia experienced a sharp rise in the penetration of mobile e-commerce, from less than 5 percent in 2011 to 80 percent in 2018—a huge transformation in only a few years. In 2018, Indians downloaded more apps—12.3 billion—than residents of any other country except China; they average 17 hours per week on social media, more time than users in China and the United States. The share of adults with at least one digital financial account has more than doubled since 2011.[91]

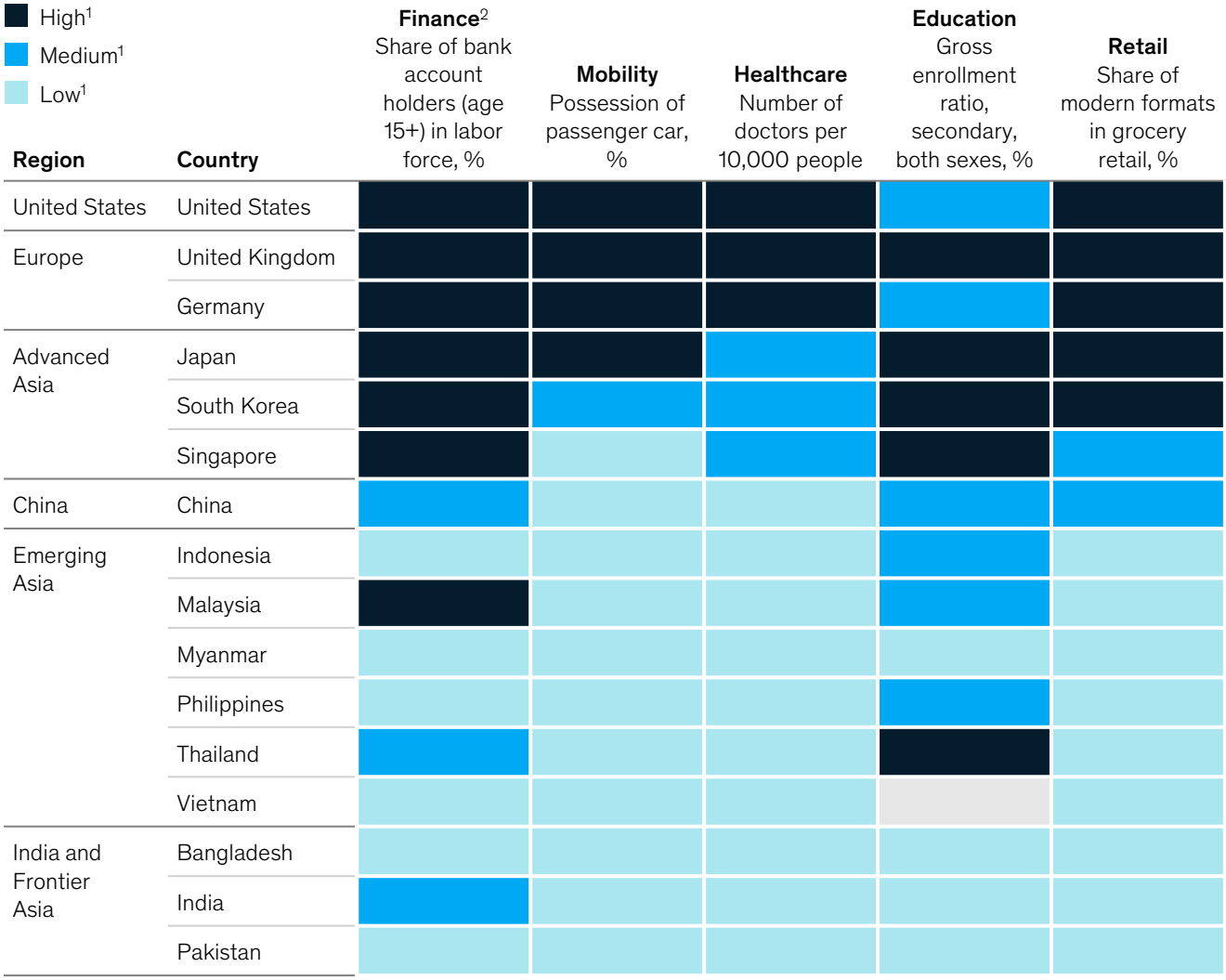
[90] This worldwide index measures countries' digital adoption on three dimensions: people, government, and business.
[91] *Digital India: Technology to transform a connected nation*, McKinsey Global Institute, March 2019.

The first opportunity to reimagine the consumer experience is digitizing buying channels, thus overcoming market gaps and inefficiency

Although mobile internet and digital broadband are becoming commonplace among Asian consumers, users still encounter bottlenecks and stresses. If digital technologies help to tackle these, Asia could have the potential to digitize consumer buying channels to a much greater extent (Exhibit 13). A proliferation of data on Asian consumers, their preferences, and their behavior gathered through online monitoring and tracking services demonstrates unique market gaps.

Exhibit 13

There are widespread untapped opportunities in the Asian consumer sector.



1. High value is defined as >90% of average of the top 5 countries; medium is >70% but <90% of top 5 country average; low is <70% of top 5 country average.
2. Latest year available 2015–19.

Source: Euromonitor International Limited; UNESCO; WHO; World Bank; McKinsey Global Institute analysis

Asia is coming into its own, with consumers expressing unique tastes, indigenous modes of behavior, and new ways of consumption. Building on the existing base of digitized product offerings for consumers, digital consumption will increasingly be oriented toward technology developed specifically for markets in Asia. As these technologies become mainstream and Asia's cultural influence radiates outward, some of these consumer technologies will be exported and adopted in more mature markets overseas.

Digital commerce: Asia has a strengthening position in social commerce and new digital business shopping models as COVID-19 further accelerates adoption

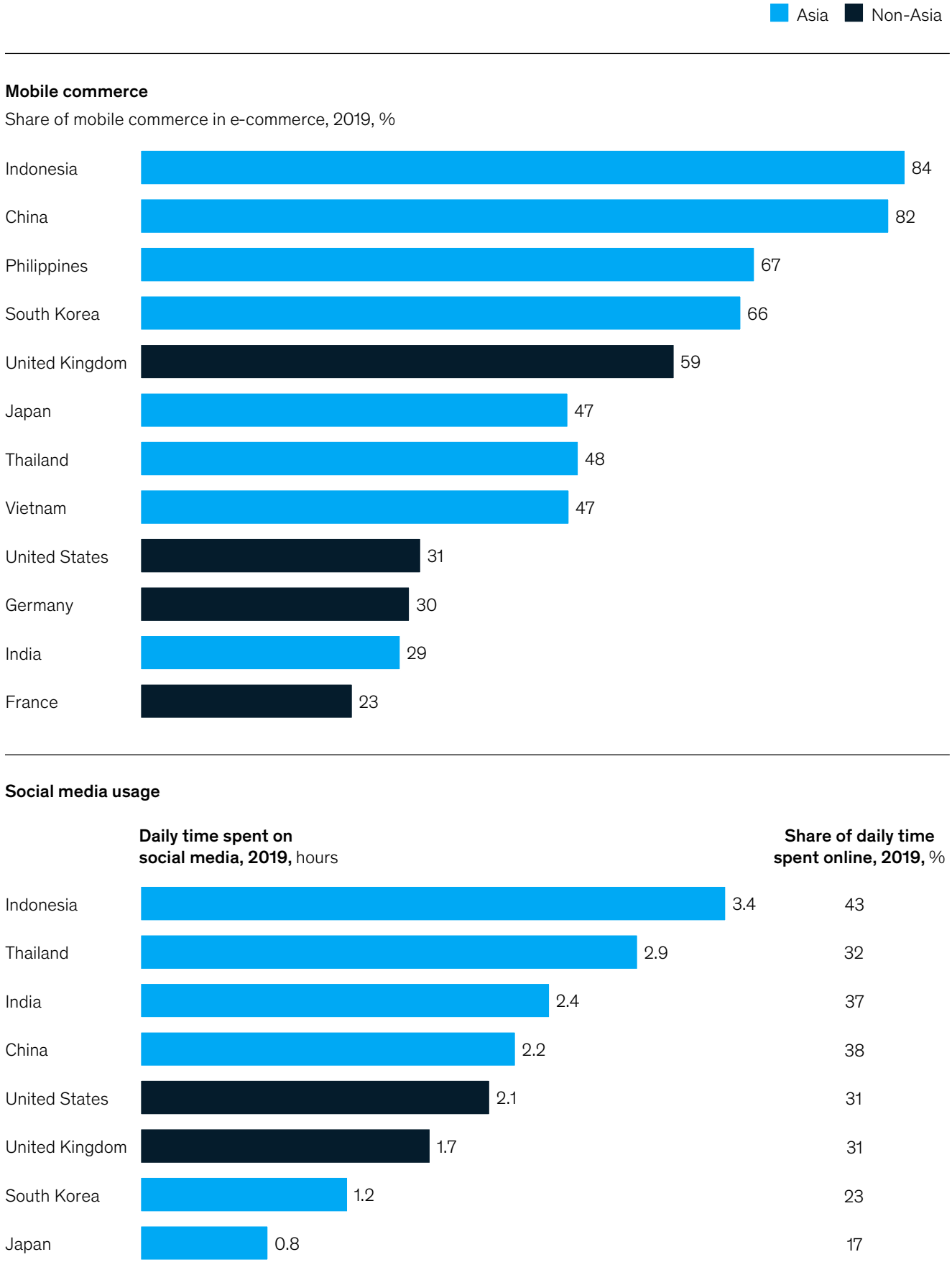
Asia has considerable strength in digital commerce and, in particular, social commerce—the use of social media websites, apps, and technologies to promote and drive consumer sales—that is becoming an increasingly popular type of digital commerce (Exhibit 14). Startup investment continues to pour in from global and Asian sources.[92] This investment surge shows no signs of stopping. Emerging Asia countries such as the Philippines have much room for growth, as cash transactions are still prevalent.[93] From expediting payments for small business owners in remote parts of Asia to accessing online marketplaces and integrating offline and online commerce, opportunities for growth are high. In particular, mobile commerce as a percentage of e-commerce is significantly higher in China (82 percent) and Indonesia (84 percent) than in more mature markets like the United Kingdom (59 percent). The leapfrogging from desktop PC or laptop to mobile phones enables businesses to consolidate channel management and marketing efforts in a more focused fashion to drive consumer experience and purchasing. If anything, growth in digital and social commerce accelerated during the COVID-19 pandemic, when online transactions were the only channel for buying and selling while observing lockdowns and physical-distancing measures (see Box 3, "The COVID-19 impact on digitization in Asian consumer markets").

In China and parts of Advanced Asia, acquisition and retention costs are increasing for established e-commerce platform players. Elsewhere in Asia, e-commerce is experiencing high growth rates. There are, and will continue to be, plenty of opportunities in social commerce. In China, social media-savvy shoppers and businesses have leveraged social commerce to initiate more and more purchases.[94] Consumers in Asia are 1.3 times more likely than the global average to interact with a brand via conversational commerce, in which people connect with businesses through chat or voice with the intention of purchasing goods or services. LINE aand Wechat are examples of a platform being used for conversational commerce.[95]

[92] Kentaro Iwamoto, "Startup investments in Southeast Asia nearly double despite COVID," *Nikkei Asian Review*, July 23, 2020.
[93] *The state of digital payments in the Philippines*, Better Than Cash Alliance, 2019.
[94] Kevin Wei Wang, Alan Lau, and Fang Gong, *How savvy, social shoppers are transforming Chinese e-commerce*, McKinsey & Company, April 15, 2016.
[95] Eunice Loh, *An introduction to social commerce*, IAB SEA+India, March 27, 2020, iabseaindia.com.

Exhibit 14

Asia exhibits strength in mobile commerce and large potential for social commerce.



Source: Euromonitor International Limited; Statista; We Are Social, *Digital 2020;* McKinsey Global Institute analysis

Box 3

The COVID-19 impact on digitization in Asian consumer markets

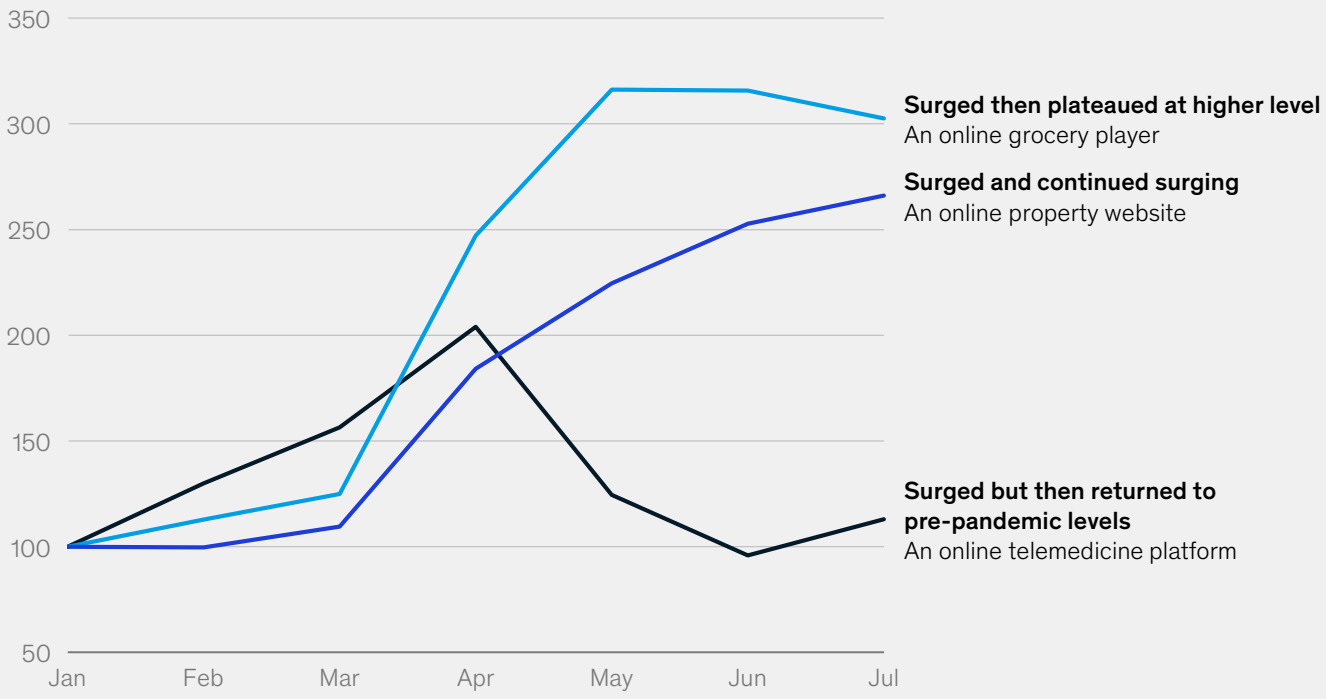
The COVID-19 pandemic has accelerated the adoption of digital solutions by consumers in Asia—and across the globe.[96] In Asia, as elsewhere, consumer segments that had been slow in deploying digital technologies—instead relying largely on face-to-face interactions—such as medical appointments, car showrooms, real estate selling, and education and training, have stepped up their digital deployment. It is as yet unclear whether the new, more digitized approaches in those sectors will become permanent after the pandemic. It is possible that the use of digital technologies that accelerated because of the need to physically distance during COVID-19 may persist, but potentially at a somewhat lower level.

In consumer services, three trends emerged among monthly active users during and after the initial peak of COVID-19 in Asia in the first half of 2020 (Exhibit 15). Telemedicine apps surged before returning to pre-pandemic levels, in part due to movement restrictions as well as the interpersonal nature of healthcare. One online telemedicine app's monthly average users doubled from January to April 2020 before dropping back to January levels in June 2020. Use of grocery apps surged before plateauing and are maintaining the higher level achieved when the pandemic was at its height in the region. Leading players were able to preserve significant value without compromising on freshness, and maintained a higher level of monthly average users. Finally, demand for some digital services surged and continued increasing in popularity. In the case of one online property app, the number of monthly average users almost tripled from January to July 2020, likely because it offered showings around the clock and allowed virtual access to properties regardless of the distance between a user and a property. Other services that experienced a surge online during the pandemic may revert partially or wholly to offline-based interaction models, particularly in businesses with a high degree of personalization that cannot be replicated easily online.

Exhibit 15

COVID-19 accelerated consumer adoption of digital solutions in less digitized sectors in Asia; in some cases, the surge was temporary.

Average monthly users, January–July 2020, index: 100 = January 2020



Note: The trend is analyzed based on consumer panel behavior monitored by Priori.
Source: Priori; McKinsey Global Institute analysis

[96] Nick Leung, Joe Ngai, Jeongmin Seong, and Jonathan Woetzel, *Fast-forward China: How COVID-19 is accelerating five key trends shaping the Chinese economy*, McKinsey & Company, May 2020; Oliver Tonby, Jonathan Woetzel, Noshir Kaka, Wonsik Choi, Jeongmin Seong, Brant Carson, and Lily Ma, *How technology is safeguarding health and livelihoods in Asia*, McKinsey & Company, May 2020; Rachel Diebner, Elizabeth Silliman, Kelly Ungerman, and Maxence Vancauwenberghe, *Adapting customer experience in the time of coronavirus*, McKinsey & Company, April 2, 2020; and Ralph Breuer, Harald Fanderl, Markus Hedwig, and Marcel Meuer, *Service industries can fuel growth by making digital customer experience a priority*, McKinsey & Company, April 30, 2020.

In Emerging Asia and Frontier Asia, social commerce appears to have reached a tipping point at which huge opportunities can materialize.[97] In Thailand, for example, 52 percent of shoppers interacted with social media before making a purchase. In India, 93 percent of SMEs surveyed reported using WhatsApp as a means of selling online.

There are three implications of the increasing popularity of social commerce. First, with individuals increasingly serving as the nexus for product sales, the capture of value becomes more dispersed. Millions of individual content creators are becoming microentrepreneurs or forming micro SMEs with loyal followings, using the force of personality and opinion to move products.[98]

Second, new business models are developing within Asia, bypassing modern retail and even big internet e-commerce players.[99] In China and Emerging Asia countries such as Thailand, livestreaming by individual sellers has created a huge opportunity for social commerce, demonstrating that audiences crave greater interactivity and personalization of the online shopping experience. Apps like Pinduoduo, a group-buying application that recruits users through social media to unlock discounts, aim to make group buying and impulse buys fun and easy with gamified elements.[100] In China, "shoppertainment" events, which marry online sales with game shows, celebrity appearances, and musical performances, have led to large spikes in sales.[101] In India, variants of social commerce have emerged. Meesho enables resellers to leverage WhatsApp, Instagram, and Facebook to market and promote products and drive sales of products Meesho sources from distributors. Meesho has two million social sellers, 80 percent of whom are women.[102] Dealshare, another group-buying platform from India, targets lower-income consumers in small cities and towns and focuses on group buying of grocery and home items. Technologies supportive of social commerce are also growing in Asia. Shoplus, a social commerce merchant tool, processes buying intent from social media comments—for example, in a livestream—and uses a chatbot to convert intent into orders.[103]

Finally, social commerce creates a virtuous cycle of improvements in consumer technology. The adoption of new modes of consumption, and optimized value chains to meet those needs, facilitates the development of consumer technology. New social commerce business models are likely to surge well beyond China and Advanced Asia, but they may well mimic patterns of technological development in these two regions.[104] Demand for virtual fitting rooms and showrooms is already propelling the development of improved augmented and virtual reality technology.[105] Social commerce requires responsive user interfaces and back-end technology to handle more complex marketing funnels, group buying logic, dynamic pricing, and multimodal shipping journeys. Interactive livestreaming capabilities will be needed to cater to the growing shoppertainment and interactive livestreaming formats of e-commerce.[106]

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[97] There are five key social commerce archetypes. Social-first commerce is selling through key opinion leaders (KOLs) and key opinion consumers (KOCs) with on-platform sales. In the case of e-commerce platforms with social marketing, selling happens through KOLs and KOCs on branded e-commerce storefronts. The social discounter model incentivizes sharing buying through lower prices with every incremental customer. In community buy, direct sales by consumers and small businesses are encouraged by commissions for selling to friends. Social direct-to-consumer is when social engagement is catalyzed by brand or KOLs and KOCs in a social messaging app that may be integrated with physical retail.

[98] Eelynn Sim and Meloney C. Lindberg, *Southeast Asia's microbusinesses go digital to compete*, The Asia Foundation, May 13, 2020.

[99] Nilesh Christopher, *Want to buy a parrot? Please log in via Facebook,* Rest of World, July 21, 2020.

[100] Anu Hariharan and Nic Dardenne, *Pinduoduo and the rise of social e-commerce*, Y Combinator, ycombinator.com.

[101] Jane Zhang, "Social commerce taking larger share of China's online retail sales as coronavirus pandemic accelerates 'shoppertainment,'" *South China Morning Post*, June 12, 2020.

[102] Sohini Mitter, *Rise of social commerce startups in India: Meesho, Bulbul, and others leading the way*, Your Story, March 4, 2020.

[103] *AI solution for social commerce*, Shoplus, shoplus.me.

[104] Eunice Loh, *An introduction to social commerce*, IAB SEA+India, March 27, 2020, iabseaindia.com.

[105] Heidi Reidel, *How augmented reality is reshaping retail*, Prescouter, May 2017.

[106] Franklin Chu, *How livestreaming will transform global ecommerce in 2020*, Digital Commerce 360, March 31, 2020.

Through increased interactivity in social commerce, massive amounts of data will be collected to influence the consumer experience, improving the technological sophistication of consumer businesses in Asia. Pinduoduo uses a team purchase model (distributed AI networks) to tailor recommendations for users. Combined with this, and the use of online games to promote what it terms "entertaining consumption," it obtains more data to create better user profiles and tailor promotion strategies.[107] Finally, this technology could cross-pollinate into other sectors of the economy and affect the value chain for commerce. Pinduoduo is able to provide farmers with predicted purchase patterns for fruit, and therefore ensure that their planting schedule is able to match demand at the right time.[108]

Finance: Digital banking promotes financial inclusion and offers personal finance solutions to previously underbanked populations

Outside Advanced Asia, China, India, and Thailand, access to financial services has risen rapidly. In China, Thailand, and India, about 85 percent of people in the labor force have bank accounts, a high share enabled by the widespread adoption of digital payment services that have been encouraged by central government policies, entrepreneurship, and investment. But beyond these and other Asia economies, access to financial services has risen rapidly on the back of digitization that has stimulated financial inclusion.

The government of India has prioritized creating digital identification and payments technology such as the Unified Payment Interface, an instant real-time system that facilitates interbank transactions through mobile phones.[109] The Jan Dhan bank channels government transfer payments to vulnerable segments of society, driving inclusion, and many other opportunities exist for digital commerce to further expand inclusion across Asia.[110] Low-cost and transparent digital banking can improve users' financial health and knowledge, notably among the poor. The design and interface of apps and mobile wallets are simple and improve personal financial knowledge through the ability to track and understand where and how money is being spent. These technologies enable more tailored services for those with low incomes, including remitting money to a family at home, receiving wages, and paying utility bills electronically instead of using cash, which is riskier and more inconvenient. The data trail created helps providers to derive credit scores for small businesses and people working in informal sectors, which opens the way for them to obtain small and micro loans, improving their financial health. Digital payment apps in India such as Paytm and MobiKwik are evolving into digital lending platforms as they accumulate more and more user data. In 2019, MobiKwik disbursed 100,000 fully digital loans ranging from 2,000 rupees to 200,000 rupees (approximately $27 to $2,700). The company experienced fourfold growth in the value of loans disbursed between the first half of the 2019 fiscal year to the first half of the 2020 fiscal year.[111]

Over time, regulators could permit the formation of digital-only banks. Interest is on the rise in Emerging Asia, including Malaysia, emulating more advanced economies in Asia that already allow digital-only banks, such as China, Singapore, and South Korea.[112] New competitors could offer compelling value propositions and steal a march on incumbents. KakaoBank, a South Korean internet company known for its social media messenger service KakaoTalk, obtained a digital banking license and offered lower lending and higher deposit rates to amass 350,000 security accounts within the first ten days of its launch.[113]

[107] Song Jingi, *Pinduoduo is setting up a new tech advisory board led by Baidu's vice chairman Lu Qi*, KrASIA, March 14, 2019; and Butao Wang, *Reflection on our talk with Pinduoduo VP in view of the firms Q2 financials*, Equal Ocean, August 21, 2019.

[108] *Pinduoduo's AI-driven Duo Duo farm empowers farmers, helping to alleviate poverty in rural areas*, Pinduoduo blog, July 12, 2019.

[109] *India digital financial inclusion: Journey map report,* USAID, March 2019; *Digital identification: A key to inclusive growth*, McKinsey Global Institute, April 2019; and *Digital India: Technology to transform a connected nation*, McKinsey Global Institute, March 2019.

[110] Melissa Frakman, *India's digital financial services opportunity in a post-COVID world*, Digital Frontiers, June 15, 2020.

[111] "Seeing strong lending biz growth, MobiKwik targets Rs 1500 cr disbursement this fiscal," *Economic Times*, November 10, 2019.

[112] *Regulatory framework for digital banks (update)*, Bank Negara Malaysia, March 20, 2020.

[113] Sandra Sendingan, "How kakaobank successfully cracked the profitability code two years after rocket launch," *Asian Banking & Finance*, November 17, 2019.

Fintech companies can also offer more services, expanding from simple deposit accounts to micro business loans and eventually investment products, investment advising, and insurance services. Fintech companies that can enter the market alone or form strategic partnerships with incumbent players will have significant opportunities to drive the opening of digital accounts as well as novel ways of engaging with new bank customers.

Building on the foundation of maturing digitized financial systems, the next phase of digitization could propel a change of financial systems across Asia. The People's Bank of China is experimenting with the adoption of the digital yuan, which is poised to become legal tender. The digital yuan is intended to make cross-border settlements more efficient, crack down on counterfeit physical notes, and popularize e-money with partner trading countries.[114]

Other potential offerings include the monetization of data, providing next-generation banking architecture solutions out of Asia, and introducing robo-advisory services to handle the increasingly complex financial and payments landscape.

Mobility: New multimodal transportation solutions are evolving in Asia

Opportunities for change exist in both public and private transportation solutions. Asia is unique in that large swaths of the population rely on affordable two-wheeled motorized vehicles as a primary means of transport. In China, ownership of passenger cars is only 17 percent; in Thailand, the share is 23 percent. This low ownership could be another leapfrogging opportunity.

On the one hand, mobility options need to evolve along with infrastructure. Gridlocked traffic in Indonesia and India means unique solutions will be required for digital transportation to work. In some Asian cities, the starting point for public transport is a *tuk-tuk*, an auto rickshaw, or a jeepney. In Thailand, a public-private partnership will conduct a trial of self-driving tuk-tuks in gated communities to accelerate the development of alternative autonomous vehicles.[115] Data from this trial will be analyzed, and will in future include other autonomous vehicles such as minibuses. Thailand is Southeast Asia's car production hub, and the government has offered incentives to electric vehicle (EV) manufacturers to make the sector competitive.[116] New solutions will have to be built around culturally driven patterns in traffic, such as digitizing dabbawalla deliveries of home-cooked meals to offices around India.[117]

On the other hand, in Advanced Asia, mobility is focused less on optimizing existing transportation modes and more on creating testing grounds for future solutions. In Singapore, the government has deployed a series of smart sensors to gauge vehicle and pedestrian movement and then adjust real-time traffic light signals.[118] In China, driverless air taxis are being developed to ferry passengers and heavy cargo across cities. Shanghai has developed a 100-square-kilometer National Intelligent Vehicle Pilot Zone for autonomous vehicles.[119]

The opportunity exists to move toward environmentally sustainable solutions such as EVs—thereby helping to cut high pollution levels—and, in the case of public transportation in cities, even autonomous people movers such as trains. As Asia's purchasing power grows, autonomous vehicles may also find buyers who are trading up or buying passenger vehicles for the first time. Broader use of technology in mobility solutions could, in turn, advance the use of digital and frontier technologies in the logistics industry.

[114] Zheping Huang, "China's digital yuan gets first big test via tech giant Didi," Bloomberg, July 8, 2020; and Frank Chen, "Beijing to bypass US systems with e-RMB drive," *Asia Times*, June 4, 2020.
[115] "Thailand's iconic tuk-tuks get a makeover as start-up gears up for tests of self-driving models in Bangkok," *South China Morning Post*, September 19, 2019.
[116] Alita Sharon, *Thailand to get self-driving tuk-tuks*, Open Gov, September 19, 2019.
[117] Edd Gent, "The unsurpassed 125-year-old network that feeds Mumbai," BBC, May 16, 2020; and Stefan Thomke, "Mumbai's models of service excellence," *Harvard Business Review*, November 2012.
[118] Janet Pau and Hanson Qu, *Smart cities and urban innovation in Asia*, Asia Business Council, February 2016.
[119] Yujie Xue, "Chinese flying taxi maker Ehang gets approval to test drone deliveries for cargo weighing over 150kg," *South China Morning Post*, May 29, 2020.

Asia also has an opportunity to build smart cities using geolocation, telemetry, battery technology, high-conductivity wiring, and data processing services. Technology could, for instance, improve the efficiency of routes and route planning, and transform last-mile delivery. These solutions could become even more important in the wake of the COVID-19 crisis and the new emphasis on physical distancing.

Healthcare: Opportunities to improve access with telehealth solutions and modernize the sector

Doctor-to-population ratios in Asia lag behind those in Europe and the United States, suggesting a considerable opportunity to use digital technologies for healthcare. Already, wearable tech collects health data, providing early-stage intervention and progress tracking. Telemedicine may be both a stand-alone offering and a way for healthcare systems to rebalance capacity and offer a seamless experience to customers.

COVID-19 catalyzed the development of telehealth services amid soaring demand for remote medical delivery, not only in China and Advanced Asia but across the region where needs are even greater due to low doctor-patient ratios and gaps in quality and provision. In India, the telemedicine company 1mg experienced a surge in the share of customers willing to pay for doctor consultations, from 8 to 70 percent, between March and May 2020. The number of doctors showing interest in the platform jumped from 150 to 10,000.[120] Practo, which offers both remote consultation within 60 seconds and practice-management software, is using algorithms to help patients search for the right doctors and healthcare providers. Practo responded to the pandemic by using an AI tool to assess patients through guided pre-consultation screenings and used World Health Organization protocols to profile high-risk people based on their travel and contact history.[121] In the case of India, the tide turned toward remote medicine when online medicine and doctor consultations were designated essential services.[122] In February 2020, Apollo Hospitals, the largest hospital chain in India, launched the country's largest end-to-end omni channel healthcare digital platform—Apollo 24|7—which so far has served 15 million users across 440 cities in India. Apollo leverages AI systems and rich data together with its 7,000 doctors across over 50 specializations to deliver services to patients.[123] Competition in online pharmacies has heated up in Asia. One analysis puts the potential value of India's online pharmacy sector at $5.4 billion.[124] Already, Amazon Pharmacy delivers prescription medicines, medical devices, and healthcare packages.[125] Reliance recently acquired a majority stake in online pharmacy Netmeds' parent company for $83 million.[126]

In Indonesia, the HaloDoc app facilitates the delivery of medicines to more rural parts of the country in partnership with thousands of pharmacies nationwide. As a source of rich healthcare and patient data, HaloDoc has also partnered with insurers, last-mile logistics providers, and hospital networks to book laboratory tests, schedule hospital appointments, and make claims more seamless.[127]

Some new delivery models integrate telehealth with the wider healthcare network. In the burgeoning "discreet telemedicine" economy, practitioners diagnose and dispense medicine related to fertility, contraceptives, and other areas considered taboo in some parts of Asia, such as mental health. Online healthcare systems also can mesh with existing clinic networks. Ping An Good Doctor is building "internet hospitals" by integrating with the hospital information system in Guangxi to provide step-down and follow-up consultations for chronic illnesses and monitor patients using connected health tools and online diagnosis systems.

[120] Mihir Dalala, *The coming of age of e-health platforms*, Mint, May 25, 2020.
[121] Nikhar Aggarwal, "How Practo uses artificial intelligence," *Economic Times*, September 3, 2020.
[122] Mihir Dalala, *The coming of age of e-health platforms*, Mint, May 25, 2020.
[123] Jwalit Vyas, "For Apollo Hospitals, online pharmacy is the new growth frontier," Economic Times, June 30, 2020; and Sudipta Dev, "AI powered tech of Apollo 24|7 serves millions since Feb this year," Express Computer, August 11, 2020.
[124] Soumen Mandal, *Why telemedicine is the next big opportunity in Indian healthtech,* Inc 42, April 16, 2020.
[125] Avinash Tiwary, *Amazon now delivers medicine to Indians' doorstep*, KrASIA, August 14, 2020.
[126] Manish Singh, "India's Reliance Retail acquires a majority stake in online pharmacy Netmeds' parent firm for $83.2m," TechCrunch, August 18, 2020.
[127] Dafizeck Bin Daud, *Indonesia's Halodoc receives series B+ funding from Bill Gates, others,* Tech In Asia, July 25, 2019.

Other telehealth opportunities reflect Asia's diverse healthcare landscape. Among them is the opportunity to modernize traditional health practices and bring them to younger audiences. In China, JD Health has launched a traditional Chinese medicine consultation product, which allows experts to provide consultation and live broadcasts for patients in both English and Mandarin, appealing to the Chinese diaspora and wider audiences internationally.

The second opportunity is developing cross-sector platforms to expand consumer offerings and communities of customers

The digitization in consumer markets observed thus far is just the starting point of an ongoing process. Digital payments, for instance, established a beachhead for other connected financial services, including consumer-facing digital banks, robo-advisory services, and online wealth-management tools.

Consumer-facing technology companies that have loyal customer bases are expanding horizontally by becoming "superapps," a trend already well under way in China. Alibaba has established services including mobile payments and cloud computing through Alipay and Alibaba Cloud, and added remote work service DingTalk and telehealth service AliHealth.[128] Other Asian countries are fast catching up. Grab, for instance, began as a mobility solution and has expanded into providing a wallet and services from travel to hospitality, food, entertainment, and healthcare. In India, Jio has reinvented itself by providing a range of digital services, including JioCinema, which lets users stream movies; JioChat, which provides free chat and voice and video calls; JioMoney, for payments; and JioHealthHub, where customers can store and manage health data. In South Korea, Kakao is broadening its content value chain by, for instance, launching Kakao TV, with entertainment content produced in-house.[129] The company is also planning to launch new delivery services using the KakaoTalk chatbot ordering function.[130] Existing offerings such as a service enabling the transfer of money experienced a threefold increase in use during the pandemic because of physical distancing rules.[131]

By offering complementary services to their user bases, technology companies that sit at the center of considerable ecosystems are connecting with consumers through multiple touchpoints, bringing down the cost of acquisition and marketing, and reaping even more network effects. Such ecosystem tech players have the advantage of deep pockets, broad market access, and loyal—and large—customer bases, and therefore have the ability to commercialize new solutions rapidly. These companies store a great deal of customer data that, with growing AI and machine learning capabilities, can be used to develop even more targeted products and advertising. Enormous volumes of customer data generated in Asia coupled with growing opportunities to monetize those data are creating platform economies that could unlock significant value in the future.

[128] *Digital China: Powering the economy to global competitiveness*, McKinsey Global Institute, December 2017.
[129] Choi Moon-hee, "Kakao and Naver to square off with Netflix in OTT market," *Business Korea*, August 25, 2020.
[130] "Kakao's new delivery service has competitors on edge," *Korea Bizwire*, August 7, 2020.
[131] Park Sae-jin, "S. Korea uses digital payment more frequently to offer condolence money amid pandemic," *Aju Business Daily*, August 25, 2020.

Companies can amass enormous amounts of customer data via multiple touchpoints to build ecosystems that provide a wide array of opportunities in personalization, cross-selling, and targeting. A 360-degree view of the customer represents considerable opportunities for monetization. Health, behavioral, location, and financial data can help these ecosystems unlock significant value by identifying underserved customers, launching new products and services, taking in feedback and refining products, and sharing data with other partners to further enrich the data set. Grab, for instance, collects data from multiple nodes across its ecosystem. The data are used to strengthen its product offering, for instance by suggesting pickup locations at a particular time and day of the week, or deciding which product features to prioritize when launching in a new city.[132] Grab can also use rider and delivery data to optimize routes by sharing data, often in public-private partnerships, and helping to craft improved transportation regulation.[133] Data on consumer and business payments on GrabPay can be used to make decisions about whether to extend loans.

Ecosystems also integrate data so that they can provide timely interventions to secure customers' lifetime value and offer opportunities to develop customer loyalty. For instance, an e-commerce company may deliver "nudges" via its app at a time when a user is most likely to migrate to another provider, thus encouraging continued use of its app.

The third opportunity is digitizing value chains, including routes to market and business processes, creating a technological ecosystem

The combination of proven technological leapfrogging across Asia, many inefficiencies and gaps in consumer markets, and rapid digitization across industries suggests that there are three broad and significant opportunities ahead. The first is that technological advances will permeate more areas of the value chain through world-leading digital commerce. The second is innovative route-to-market solutions. The third is digitization of business processes.

Routes to market across the retail value chain

The way goods make their way to consumers is changing throughout the supply chain. Digital business-to-business (B2B) players are joining supply chains, adding value to small businesses and ultimately to the consumers these small businesses serve. These digital B2B companies are disrupting the traditional business-to-consumer route to market in Asia through a combination of digital platforms, logistics, payments, and inventory services.

Business models are being disrupted as traditional trade contends with digital native players. In the first wave of digitization, offline businesses largely dug in their heels and competed with online businesses for eyeballs, traffic, and dollars. In this next wave, most businesses will have an online-only, online-to-offline, or hybrid business model that leverages the ease of doing business on the internet. Instead, businesses are evolving to utilize innovative route-to-market solutions. Ecosystem businesses that solve multiple pain points in digital payments, logistics, inventory management, and marketing will form a necessary conductive membrane for commerce in Asia. B2B digital players like Alibaba's LST and Udaan in India are reducing the number of unnecessary intermediaries in the entire sourcing-to-payment process by orchestrating all supply-chain actors via a central node on their platforms. Payment cycles are reduced, pricing is more transparent, choice is plentiful, and analytics on both business performance management and customer behavior are increasingly offered, growing revenue.

[132] *Ride-sharing company, Grab analyzes millions of rose of user data to optimize customer experience*, Tableau.
[133] *Understanding big data to unlock the future of smarter transportation*, Grab, September 27, 2018; and Nina Teng, *Grab's proactive approach to regulatory affairs*, International Telecommunication Union, May 18, 2016.

Spreading digitization in Asia is bringing into the fold businesses once thought to be beyond the reach of efforts to digitize. Asia has millions of small traditional retailers. These mom-and-pop stores tended to be concentrated in lower-tier cities and outside urban areas, and obtained goods from a network of middlemen and local suppliers, often known to the family. In the early phase of digitization, many of these stores were replaced by e-commerce. Now, however, digital players such as Alibaba's LST and JD's Xin Tong Lu connect these small stores by providing them a range of digital services including sourcing (transparent and real-time prices), financing (trade financing loans), ordering (digitized replenishment of goods), and the creation of online storefronts (virtualizing of offline stores). The result is that millions of mom-and-pop stores can grow in scale and benefit sufficiently from technology to become plugged into global markets. The Udaan platform experienced a 14-fold growth in revenue in 2018 and 2019 alone.[134] Alibaba's LST increased its coverage of these small stores by 43 percent from 2017 to 2018.[135]

Digitization of business processes

Digitization is occurring not only at the interface with customers, but in back-end business processes. Many companies have embarked on large-scale digitization of core business functions and processes, reorienting the way they do business.

Banking is a case in point.[136] YONO, the State Bank of India's digital platform, serves customers through its app as well as an omnichannel for employees that they can use to open an account, take out a loan, and access a number of nonfinancial services. Within 14 months of its launch, YONO had become the market leader in India in digital personal loans, with about $200 million of preapproved personal loans disbursed, and had reduced the time it takes to open an account by 80 percent.

In workforce planning, Indonesian enterprises are leveraging automation. Some 27 million to 46 million new jobs could be created, outpacing the number of jobs lost to automation.[137] Automation has the potential to raise productivity and GDP growth and to generate higher incomes for workers and market opportunities for companies. Automation will take on activities such as data collection and processing, and demand for new skills for work not easily done by machines could rise.

[134] Jai Vardhan and Gaurav Tyagi, *Exclusive: Udaan by the numbers, Rs 20,00 Cr valuation and 46 Cr revenue*, Entrackr, February 3, 2020.
[135] Lulu Yilun Chen, "Alibaba prepares a grand retail experiment for this Singles' day," Bloomberg, November 8, 2017; and Joey Hu, *Alibaba LST plans to cover 30% of retail stores in China*, Cifnews, September 5, 2018.
[136] Jacob Dahl, Ervin Ng, and Joydeep Sengupta, *Future of Asia: Banking: How Asia is reinventing banking for the digital age*, McKinsey & Company, January 2020.
[137] Vishal Agarwal, Michael Chui, Kaushik Das, Vivek Lath, and Phillia Wibowo, *Automation and the future of work in Indonesia: Jobs lost, jobs gained, jobs changed*, McKinsey & Company, September 2019.

3.2 Turning manufacturing strength into technology advances

With a rapidly growing share of global consumption and (thus far) resilient manufacturing supply chains, Asia is well positioned to leapfrog in future technologies. The region's position as the epicenter of global manufacturing has strengthened over the years. A strong manufacturing sector accelerates technological advances because manufacturing typically accounts for the majority of business R&D investment, helps to speed up iterations needed for innovation, and contributes to technological accumulation.[138] Nevertheless, in some areas of core technology, including, for instance, semicondictor chips, software, and the design of solutions, Asia lags behind other regions. Broadly, Asia may continue to find it difficult to compete with leading players on legacy technologies, but it has a distinct opportunity to forge a world-competitive position in industries that are experiencing disruptive, dynamic change and emerging technologies. To overcome these challenges, Asia may consider strengthening its development of intangible assets, build strength as a solutions provider, and accelerate digital transformation in the operations for firms.

In this section, we look in some detail at key capital goods and information and communications technology (ICT) sectors to gauge Asia's potential in new and emerging technologies. We focus on mobile phone and automotive value chains to explore the factors that may enable the region to achieve a technological leap forward.

Asia's manufacturing value chains have remained robust so far, and shifts in footprint are mostly happening within the region

Numerous events in recent years, including the current COVID-19 pandemic, have disrupted production by many companies and raised concerns about the resilience of supply chains. Much of the discussion of this topic in advanced economies focuses on reshoring or relocation. MGI research found that 16 to 26 percent of exports worth $2.9 trillion to $4.6 trillion in 2018 has the potential to move to new countries.[139] In general, the economic case is most viable for moving labor-intensive value chains such as textiles and apparel. Value chains in the global innovations category, including mobile phones and automotive, are subject to the most scrutiny and possible government intervention based on their high-value, cutting-edge technologies and their perceived importance for national competitiveness.

Asia demonstrates signs of robustness and resilience in technology value chains based on the evidence of smartphone and EV manufacturing ecosystems. In each, the region accounts for more than half of global market demand—52 percent in the case of smartphones and 62 percent in the case of EVs.[140] Manufacturing footprints are as large as or even greater than these market shares.

[138] *Manufacturing the future: The next era of global growth and innovation*, McKinsey Global Institute and McKinsey Operations Practice, November 2012; and Dan Su and Yang Yao, "Manufacturing as the key engine of economic growth for middle-income economies," *Journal of the Asia Pacific Economy,* 2017, Volume 22, Issue 1.
[139] *Risk, resilience, and rebalancing in global value chain*s, McKinsey Global Institute, August 2020.
[140] According to IDC, IHS Markit, and the McKinsey Center for Future Mobility database.

Based on our analysis of the changing position of capital goods and ICT, we found that manufacturing footprints have largely shifted within Asia because of the need to remain close to end customers, favorable labor-market conditions compared with other regions, the existence of well-established and cohesive supplier ecosystems within Asia, and established and improving infrastructure:

— **Proximity to large markets.** Manufacturing tends to be located close to large markets, and Asia's share of the value of global consumption is projected to grow rapidly, from 29 percent in 2019 to 39 percent in 2040. Moreover, the quality of consumption is likely to rise as the region's rapidly growing middle class—projected to account for 54 percent of the global middle class by 2035—continues to trade up.[141] The trend is likely to be more pronounced in consumption of technology-intensive products as adoption rates of key products accelerate. In the case of smartphones, the adoption rate in Asia was only 40 percent in 2018 versus 77 percent in the United States, suggesting significant room to increase. As demand within Asia rises, it is highly probable that technology-intensive value chains within the region will remain strong to serve local demand.

— **Favorable labor-market conditions.** Labor-market dynamics, specifically more access to skilled labor at a low cost, are likely to favor Asia over other regions. Although the gap with advanced economies has narrowed in recent years, Asian countries' manufacturing labor still has a significant cost advantage. In the case of China, labor costs remain at 26 and 16 percent of those of Europe and the United States, even after having grown at a compound annual rate of 11 percent over the past decade.[142] Labor costs in emerging manufacturing centers such as India and Vietnam are 30 to 40 percent lower than in China. Access to labor is relatively easy in Asia, which has an average Hays Global Index Score of 5.0, compared with 5.4 in Europe and 5.6 in North America (the lower the score, the better the access).[143]

— **Supplier ecosystem.** Asia is home to strong manufacturing clusters that are difficult to replace. Asia accounted for half of global manufacturing value added in 2018. Advanced Asia and China are investing heavily in the manufacturing sectors of Emerging Asia economies. China is shifting away from labor-intensive manufacturing, and Emerging Asia and Frontier Asia are picking up a share of this activity.[144] The strong supplier ecosystem creates momentum for additional manufacturing capacity to stay in the region so that companies can access upstream vendors easily.

[141] In McKinsey's 2015 China Consumer Survey of 10,000 consumers, more than half of respondents said that they were willing to trade up to premium offerings in fast-moving consumer products such as cosmetics, spirits, and oral care. About 60 percent of respondents said that whether a product is a famous brand or organic is an important factor they consider when buying food and beverages. See *China and the world: Inside the dynamics of a changing relationship*, McKinsey Global Institute, July 2019; and *China's choice: Capturing the $5 trillion productivity opportunity*, McKinsey Global Institute, June 2016.

[142] Europe's manufacturing labor cost is calculated as the aggregated manufacturing labor cost of 25 major European countries weighted by population.

[143] The Hays Global Skills Index measures labor skills based on factors such as educational flexibility, labor-market participation, talent mismatch, wage pressure, and so on, hays-index.com.

[144] *The future of Asia: Asia's flows and networks are defining the next phase of globalization*, McKinsey Global Institute, September 2019.

— **Established and improving infrastructure.** The economies of Advanced Asia have longer histories as manufacturing hubs and generally have well-established infrastructure for technology manufacturing while Emerging Asia is rapidly catching up with global standards. Advanced Asia has one of the most stable electrical supplies in the world.[145] Using the World Economic Forum's rankings on the quality of electricity supply as our metric for comparison, Asia has a standardized score of 6.4, compared with 5.9 in North America and 5.8 in Europe. Developing Asia lags behind the 4.7 global average with a score of 4.4, but the electricity supply has improved rapidly. Between 2007 and 2017, China's index score rose from 3.8 to 5.0, in India from 3.2 to 4.7, and in Southeast Asia from 4.1 to 4.6. Asia also has the world's most extensive rail transport network. China and India have 131,000 kilometers and 67,415 kilometers of rail in place. These two countries alone account for the equivalent of 133 percent of the US rail network and 91 percent of EU rail network capacity.[146] The quality of Asia's rail infrastructure is also improving. On the World Economic Forum's index of the quality of railroad infrastructure, scores rose from 3.7 in 2010 to 4.0 in 2017, nearly closing the gap with Europe at 4.1 and North America at 4.4.

Gaps in core "old" tech remain, but Asia has an opportunity to develop a strong position in "new" technologies

Most Asian countries lag behind other regions in the production of established "old" technologies including, for instance, semiconductor design. Previous MGI research noted that China still depends on imports of some core technologies, such as semiconductors and optical devices, as well as IP. In 2017, China incurred $29 billion worth of imported IP charges while charging only about $5 billion for exported IP (17 percent of its imports).[147] Japan and South Korea have a solid technological knowledge base, but innovation is slowing. Emerging Asian economies still lag significantly behind China and Asia's advanced economies in technological capabilities. However, they have begun to carve out a leading position in newer technologies, including smartphone chips and EV batteries.

Through continuous R&D investment, leaders in each industry opened up technological gaps with lagging firms; the older the technology, the wider the difference. Gaps remained in industries where software and IP are significant barriers to newcomers. Broadly, Asia has made the most headway in industries where it has been able to use its prowess in manufacturing as an effective entry point. In emerging technology areas, Asia has the potential to leverage its manufacturing strengths, ensuring the efficient transfer of innovations into manufactured products.

How could this play out in smartphones?

Asia's strong position in manufacturing is prominent including the case of smartphones, with about 97 percent of assembly taking place in the region in 2017. That is a higher percentage than Asia's share of global demand for these items or the 59 percent share commanded by manufacturers headquartered in the region. Asia's very high share of global smartphone manufacturing reflects the fact that it is the location of significant clusters of value chains with core components largely produced in the region. In addition, Asia's share of semiconductor production is also significant, with about 69 percent of semiconductor players in production volume and roughly 78 percent of global production capacity located in the region (Exhibit 16).

[145] *The global competitiveness report 2017–2018*, World Economic Forum, September 2017. The index on the quality of electrical supplies goes from one to seven.

[146] Data come from multiple sources, including national statistical agencies and the United Nations Economic Commission for Europe.

[147] "Imported" IP charges are payments China makes to other countries for their IP. "Exported" IP charges are payments China receives from other countries for domestic IP. See *China and the world: Inside the dynamics of a changing relationship*, McKinsey Global Institute, July 2019.

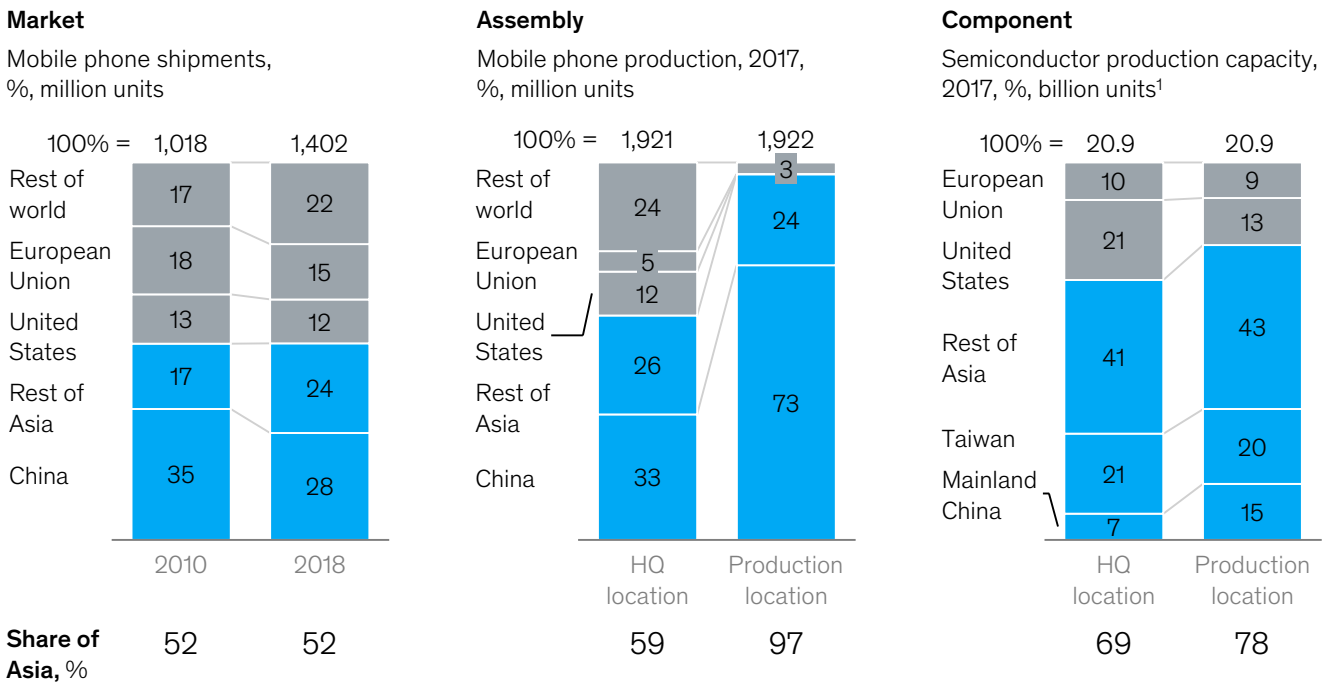
Mobile-phone manufacturing in Asia benefits from the region's well-connected and cohesive manufacturing ecosystem. The fact that about 85 percent of semiconductors are exported by Asian countries has helped to develop the region's core manufacturing ecosystem. Semiconductors account for about 40 percent of the total cost of mobile phones (bill of materials), and the speed of technological development is very rapid, emphasizing the importance of time to market more than any other components.

Regional mobile value chains are robust, and most shifts in manufacturing footprint in recent years have been within Asia (Exhibit 17). Some recent shifts have seen manufacturing go from China to India and Vietnam, which both increased production.[148] Because Asia's manufacturing ecosystem is largely within the region, it is gradually absorbing the value added from the manufacturing of communication equipment.

Exhibit 16

Asia's manufacturing value chains have been strong and resilient thus far.

Example: Mobile phones



1. Million wafer starts per month.
Note: Figures may not sum to 100% because of rounding.
Source: IDC Quarterly Mobile Phone, Q3 2020; IHS Markit; McKinsey battery database; McKinsey Center for Future Mobility datab ase; NVR; SEMI World Fab Watch; Strategy Analytics; McKinsey Global Institute analysis

[148] *Samsung makes a move to India and Vietnam after officially shutting down production in China*, Tecoholic, October 8, 2019.

Exhibit 17

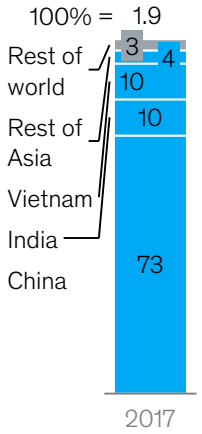
Shifts in manufacturing footprints have largely been within Asia.

Asia

Example: Mobile phones

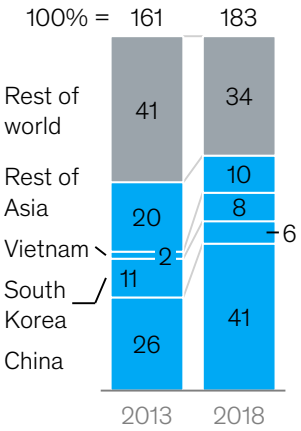
Production

Mobile phone production, 2017, %, billion units



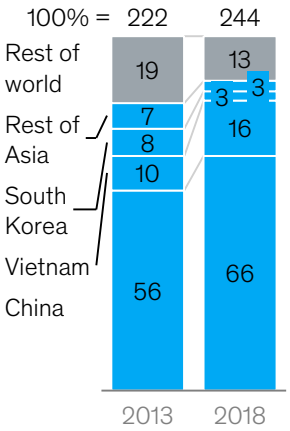
Value added

Value added in manufacturing of communication equipment, %, $ billion

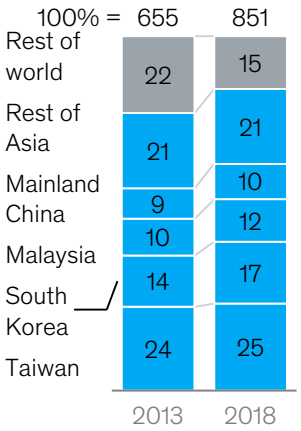


Exports

Mobile phone exports, %, $ billion[1]



Semiconductor exports, %, $ billion[1]



Share of Asia, %	97	59	65	81	88	78	85

1. May include trade of intermediate goods.

Note: Figures may not sum to 100% because of rounding.

Source: IHS Markit; NVR; SEMI World Fab Watch; Strategy Analytics; UN Comtrade; McKinsey Global Institute analysis

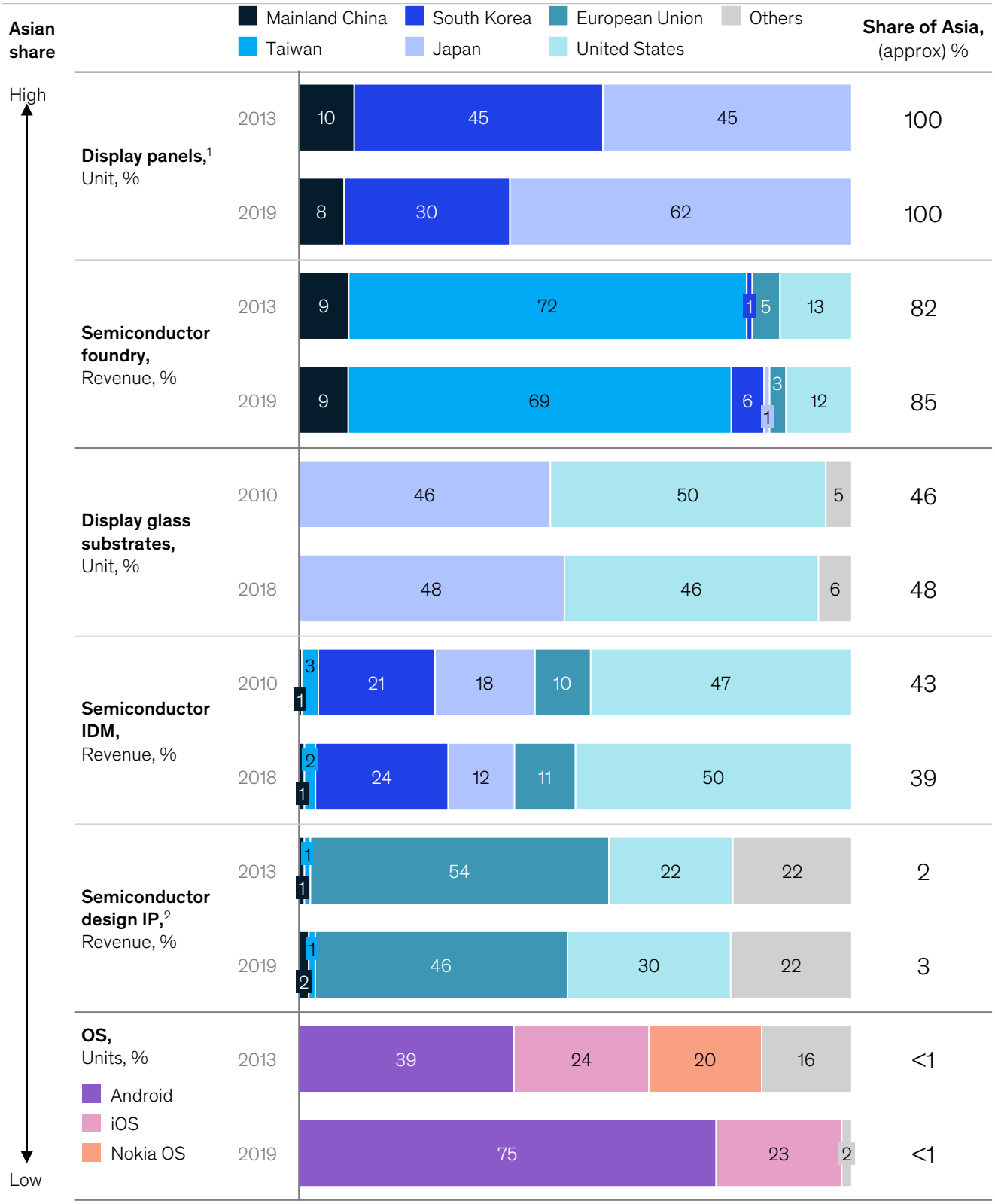
Nevertheless, Asia lags behind in the manufacture of old technologies even while carving out globally competitive positions in some frontier technologies (Exhibit 18). The region has a minimal footprint in nonmanufacturing value chains such as semiconductor design IP, and operating systems. Economies in Advanced Asia have managed to build share in some related segments, namely glass substrates, and in integrated device manufacturing, but still lag behind in others. Asia has trailed the rest of the world in R&D spending on core component technology such as semiconductors, for instance. Asian players have, however, become leaders in display panel and foundry value chains. These segments originated in the less technology-intensive parts of the smartphone value chain where there is less need to own the IP. Over time, however, leading enterprises in these parts of the value chain have erected high barriers to entry by cultivating process technology and developing economies of scale.

Exhibit 18

Asia's gaps in "old" core technologies remain.

Example: Mobile phones

The United States and Europe have a high share in the core technology of key components



1. 2013, all electronic panels manufactured, 2019 smartphone panels shipped.
2. Nationality specified only for top ten companies; others may include all geographical areas.

Note: Figures may not sum to 100% because of rounding.

Source: IC Insights; IHS Markit; IPnest; McKinsey Semiconductor Practice; McKinsey Global Institute analysis

We look at examples of technologies relevant to mobile telephony where manufacturing strengths have enabled Asia to develop innovations, including the following:

— **Mobile application processors.** As noted, the smartphone value chain is largely in Asia, a situation that offers opportunities for upstream vertical integration. Asian smartphone OEMs are internalizing the design and manufacturing of mobile application processors using cash flow built on the back of growing demand in the region. Smartphone penetration rates—53 percent in China and 31 percent in India in 2019—clearly signal room for further growth in demand, encouraging and enabling OEMs to invest more.[149] The mobile application processor value chain is less vertically integrated than those of central processing units (CPUs) and graphics processing units, where most of the value chain from IP to design and manufacturing comprises only a small number of players. This characteristic offers Asian OEMs an opportunity to break into the mobile application processor design value chain without developing IP in-house.

— **5G.** Asia has been quick to adopt the latest communication infrastructure and reinvest in R&D to support innovation in a range of technologies related to mobile. Demand for 5G is high and growing in Asia, which is home to a majority of the world's subscribers to this technology. This lead may persist given that the region is also home to strong wireless-network infrastructure players that are developing key types of IP in this area. Asian players are leading the race in 5G-related IP. Of the top five companies that hold the majority of 5G patents, four are Asian. Also, more than one-third of 5G patent declarations have come from Chinese companies, with Korean companies accounting for an additional 27 percent.[150]

— **Advanced display.** The majority of global production capacity in the display panel industry is in Asia. This implies that advanced display technology, including, for instance, foldable displays, and under-screen cameras (hidden beneath a smartphone screen), is highly likely to be developed by the region's display panel players in cooperation with OEMs. In 2019, Royole, a relatively small Chinese OEM, released the world's first commercially available foldable phone.[151] In early 2020, Samsung launched the Galaxy Z Flip, the first foldable phone with a foldable glass screen (all previous foldable phones used plastic covers). In mid-2020, Samsung was reportedly planning to increase the production of foldable displays to up to a million units by the end of the year.[152]

[149] Penetration data from Statista.
[150] *Top 10 5g patent holders*, Digianalysys, digianalysys.com; Statista.
[151] Ben Sin, "Review: The world's first foldable phone is surprisingly usable," *Forbes*, July 29, 2019.
[152] *Samsung to quadruple foldable display production by the year end*, SamMobile, March 4, 2020.

How could this play out in mobility?

Asia has strong EV manufacturing ecosystems (Exhibit 19). The preference for manufacturing close to markets is particularly strong in the case of automotive, as reflected in the fact that Asian exports in this case account for a smaller share of global exports, at about 25 percent. Some manufacturing footprints have shifted, but again, the changes have tended to be within Asia (Exhibit 20). China has become the largest automotive market in the world, and its share of global value added in automotive manufacturing increased from 17 percent in 2010 to 29 percent in 2018. As the penetration of vehicle ownership rises in Emerging Asia and in Frontier Asia and India, automotive manufacturing footprints in these economies are expected to grow. China's strong position in the adoption of EVs should fortify Asia's position in automotive manufacturing.

Exhibit 19

Asia's manufacturing value chains have been strong and resilient thus far.

1. Million wafer starts per month.

Note: Figures may not sum to 100% because of rounding.

Source: IHS Markit; McKinsey battery database; McKinsey Center for Future Mobility database; NVR; SEMI World Fab Watch; Strat egy Analytics; McKinsey Global Institute analysis

Exhibit 20

Shifts in manufacturing footprints have largely been within Asia.

Asia

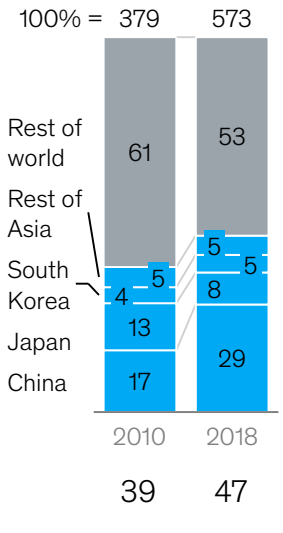
Example: Automotive

Production

Automotive production, %, million units

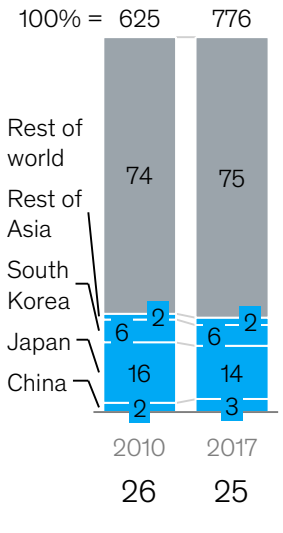
Value added

Value added in motor vehicle manufacturing, %, $ billion[1]

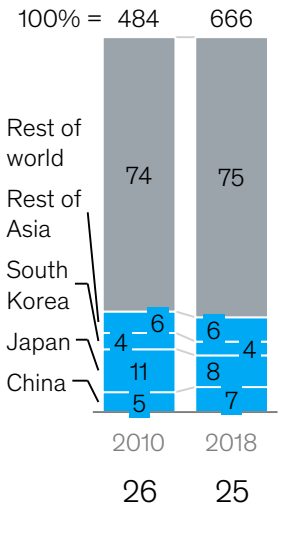


Exports

Automotive exports, %, $ billion[1]



Automotive parts exports, %, $ billion[1]



Share of Asia, %

Production		Value added		Exports		Exports
50	52	39	47	26	25	26	25

1. Potential double counting if products cross borders multiple times during transit.

Note: Figures may not sum to 100% because of rounding.

Source: IHS Markit; NVR; SEMI World Fab Watch; Strategy Analytics; UN Comtrade; McKinsey Global Institute analysis

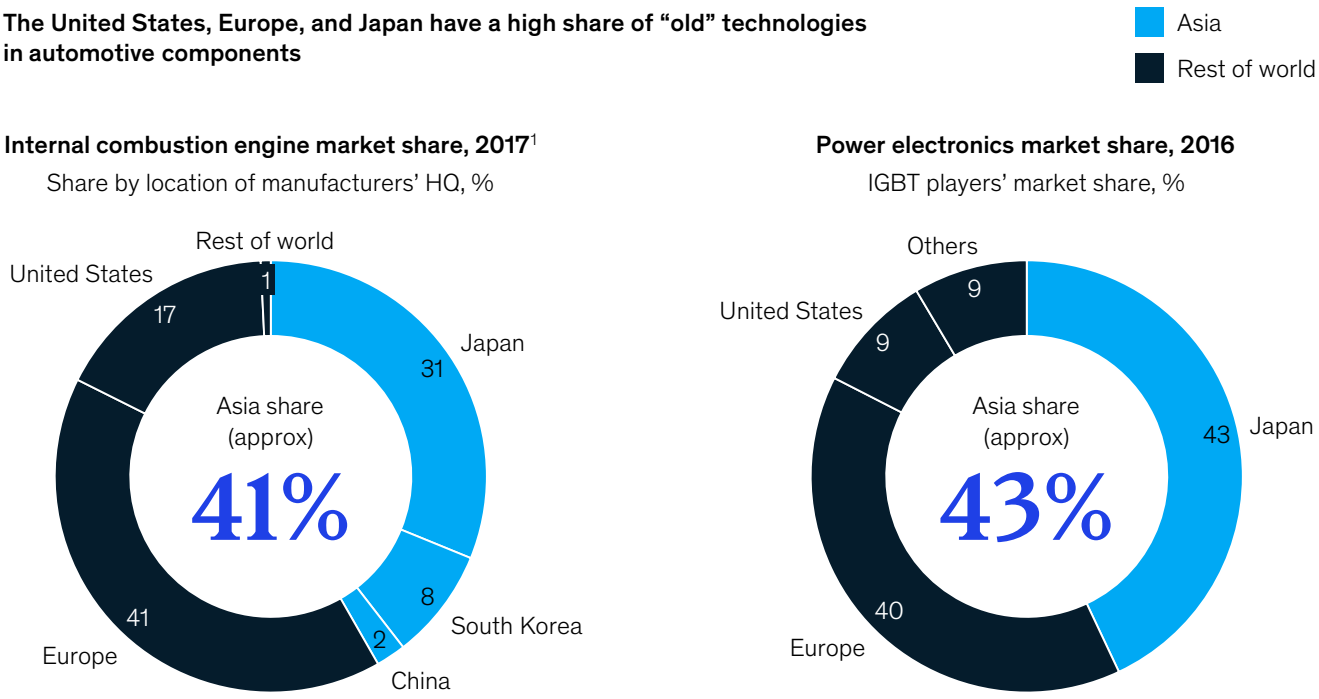
Asia's position in EVs is somewhat different from its position in smartphones. In the latter, the region punches above the weight of its demand in its assembly of mobile phones; in the former, Asia's 61 percent share of EV assembly is very similar to its 62 percent share of regional demand. The reason for this distinction between the types of product is that automotive value chains tend to be more regional and the assembly of larger items (such as EVs) tends to happen close to end markets, while smaller items can be made at distance from end customers because they are cheap and easy to ship to where the demand is (Exhibit 21). Within Asia, the share of EVs being manufactured in China increased sharply from 25 percent in 2010 to 45 percent in 2019, reflecting China's growing EV market, whose share of global sales has risen from 17 percent in 2010 to 56 percent in 2018. Similar to mobile phone components, core EV components are largely produced within Asia; the region accounts for 76 percent of worldwide manufacturing of EV batteries, for instance.

Exhibit 21

With the exception of Advanced Asia, other Asia's gaps in "old" core technologies remain.

Example: Automotive

The United States, Europe, and Japan have a high share of "old" technologies in automotive components



1. Based on outside research of top 25 OEMs.
Note: Figures may not sum to 100% because of rounding.
Source: iSupplier, 2Q 2016; OICA correspondent survey of world ranking of manufacturers, 2017; McKinsey analysis; McKinsey Global Institute analysis

In automotive, Advanced Asia is the only part of the region that can fill the gap with world-class technology in legacy components. In the case of internal combustion engines, for instance, which are closely aligned with leading OEMs' core technology, in 2017 players in Europe, the United States, and Japan held market shares of 41, 17, and 31 percent, respectively. Only firms in South Korea have managed to capture meaningful market share, at 8 percent. The dominance of Europe, the United States, and Japan has been even more pronounced in key power electronics components, especially in insulated gate bipolar transistor diodes for semiconductors, where their market shares were, respectively, 40, 9, and 43 percent in 2016, according to iSupplier. Developing Asian players have virtually no presence in either internal combustion engines or the diodes.

In several types of new technology relevant to the automotive industry, Asian players are visible and could experience growth given the fact that the region appears to be entering a new era of autonomous driving, connected cars, EVs, and shared mobility. Many Asian companies are active in these areas, often supported by existing manufacturing capacity and governments, as in the following examples:

— **Next-generation EV batteries.** As noted, Asia has a strong position in the batteries that are the core component in EVs, accounting for up to 40 percent of EV value added. In Japan and South Korea, companies established leading positions in the EV battery market early on, building upon existing technology leadership in smaller batteries. China has built a strong position in the market for larger EV batteries with the backing of government policy. Asian incumbents compete very successfully on key battery factors including energy density, service life, and reliability. Next-generation EV batteries thus represent a significant opportunity in the region. In Europe, both OEMs and policy makers are involved in battery development. Volkswagen, for example, has set aside more than €1 billion for next-generation battery research and production, and the government of Germany has earmarked the same amount for EV battery research.[153] In the United States, several startups have focused on the development of next-generation solid-state batteries, which are seen as a potential industry game changer because they would offer much higher energy density and reliability than current technology. One startup, QuantumScape, has received financial and strategic backing from Volkswagen.

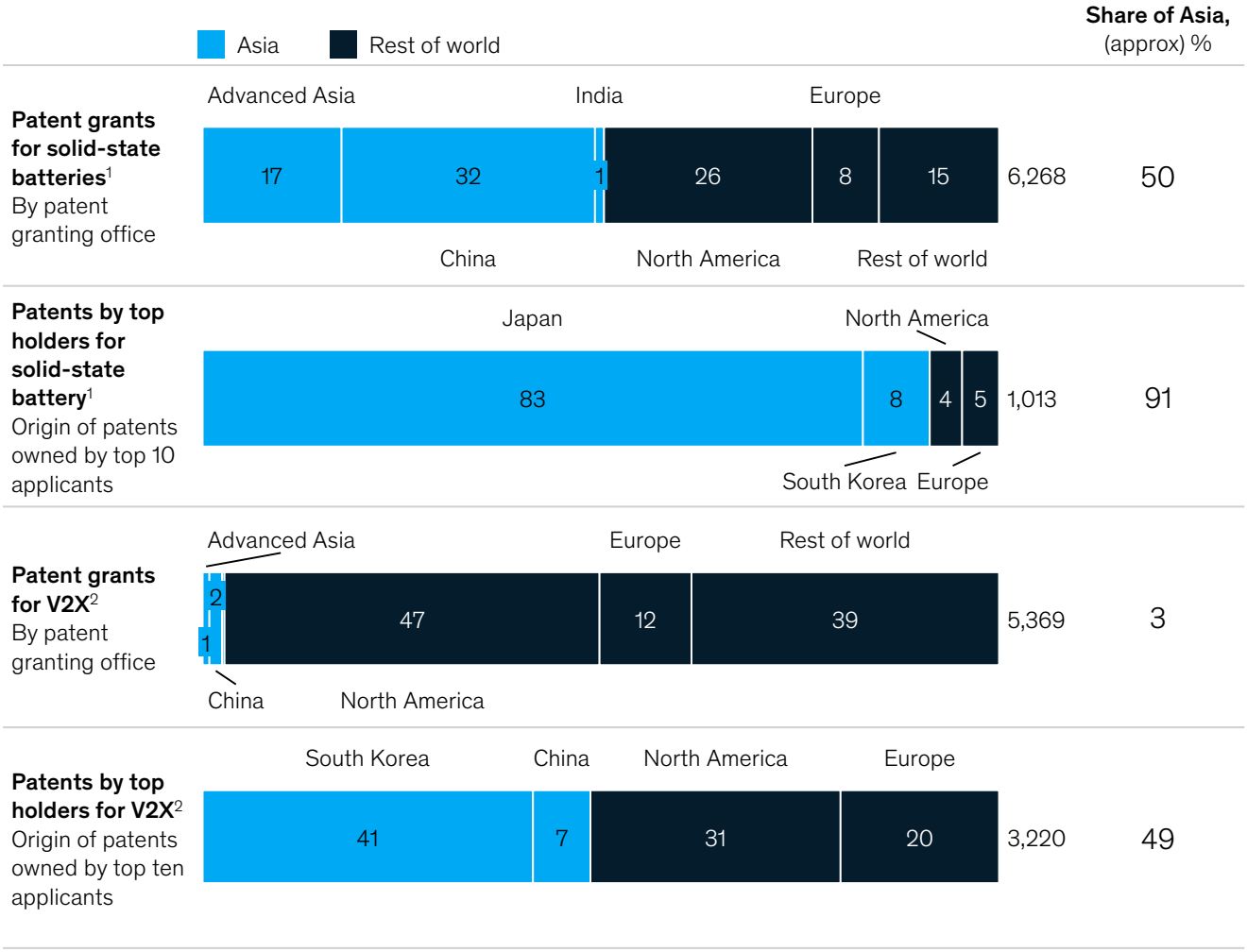
  However, Asian players can step up in R&D in this area. Incumbents are using cash flows from their current battery businesses to explore opportunities in next-generation technology, not only in solid-state batteries but also in a more efficient battery mix. In collaboration with Panasonic, Toyota announced it will spend about $13 billion on R&D over the next decade, and Samsung led research on an all-solid-state battery technology.[154] Eighty-seven percent of the patents owned by the top ten solid-state-battery patent holders belong to Asian enterprises, and more than half of patents related to solid-state battery technology were granted by Asian patent offices (Exhibit 22).

[153] James Eddy, Alexander Pfeiffer, and Jasper van de Staaij, *Recharging economies: The EV-battery manufacturing outlook for Europe*, McKinsey & Company, June 5, 2019.
[154] *Samsung presents groundbreaking all-solid-state battery technology to "nature energy,"* Samsung, March 10, 2020.

Exhibit 22

Asia has started to build strengths in some next-generation automotive technologies.

Example: Next generation solid-state EV batteries and V2X technologies, 2011–20, %, total number of patents



1. Based on keyword search in WIPO data base.
2. Based on keyword search in WIPO data base.

Note: Figures may not sum to 100% because of rounding.

Source: Crunchbase; WIPO; McKinsey Global Institute analysis

— **Automotive software.** Asia is projected to account for more than 50 percent of the global automotive software and electrical and electronics market. Automotive software has several layers. Operating systems and middleware largely remain the domains of well-established major US and European software companies. Some OEMs in Advanced Asia and China are making headway in these areas, but opportunities for Asian players largely lie in applications for human-machine interfaces and voice recognition, infotainment, and connectivity. Cross-industry partnerships among telecommunications, automotive, and internet companies are driving innovation, together with solution co-development projects with global chipmakers. One example is the partnership between South Korean telecom operator SKT with China-based EV maker Byton to develop in-vehicle infotainment systems.[155] Another is a collaboration between Baidu, BMW, Ford, and NXP Semiconductors on Apollo, Baidu's open platform for autonomous driving and connectivity. Several Asian governments have an agenda to build mobility ecosystems in conjunction with autonomous driving ecosystems, and that commitment should give this technology a tailwind in the region.

— **Autonomous driving.** This segment is in its early stages, but Asia has the potential to establish a globally competitive position in autonomous driving technologies. The region has high adoption of 5G, which enables the reliable, high-speed connectivity that could support vehicle-to-everything (V2X) technology some argue is needed to make autonomous driving a reality. Approximately half of V2X patents granted to the top ten owners are held by Asian enterprises, despite the fact that most of the patent applications were filed outside the region. This may reflect the fact that the deployment of this technology is still nascent in Asia. In China and South Korea, however, large domestic internet and telecommunications companies have been taking majority shares in search engines and mobile maps to support developments in this area. In South Korea, domestic internet and telecommunication companies own 97 percent of the mobile map sector. These companies derive abundant local traffic data to support autonomous driving ecosystems. Public-private partnerships that support pilots are common in the region; one example is the rollout of robot taxi fleets in Shanghai's Jiading district in collaboration with autonomous driving startup AutoX and Alibaba's mobility application operator, AutoNavi.[156]

— **EV charging systems.** Different types of fast-charging plugs for EVs are not currently compatible with one another, but signs indicate a push toward standardization. China has the most extensive infrastructure in number of charging stations installed, with approximately 80 percent of stations in the world.[157] The country uses the GB/T charging standard, and because of its substantial presence in this technology, others are moving to that standard. For instance, Japan-led CHAdeMO is taking steps to consolidate its technology with GB/T, and Tesla has modified its Model X and Model S vehicles for China with second charge ports for GB/T. Given the sheer market size for EVs, Asia is likely to continue to exert its influence on next-generation technology standards.

[155] Joo Kyung-don, *CES 2020: SKT signs partnership with Byton on car infotainment system*, Yonhap News Agency, January 8, 2020.
[156] Sarah Dai, "AutoX, Alibaba's AutoNavi roll out robotaxis in Shanghai's ride-hailing services market," *South China Morning Post*, April 27, 2020.
[157] Christoph Steitz, "Plug wars: the battle for electric car supremacy," *Reuters*, January 24, 2018.

Technology will be at the core of operating and business models for the manufacturing companies of the future

To remain relevant and competitive, manufacturers can act fast to keep pace with rapid technological change in their industries and in the needs and behavior of consumers enabled and driven by that change. The region needs to tackle remaining gaps in manufacturing technology, including, as we have noted, core IP, software capabilities, and the design of solutions (as opposed to hardware). Technology can have a significant impact on operating and business models for the manufacturing companies of the future. First, it can encourage greater investment in intangibles such as R&D, brands, and IP. Second, it can motivate businesses to offer a full stack of products and services, including software. Third, through automation it will transform the factory floor and operations.

— **Strengthen the development of intangible assets.** In 2019 research on value chains, MGI noted that they are becoming increasingly knowledge intensive; therefore, R&D and intangible assets are more and more important sources of competitive advantage. Intangible assets more than doubled their share of global revenue from 2000 to 2016. In many cases, the creation of value is shifting to upstream activities such as R&D and design, and downstream to areas such as distribution, marketing, and after-sales services.[158] In the long term, manufacturers' investment in intangibles will be the foundation of developing innovative new technologies and brands that can rapidly capture market share. Digital disrupters are turning up the pressure on incumbents in all industries by expanding across value chains. Apple is a good example of a disruption through innovation, and it offers an object lesson in the value of continuously innovating and inventing. Apple is also a classic case of technology driving a full-stack approach to business models and offerings (see the next bullet point). Apple not only sells smartphones but has its own retail stores, app store, and software. It earns revenue through these channels while controlling and maintaining the customer experience. In the automotive sector, software accounts for 10 percent of the value of a car, a share McKinsey expects to increase to 30 percent by 2030.[159] Toyota recently launched a company focused on making software for vehicle connectivity, navigation, and in-car applications, exploring new connections that could offer new sources of revenue.[160]

— **Become a solution provider beyond hardware.** Manufacturers need to think beyond offering hardware products to customers. The car is becoming a mobile device packed full of technology products. Solutions such as autopilot driving, smartphone apps, video-streaming access, graphics-intensive games, and over-the-air updates (one of the best examples of the IoT in action) are constantly being added. One example is Tesla, which makes cars with a series of software solutions that can enhance the functionality of its cars through remote upgrades. In China, EV player Xpeng Motors has collaborated with Didi's Xiaoju car service, a one-stop car rental and maintenance service platform, to build a smart mobility ecosystem that provides flexible and inexpensive car rental services; the companies also intend to build charging stations together.[161] In the case of smartphones, companies can also provide a far greater range of solutions. Xiaomi is no longer simply a manufacturer of smartphones, but now offers a range of electronic products such as fitness bands, smart home sensors and systems, air and water purifiers, projectors, security cameras, and kitchen equipment.

[158] *Globalization in transition: The future of trade and value chains*, McKinsey Global Institute, January 2019.
[159] Ibid.
[160] Matt Posky, "Toyota is becoming a software company," *The truth about cars*, July 2020.
[161] *Xpeng Motors partners with Didi Chuxing's Xiaoju Car Service to develop smart mobility business*, XPeng Motors, January 4, 2020.

— **Accelerate digital operational transformation.** Manufacturing companies can also become pioneering developers of digital technologies, applying them in their value chains. Many companies have found it hard to scale technology-based operational transformations. Thus far, indeed, about 70 percent of them have failed.[162] However, the COVID-19 pandemic may well motivate companies to try again and try harder. Even before the pandemic, automated factories were becoming more widespread on the back of advanced technologies known collectively as the Industry 4.0 revolution, including robotics, big data, IoT, and cloud computing. Manufacturing activities and materials handling through autonomous processes are set to become increasingly important parts of modern factories. Robotics technologies are getting cheaper and smarter, and they are capable of adapting their behavior automatically to maximize output or minimize cost. Over the past 30 years, the average price of a robot has fallen by half in real terms, and people with the skills to make and operate these technologies are becoming widely available. Use of industrial robots in the auto industry is becoming common; this sector is leading in their use, accounting for 30 percent of global robot installations. [163]Almost all big automakers, including Ford, Nissan, Toyota, and Volkswagen, use several types of automated production and are planning to build smart factories. However, the full potential of smart factory programs has not been fully exploited, and incremental change may be a barrier. If companies choose to build smart factories on top of traditional plants, legacy infrastructure can make it difficult to implement and integrate smart technology. Conversely, greenfield smart factories may be expensive and not always practical to carry out immediately.[164]

[162] Subu Narayanan and Michael Coxon, *It's the last IT/OT mile that matters in avoiding Industry 4.0's pilot purgatory*, McKinsey & Company, October 8, 2018.
[163] "Bringing advanced automation to automotive industry," *Robotics Tomorrow*, May 5, 2020.
[164] Jonathan Tilley, *Automation, robotics and the factory of the future*, McKinsey & Company, September 7, 2017.

3.3 Expanding business technology services

Demand for digital services is soaring, and Asia's strong talent base suggests that the region has potential to substantially increase its presence in this area. It is notable that Asia still has a relatively low global share of IT services demand, and, crucially, firms that can meet that demand. Many firms still tend to be wedded to traditional organizational models, and, although the region has a rich endowment of talent in terms of numbers, quality can improve further. Globally, McKinsey estimates that about $800 billion to $850 billion can be spent on traditional IT services in 2020, and $200 billion to $250 billion—or 20 to 30 percent of the total—on digital IT services such as the design and integration of IoT, AI, machine learning, and blockchain. In five years, digital is expected to be the main driver, reaching $550 billion to $600 billion of an estimated $1.5 trillion of spending on IT services, or 40 to 45 percent of the total. The share of digital is therefore expected to double between 2020 and 2025, and to contribute to more than 80 percent of incremental outsourced IT services spending. From 2020 to 2025, spending on digital services is expected to grow at a rate of over 20 percent while expenditure on traditional IT services could grow at a meager 0 to 1 percent (Exhibit 23). The share of digital could be an underestimate given that the COVID-19 pandemic, and the physical distancing needed to flatten infection rates, triggered a sudden acceleration in digitization (see Box 4, "COVID-19 and the surge in digital adoption by companies").

Box 4

COVID-19 and the surge in digital adoption by companies

Responding to the COVID-19 pandemic has fast-forwarded digital adoption by five years, according to Gartner.[165] Chief information officers are having to reprioritize investments and move resources around; in some cases, this has meant optimizing IT budgets in response to the cash crunch triggered by an implosion of supply and demand due to the pandemic, while prioritizing perceived mission-critical initiatives—largely digital services—in order to maintain business continuity and remote operations.[166] Some companies have even accelerated spending on IT.

Medium-size and large IT and business process management companies such as TCS, Infosys, IBM, and Wipro have witnessed a sharp rise in digital transformation deals. Infosys, for instance, won two large transformation deals in the United States, with Con Edison and Vanguard.[167] Wipro signed a multiyear digital transformation contract with London-based Metro Bank.[168] TCS signed deals worth $6.9 billion in first quarter of the 2020 financial year, with a huge uptick in digital infrastructure and cloud rollout services.[169]

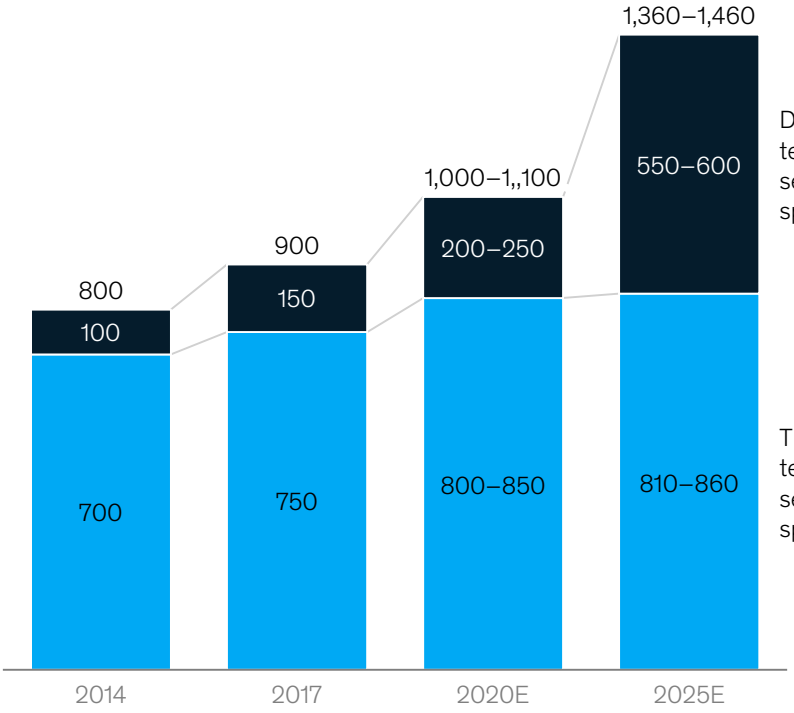
[165] Scott Engler, *Lack of skills threatens digital transformation*, Gartner, July 1, 2020.
[166] Nick Leung, Joe Ngai, Jeongmin Seong, and Jonathan Woetzel, *Fast-forward China: How COVID-19 is accelerating five key trends shaping the Chinese economy*, McKinsey & Company, May 2020; Aamer Baig, Bryce Hall, Paul Jenkins, Eric Lamarre, and Brian McCarthy, *The COVID-19 recovery will be digital: A plan for the first 90 days*, McKinsey & Company, May 14, 2020; and Jordan Bar Am, Laura Furstenthal, Felicitas Jorge, and Erik Roth, *Innovation in a crisis: Why it is more critical than ever,* McKinsey & Company, June 17, 2020.
[167] Ayan Pramanik, "IT, BPM companies see a sharp rise in digital transformation deals," *Economic Times*, August 10, 2020.
[168] Tanmay Tiwary, *Wipro signs multi-year digital transformation deal with London based Metro Bank*, Tech Circle, July 30, 2020.
[169] *Q1 FY21 earnings conference call*, Tata Consultancy Services, July 9, 2020.

Exhibit 23

Digital accounts for a majority of incremental outsourced technology services spending.

Global technology services spending, 2014 –25E

$ billion



	Incremental IT services spend, 2020–25E $ billion	Compound annual growth rate, 2020–25E %
Digital technology services spending[1]	~300	20+
Traditional technology services spending[2]	~50	0–1
	~350	5–6%

1. Digital IT includes mobile, social media, BPaaS, big data and analytics, cloud, cybersecurity, digital legacy modernization, IoT system design and integration, and 3rd horizon technologies (eg, AI/machine learning, blockchain, AR/VR, 3-D printing, and DRaaS).
2. Traditional IT includes application development and maintenance, BPO, infrastructure, IT consulting, traditional enterprise IT software products, and system integration services.

Note: Figures may not sum to 100% because of rounding.

Source: McKinsey Global Institute analysis

Interestingly, more than 70 percent of IT service demand was from Europe and the United States in 2019; Asia accounted for only 17 percent. On the supply side, Europe and the United States captured the majority of IT services revenue. Companies headquartered in Europe and the United States earned 78 percent of IT services revenue and accounted for 72 percent of all IT services firms in 2016–18. In contrast, Asian IT services companies (17 percent of the global total) earned 21 percent of revenue during this period. Overall, Asia accounts for relatively low global shares of IT services demand and of firms meeting that demand.[170]

However, Asia represents one of the fastest-growing markets for some offerings. Spending on cloud computing, for instance, is expected to hit $76 billion by 2023 in Asia.[171] This has led to a frenzy of investment from Chinese cloud vendors such as Alibaba Cloud and Tencent Cloud, as well as Western vendors including Amazon Web Services, Google Cloud, and Microsoft Azure. Players have doubled down on their commitment to, and presence in, Asia to increase the footprint of their data centers. Asia, and especially China and India, can drive growth in consumer markets, and therefore demand for IT services is expected to rise sharply in Asia.

The majority of the estimated $550 billion to $600 billion in spending on global digital services in 2025 is expected to come from ten service lines and technologies spanning ten to 12 industries (see Box 5, "An introduction to key technologies"). Some of these technologies are standardized services required across industries while others are more applicable to specific industries, including the following:

— **Standardized digital technologies.** Five of these services are applicable across industries. More standardized services are expected to account for 60 to 65 percent of the digital market. They include legacy modernization, workplace modernization, digital products, cloud computing, and cybersecurity services.

— **Industry-specific opportunities.** Five other service lines—big data, IoT, mobile user interfaces and mobile user experience, social media, and Horizon 3 technology services (which includes blockchain, 3-D printing, AI and machine learning, augmented and virtual reality, and disaster recovery as a service, or DRaaS) are more applicable to particular industries or micro industries and can be tailored to them. We expect this group of service lines to account for 35 to 40 percent of spending on digital services.

At the intersection where service lines and technologies meet industries are more than 100 industry and cross-industry digital offerings with different shares of spending and growth rates. Digital spending across industries is expected to grow at different rates. For instance, growth in spending in the consumer goods and services sector is expected to be large, but this is a relatively small market. In contrast, financial services is expected to experience low growth in spending, but it is a large market. Within the consumer sector, service lines are growing at different rates. For example, legacy modernization and Horizon 3 are expected to grow at a compound annual rate of more than 25 percent. Other service lines including cybersecurity, business process as a service, mobile user interfaces, and mobile user experience are more likely to grow at a compound annual rate of five to 10 percent (Exhibit 24).

[170] IDC Semiannual Services Tracker.

[171] Asia's spending (excluding Japan). See *New IDC forecast reveals Asia/Pacific* spending on public cloud services to reach USD 76.1 billion by 2023*, IDC, August 7, 2019.

Exhibit 24

Spending of $500 billion to $550 billion on digital IT services in 2025 is likely to be largely driven by standardized and specific services.

Service lines/technologies	Key industry verticals: Banking and financial services	Insurance	Retail	Manufacturing	Automotive	Healthcare	Lifes ciences and medical devices	Oil and gas	Telco	Travel and hospitality	Government	Others[1]	Out-sourced total address-able market, 2025, $ billion	
Big data/ analytics	Specific services tailored to industry requirements												40–45	35–40% spend
Mobile UI/UX (incl digital app development)													75–80	
Social													20–25	
IoT[2]													55–60	
Horizon 3 technologies[3]													65–70	
Cybersecurity	Standardized services applicable across industries												35–40	60–65% spend
Cloud (incl infrastructure as a service)													65–70	
Digital products (incl cloud SaaS)													65–70	
Workplace modernization (incl cloud SaaS)													20–25	
Legacy modernization													110–120	
Outsourced TAM, 2025, $ billion	95–100	30–35	70–75	45–50	15–20	25–30	20–25	25–30	45–50	35–40	65–75	45–50	**550–600**	

An additional ~$810 billion–$860 billion of traditional spend makes up the ~$1.4 trillion–$1.5 trillion IT services market in 2025

1. Includes government, IT, professional services, utilities, and media.
2. IoT includes tech services (system design/engineering) and consulting; does not include other services (eg, analytics, cloud) or hardware spend captured in separate service lines.
3. Includes AI/machine learning, blockchain, 3-D printing, Edge computing, AR/VR, and DRaaS.

Note: This market does not include the BPO/engineering R&D product engineering-focused spend, which is covered separately. Figures may not sum to 100% because of rounding.

Source: McKinsey Global Institute analysis

Box 5

An introduction to key digital technologies

Big data and analytics. This is using advanced analytic techniques to analyze very large, diverse data sets to deliver business insights including, for instance, analyzing consumer spending patterns.

Mobile user interfaces and mobile user experience. MUI and MUX, as they're known, are the design, development, and optimization of the front-end mobile-first applications typically used to drive business value for both internal (for example, employees) and external (for example, customers and suppliers) stakeholders.

Social technologies. These focus on driving actionable and revenue-generating business insights via social media, including social media analytics, content, setup for content management systems, and social media tools.

IoT. This includes professional services for IoT applications, such as connected cars, as well as system design and integration, usually by IT service providers.

Horizon 3 technologies. These include system design, deployment, and integration for next-generation technologies, including AI and machine learning, blockchain, 3-D printing, edge computing, extended reality (including AR and VR), and DRaaS (disaster recovery as a service).

Cybersecurity. This encompasses services to enterprises including digital identity management, network security, web security, detection of potential vulnerabilities, and endpoint and data security.

Cloud computing, including infrastructure as a service (IaaS). These are services that help enterprises move from physical infrastructure to the cloud, including strategy, assessment, the building of cloud ecosystems such as private cloud setup, the management and optimization of cloud-based infrastructure services, and migration of, for instance, workloads and applications.

Digital products, including cloud software as a service (SaaS). This includes system integration services for all digital enterprise software (including customer relationship management software like sales-force CRM, and enterprise resource planning software), deployment, upgrades, maintenance, and integration of digital- and cloud-based enterprise software products.

Workplace modernization. This includes end-to-end system integration services to help enterprises deploy digital and remote workplaces, including remote cloud workplaces (for instance, virtual desktops), unified device management (such as employees' mobile phones), workplace collaboration tools (such as Slack and Teams), and connected workplaces (such as digital meeting rooms).

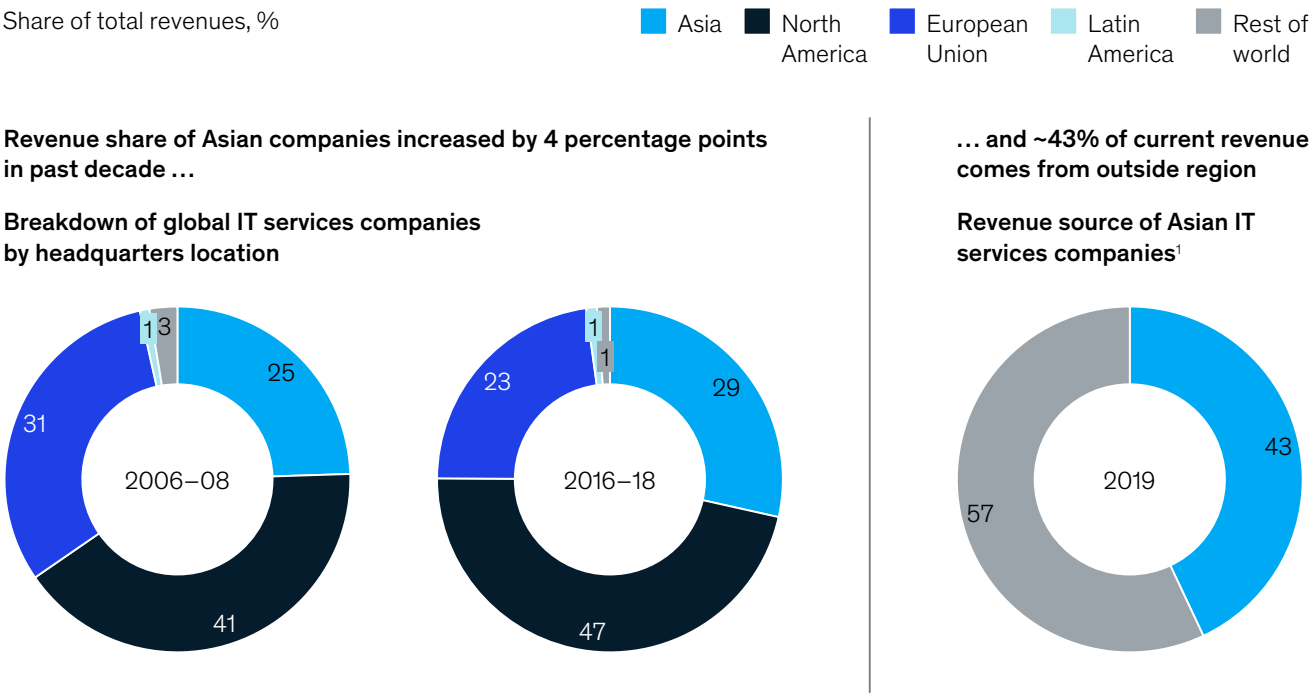
Legacy modernization. This involves comprehensive processes for transforming legacy IT systems to new-age digital systems (for instance, microservices-led architecture) in order to reduce the complexity and cost of IT, increase data consistency, enable collaboration across platforms, and improve process flexibility. It includes systems assessment, modernization, workload migration, architecture modernization, front-end digitization, and automation.

Asian companies can strengthen their position in the IT services market by leveraging their wealth of tech talent

Asia has increased its share of the global IT services market over the past decade, from 25 percent in 2006–08 to 29 percent in 2016–18. Asian players largely took share from their European counterparts. Asian firms have already become a significant global presence, with the region's top 200 IT services companies earning about 43 percent of their revenue from outside the region in 2019 (Exhibit 25).

Exhibit 25

Asia has increased its share of the IT services market over the past decade and now earns ~43 percent of revenue outside the region.



1. Top 200 Asian IT service companies in 2019.
Note: Figures may not sum to 100% because of rounding.
Source: CPAT; IDC Services Tracker; McKinsey Global Institute analysis

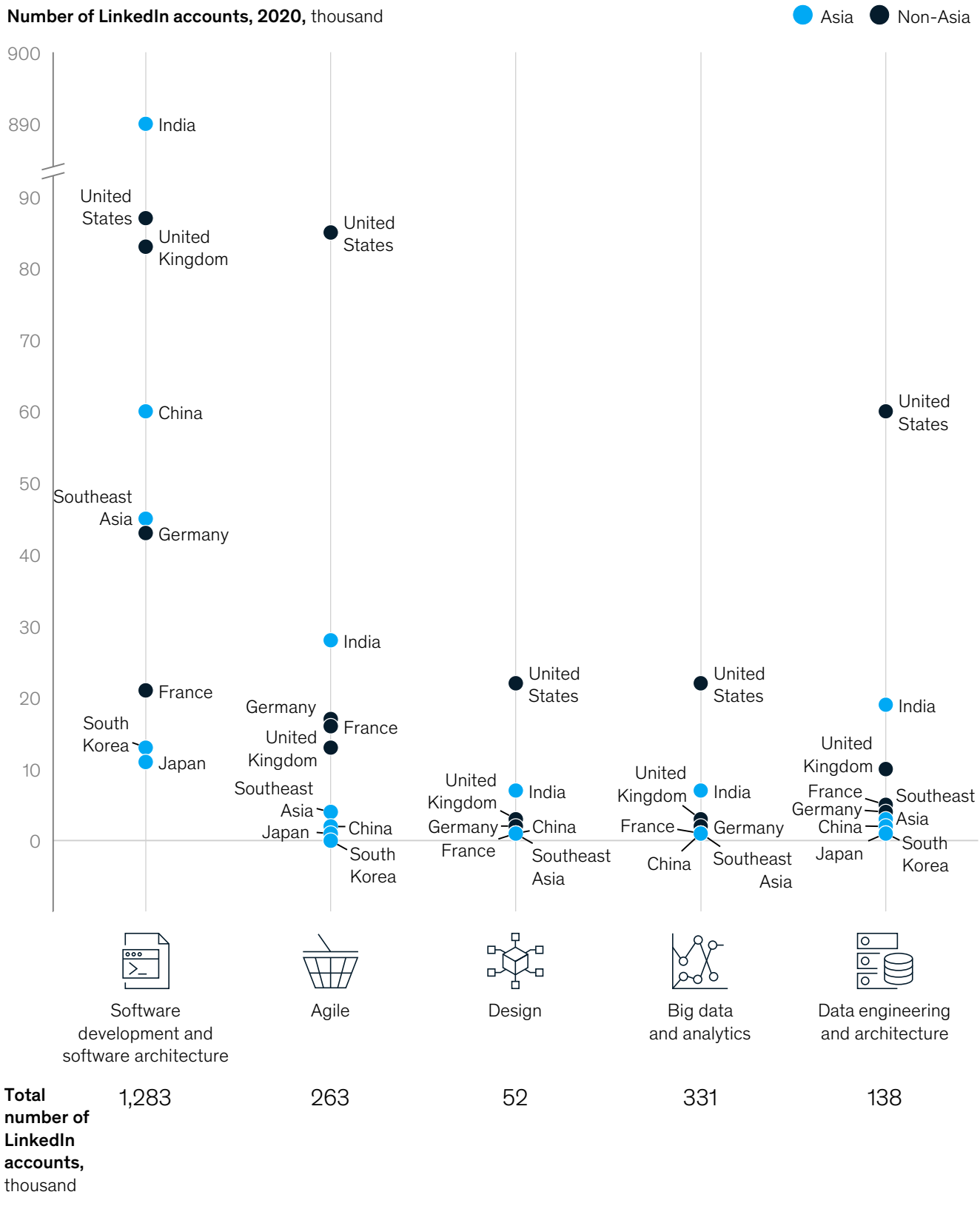
Readily available high-quality tech talent is one of the primary levers that determine the success of IT services companies, and Asia is in a strong position to supply a large pool of technology workers. On LinkedIn, more than 60 percent of tech talent is in software development and architecture, and India has ten times more software developers and architects than the United States (Exhibit 26).[172] Singapore ranked second in the world (behind Switzerland) for attracting and developing talent in the 2019 Global Talent Competitiveness Index.[173] In positioning for the future, Asian countries together produced 76 percent of the world's STEM graduates in 2016–18 (Exhibit 27). Furthermore, India produces the most computer science graduates in the world—about 215,000 each year.[174] Asia can benefit more if it further improves the skills and quality of its large base of STEM resources. According to one study, India's computer science graduates outperform their peers in some other emerging economies.[175]

Not only does Asia offer a large volume of talent, but it does so at a competitive price. Although the gap in talent costs that separates European and US hubs from advanced Asia—specifically, Japan, Singapore, and South Korea—has narrowed in recent years, Asian IT services hubs (India, Indonesia, Malaysia, and China) remain cost competitive, providing tech talent at about 20 to 60 percent of the cost in European and US hubs, depending upon the role. The cost competitiveness of senior roles, such as head of IT, is relatively low, with Asian IT service hubs providing talent at about 60 percent of the cost in European and US hubs. However, in the case of other roles. such as IT support analyst and IT user support analyst, Asia is extremely cost competitive at about 20 percent of the cost in European and US hubs.[176]

[172] A LinkedIn search was used to identify 23 types of technology roles in 12 countries: China, France, Germany, India, Indonesia, Israel, Japan, Malaysia, Singapore, South Korea, the United Kingdom, and the United States.
[173] *Why the world's software engineers are moving to Singapore*, EDB Singapore, October 30, 2019.
[174] *Technology sector in India 2020 – TECHADE – The new decade strategic review*, NASSCOM, February 2020; and G. S. Mudur, "Computer science skill wake-up call in study," *Telegraph*, March 18, 2019.
[175] Prashant Loyalka et al., *Computer science skills across China, India, Russia, and the United States, Proceedings of the National Academy of Sciences of the United States of America*, April 2, 2019, Volume 116, Number 14.
[176] fDi Benchmark.

Exhibit 26

Asia is well positioned to capture the IT services opportunity given its high share of relevant talent.

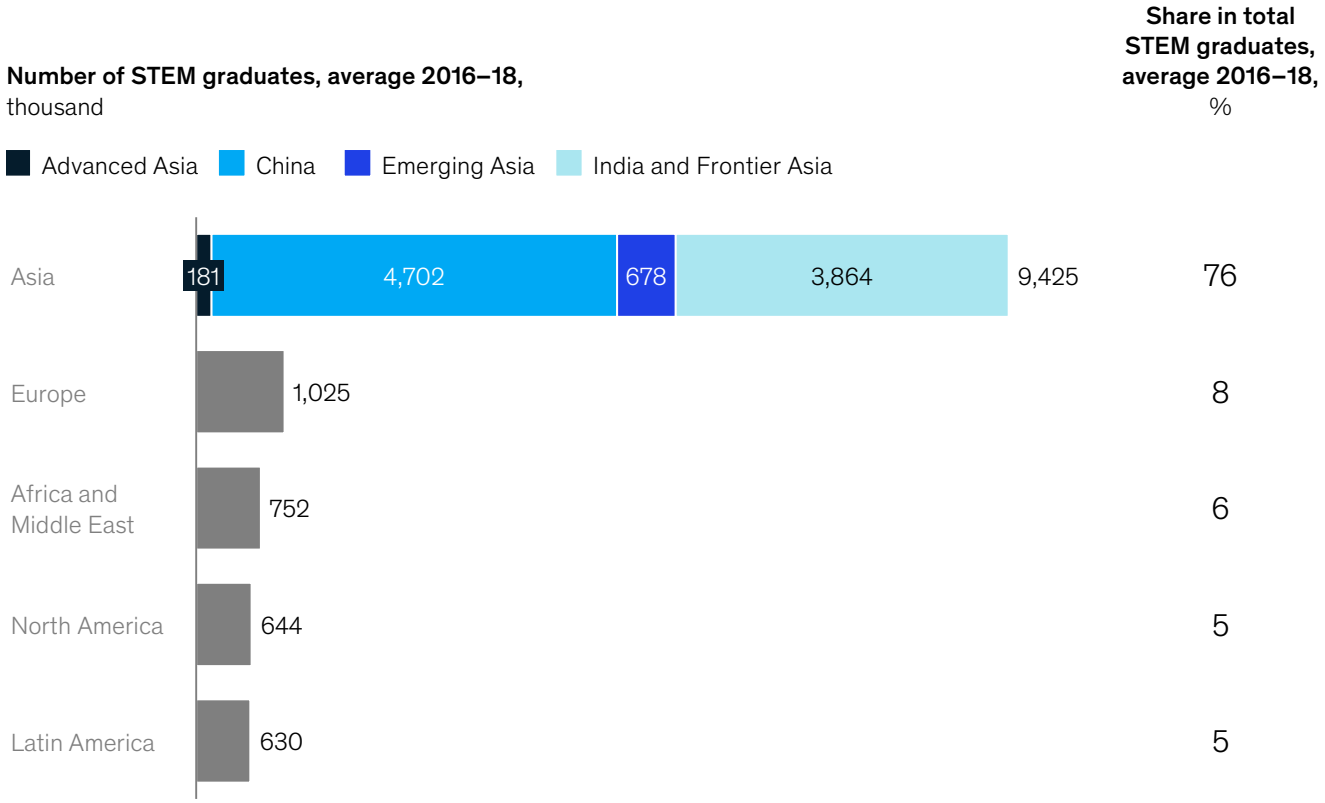


Note: Analysis based on LinkedIn data and therefore sensitive to LinkedIn penetration in different geographies. For example, in China, where local recruiting platforms are strong, the number may be underestimated. Software development roles include front-end developer, software engineer, full-stack developer, and software developer. Software architecture roles include technical architect and solutions architect. Agile roles include DevOps engineer, agile coach, product owner, and scrum master. Design roles include UX designer and visual designer. Big data and analytics roles include data scientist and data analyst. Data engineering and architecture roles include data architect, machine learning engineer, and data engineer.

Source: LinkedIn; McKinsey Global Institute analysis

Exhibit 27

Asia accounts for 76 percent of the world's STEM graduates.



Source: United Nations; McKinsey Global Institute analysis

India remains a global hub for IT services and offers talent at a lower cost than advanced economies. Now India is improving in digital skills, with more than four million people employed in digital sectors accounting for three-quarters of the global digital talent pool. As a result, the number of multinational corporations setting up global capability centers in India soared from about 700 in 2009 to about 1,250 in 2019.[177] In an August 2020 report, MGI estimated that India can generate $285 billion in economic value in 2030 by becoming a global IT and digital service hub with an average annual investment of about $10 billion.[178]

[177] *Technology sector in India 2020 – TECHADE – The new decade strategic review, NASSCOM*, February 2020, nasscom.in.
[178] Economic value is estimated as the annual value of productivity gains, cost savings, and incremental gross value added. See *India's turning point: An economic agenda to spur growth and jobs*, McKinsey Global Institute, August 2020.

Asia can reinforce and strengthen its position in digital services through a next-generation operating model

The response to COVID-19 meant physical distancing, and remote working therefore became the norm in many countries. During the pandemic, many IT service companies had no choice but to move to a remote-working model, and this approach may become a permanent feature of how companies operate. It may even prove to be a reset button for the way the IT services industry works. One of India's largest software companies, Tata Consultancy Services, said recently that, by 2025, three-quarters of its workforce of nearly 450,000 will not be required to work in the office.[179] Tata has already developed secure borderless workplaces that have enabled about 90 percent of its employees to work from home. This model is expected to increase the company's throughput by 25 percent.[180] Another shift expected among IT companies is doubling their use of the gig economy, with an increasing share of work likely to be performed through crowdsourced or part-time workers.

Looking to the post-pandemic future, Asian players have considerable scope to raise efficiency and resilience in their delivery networks by focusing on the following five drivers of value:[181]

— **Distributed operating model.** Remote working during COVID-19 demonstrated that this is a viable and even effective option, cutting costs and raising productivity. A distributed operating model centered on a higher share of remote working could reduce delivery costs by 7 to 10 percent. In this model, the emphasis would shift from having a headquarters in a major city to having a workforce distributed across a range of large and smaller cities with a higher share of workers operating from home. The benefits could be further enhanced if workers were offered an option of choosing shifts that suit their personal preferences; this could lower attrition rates and open the door to new sources of talent.

— **Digitally optimized delivery.** The pandemic also proved the usefulness of expanded digitization for delivery, which could boost productivity by 15 to 25 percent. About 34 percent of respondents in one McKinsey survey mentioned "lack of collaboration" as the main reason for a decline in productivity during the crisis. One executive at a leading pharma company said, "Our ops team faced a productivity loss because it required multiple huddles and collaboration throughout the day." Digital solutions can be used to match capacity to demand, creating more seamless collaboration.

— **Virtualized talent life cycle.** Demand can be satisfied more quickly if companies use a next-generation talent life cycle approach. This operating model involves using a mobile-first, online-apps approach to identify, engage, and track talent; automating 70 to 80 percent of the entire talent acquisition process, from demand planning to onboarding new employees; using social media to promote collaboration, motivation, and a sense of belonging among employees; and deploying advanced analytics to create micromodels for demand. In combination, these four elements can enable IT services companies to reduce the time it takes to hire, allocate, and reskill talent.

[179] "TCS 'work from home' policy: Only one-fourth of workers to come to office; CEO explains Vision 25x25," *Financial Express*, May 27, 2020.

[180] Prabhote Gill, "TCS CEO says the business model is 20 years old – hinting that it may be time to go employee-lite," *Business Insider India*, April 28, 2020.

[181] Data and findings quoted for the five value drivers are based on an April 2020 McKinsey survey of 46 global capability centers and on interviews with tech companies about the impact of and lessons from working from home due to COVID-19. Global capability centers are large facilities that handle operations (back-office functions, corporate business-support functions, and contact centers) and IT support (app development and maintenance, remote IT infrastructure, and help desks) at scale in one location to sustain productivity growth. Some large companies use GCCs as a center of excellence for automation, innovation, and analytics, among other tasks.

— **Distributed agile organization.** New collaboration tools such as 3-D technologies, lab simulators, and digital workflows can, in combination, help to create a more agile and distributed operating model with optimized management layers than the current model of co-located teams operating in siloes. According to the survey, because distributed teams to an extent manage themselves, managers will be able to handle oversight of more people. McKinsey research has found that about 40 percent of a team leader's time is spent on the allocation, tracking, and reporting of team members. This time can be optimized by using multiple solutions that have enabled team leaders to manage 25 percent more people. Companies that used this approach during the pandemic are planning to adopt it for the longer term. However, following the pandemic, the approach needs to be further pressure tested for sustainability and efficiency.

— **Next-generation infrastructure and facilities.** About 60 percent of respondents to a McKinsey survey conducted in April said that 25 to 50 percent of the workforce could work from home in the future. Investment in next-generation infrastructure—including remote collaboration tools, cybersecurity, hiring and talent development processes, and standardized operating procedures for work, for instance—is needed to support this shift, which has the potential to offer substantial savings on traditional physical office and infrastructure costs.

3.4 Being at the forefront of the energy transition

Asia is a critical link in the world's global energy transition. It can contribute its capacity in driving the development and adoption of renewable technologies. The region's position is unique: it can be the key driver of new global energy demand, unlike the advanced economies of the OECD, where growth in demand is likely to fall or flatten. Asia is expected to account for 43 percent of energy demand by 2040 and 50 percent of the growth in demand. Moreover, it is arguably more exposed to climate risk than any other region in the world, and therefore has the additional task of addressing its rising energy needs sustainably. Recent MGI research found that by 2030, without action to mitigate climate risk, up to 200 million people in India could face a 5 percent probability of a heat wave that exceeds the threshold for human survivability; those figures rise to 310 million to 480 million and a 15 percent probability by 2050.[182] The likelihood of severe cyclones in coastal parts of China, Japan, and South Korea could triple over the next 30 years. In a higher-emission scenario, by 2050 between 600 million and one billion people in Asia could live in areas with a material probability of lethal heat waves every year—a large share of the global total of 700 million to 1.2 billion. On average, between $2.8 trillion and $4.7 trillion of GDP could be at risk every year because heat and humidity would prevent people from working outdoors—that's two-thirds of the annual global economic impact.

The choices Asia makes to fill the energy demand gap and mitigate climate risk are not only vital to the lives and livelihoods of its citizens and the economies in which they work, but could also make or break the world's bid to constrain the average temperature of the planet at 1.5 degrees or less above the preindustrial level. In its efforts to mitigate climate risk and adapt to environmental factors, Asia has some potential advantages: increasing technological capabilities and some of the largest and most innovative companies in the world, coupled with a record of strong policy support.

Technology clearly has a role to play. One type of innovation highlighted in recent MGI research is biology based. Recent MGI research on the Bio Revolution found that around 400 applications of innovations in biology that were sized could cut annual man-made greenhouse gas emissions by 7 to 9 percent compared with 2018 emissions. That's up to eight times the total CO2 emissions of the global airline industry in 2018.[183] Many applications of the Bio Revolution could make production more sustainable and cut carbon emissions from current processes, including, for instance, using fermentation to make artificial fabrics and using renewable biomaterials to make optical films used in computer displays and flexible electronics circuits. Biological applications are being developed to produce chemicals such as fertilizers and pesticides, and to use genetically engineered microbes to create biofuels for the aviation and marine industries.

Making the energy transition will require massive portfolio reallocations by companies and countries. These moves carry implications for society (for instance, the subsidies for a high-carbon infrastructure that provides basic mobility for low-income populations) as well as for the investments needed to support a new generation of energy delivery, and R&D. This will likely result in disruption as energy companies become renewable-technology companies.

[182] *Climate risk and response in Asia: Research preview*, McKinsey Global Institute, August 2020; and *Climate risk and response: Physical hazards and socioeconomic impacts*, McKinsey Global Institute, January 2020.
[183] *The Bio Revolution: Innovations transforming economies, societies, and our lives*, McKinsey Global Institute, May 2020.

The transition to a more sustainable model that is capable of meeting the energy needs of rapid growth while tackling extremely challenging environmental issues is multifaceted. Options include solar and wind energy; cleaner transition fuels like nuclear and gas; and energy storage technologies such as advanced batteries and smart grids. All have important roles to play (see Box 6, "More sustainable new technologies will power the energy transition"). Asia has a globally competitive position in many of these technologies. China is already the world's largest producer of clean technologies such as solar panels, wind turbines, batteries, and EVs.[184]

Renewable energy has taken center stage in the energy transition that will persist, and is likely to maintain that position over the coming decade. Renewable energy is expected to account for an estimated 40 percent of average annual global energy investments until 2025. Asia is a leading player. Today, China and India have the highest and the fourth-highest installed capacity globally, and also the lowest cost in solar and onshore wind energy, a situation that is expected to continue. Government policies played a large role in helping these countries achieve this position. China has continuously expressed that vision through its five-year plans. It is aiming for renewables to supply 35 percent of electricity consumption by 2030, up from a previous goal of 20 percent.[185] India has several national-level policies and plans to increase renewable energy to 175 gigawatts by 2022 from just 36 gigawatts in 2015, and to reduce the energy intensity of its GDP by 33 to 35 percent by 2030, compared with 2005 levels.[186]

MGI research estimates that investment of $1.7 trillion a year until 2030 is required to enable the region to maintain momentum in driving the world's energy transition. China and India are likely to continue to be responsible for most of the global growth in solar and wind, the two energy forms expected to make up more than 80 percent of new cumulative renewable additions to global energy capacity from 2018 to 2040.

Asia has the largest share of installed renewable capacity, and the fastest growth

Asia has the largest share of installed renewable capacity, accounting for about 45 percent of the global total, compared with 25 percent for Europe and 15 percent for North America. That lead is expected to widen, with the region accounting for 64 percent of new renewable capacity globally from 2019 to 2040, taking its overall share to 56 percent by 2040, as projected by the International Energy Agency. Asia's rise in share is likely to be driven by the rapid expansion of solar and wind energy installations.[187] Its current share of global solar capacity is even higher, at about 59 percent (Exhibit 28).

Asia's growth in renewables can be driven by India and China and by solar and wind. India and China's combined share of global renewable installed capacity is already high, at 35 percent in 2019, and is expected to rise to 46 percent in 2040. India and China are also among the top five countries in the world for installed capacity, ranking first and fourth, respectively. Within the different types of renewable energy, today hydropower dominates Asia's renewables with a share of 43 percent, followed by solar at 30 percent and wind at 23 percent. Bioenergy and others account for 4 percent. However, wind and solar will dominate Asia's future portfolio, accounting for more than 80 percent of new capacity in the region; the share of hydropower is expected to fall to 24 percent, and solar and wind combined are forecast to rise to 73 percent (Exhibit 29).

[184] *Asia focus: Innovations in renewable energy,* Open Access Government, September 2, 2019, openaccessgovernment.org.
[185] "China sets new renewables target of 35 percent by 2030," Renewable Energy World, September 26, 2018.
[186] *India's intended nationally determined contribution: Working towards climate justice*, Ministry of Environment, October 2, 2015.
[187] Current policy scenario projections show what happens if the world continues along its present path without any changes in policy. It excludes nuclear energy.

Box 6

More sustainable new technologies will power the energy transition

Asia is well positioned in innovative energy technology, including batteries and smart grids.

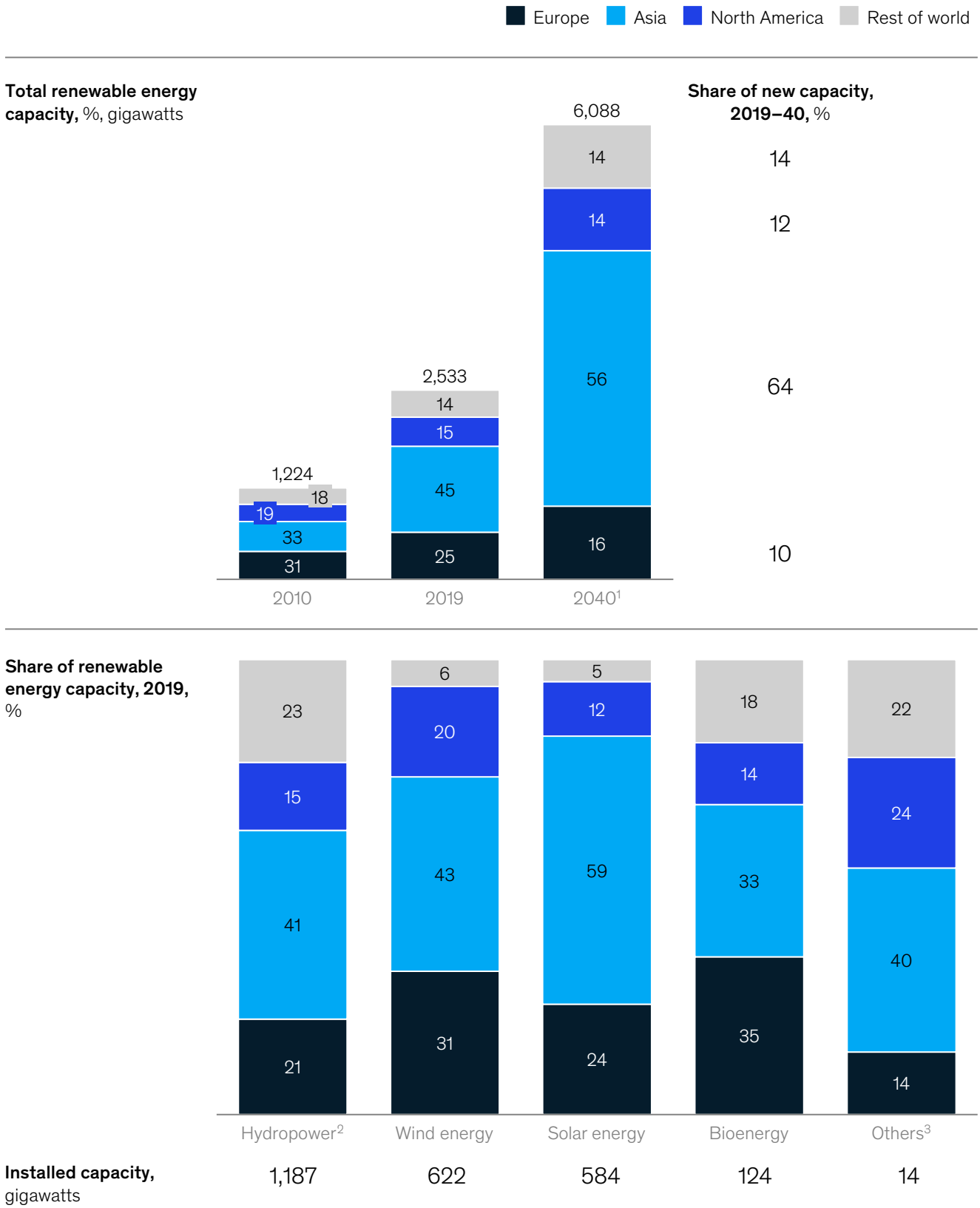
Batteries. Lithium-ion batteries are a game changer in the energy transition because they can be recharged faster, run longer, and power heavy vehicles as well as consumer electronics. Additional attributes such as low cost and low emissions make these batteries even more popular. Production is expected to ramp up rapidly, led by Asia. In 2018 more than 80 percent of current manufacturing capacity was in the region; China alone accounted for about 60 percent of global capacity.[188] While manufacturers in China lead on lithium-ion technology, manufacturers in Japan are driving innovation on hydrogen-based batteries.

Smart grids. Smart grids use computer and digital hardware and software to help utilities conserve energy, reduce costs, and increase reliability and transparency in managing the electricity supply. Although North America has the largest market, the technology has made large strides in Asia. The biggest advances have been in Australia, China, Japan, and South Korea. Several smart grid projects initiated in these countries have tested the installation of components, including smart meters, demand response equipment, and battery storage systems.[189] The number of smart meters installed in Australia, China, India, Japan, New Zealand, and South Korea is expected to increase from 618.8 million units to in 2018 to about one billion in 2024, making Asia the largest and fastest-growing smart meter market.[190] Countries in Southeast Asia are not far behind; they are expected to invest as much as $9.8 billion in smart grid infrastructure between 2018 and 2027.[191] Asia is also expected to post the highest annual growth in microgrids—stand-alone power generation, distribution, and storage systems that can operate independently or be connected to a primary grid. This growth is expected to be 18 percent for Asia, compared with the global average of 15 percent between 2018 and 2022.[192] India and China are championing the use of microgrids to support the development of remote communities. In India, for instance, solar microgrids with aggregate capacity of 1,899 kilowatts at peak have been installed in 63 villages with financial support from the government. By 2022, the government plans to set up 10,000 renewable micro and minigrids with 500 megawatts of generation capacity, which could address unmet electricity needs for 237 million people.[193] Island economies like Australia, Indonesia, and Japan are expected to use microgrids for remote locations.

[188] Jeff Desjardins, *Battery megafactory forecast: 400% increase in capacity to 1 TWh by 2028*, Visual Capitalist, October 19, 2018.
[189] *Smart grid market by software (AMI, grid distribution, grid network, grid asset, grid security, substation automation, and billing & CIS), hardware (smart meter), service (consulting, integration, and support), and region—global forecast to 2023,* Markets and Markets, 2018; and *Smart grid market size is projected to reach $169.18 billion by 2025, increasing at a CAGR of 12.4% between 2018 and 2025,* Valuates Reports, CISION, February 10, 2020.
[190] *Global smart metering market 2019: In-depth analysis and unique insight into Europe, Asia-Pacific & North America*, Research and Markets, July 15, 2019.
[191] *Southeast Asia forecast to invest $9.8 billion in smart grid infrastructure*, T&D World, September 5, 2018.
[192] *Microgrids, update 2018*, Global Data, hot-topics.globaldata.com.
[193] "The microgrid opportunity in India, 2024–2025: Identifying unelectrified locations that are best fit for electrification through microgrids," Research and Markets, April 14, 2020.

Exhibit 28

Asia accounts for almost half of world's renewable capacity and is projected to account for 64 percent of increase in capacity by 2040.



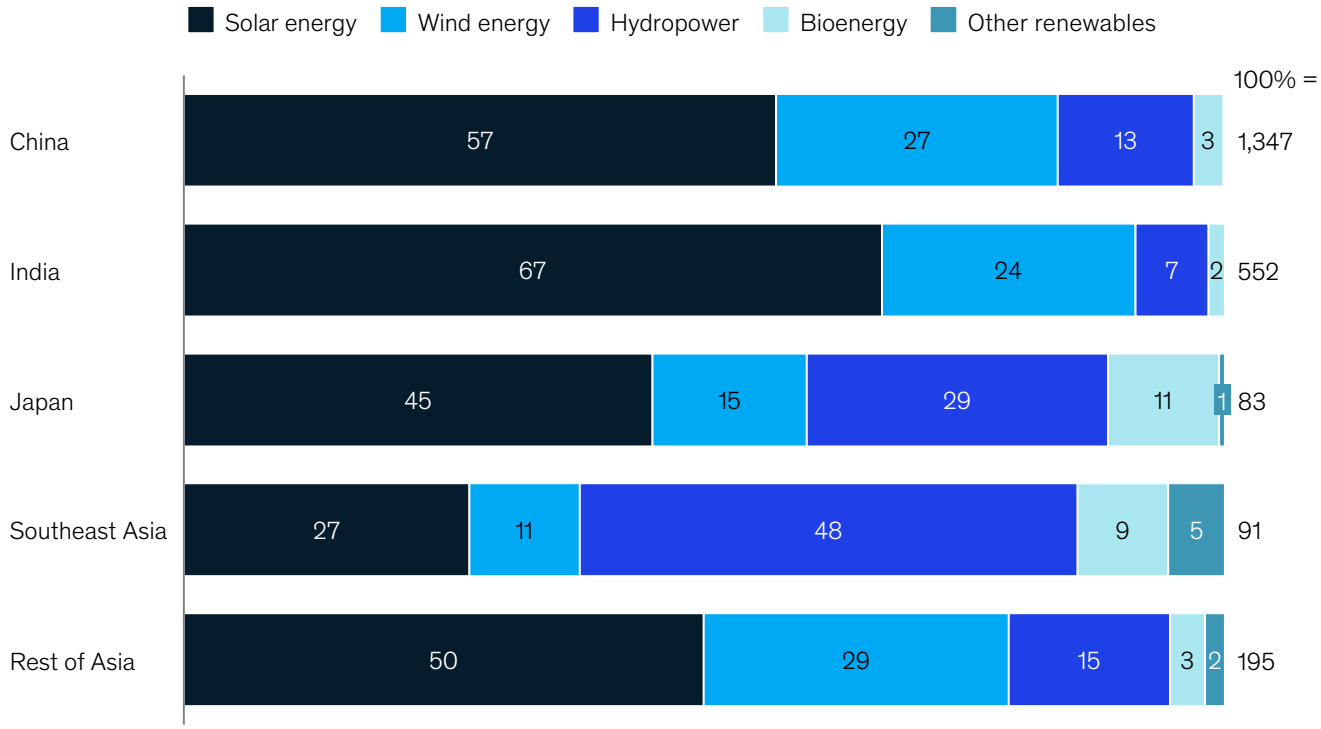
1. Projections based on current policy scenario by International Energy Agency.
2. Excluding pumped storage.
3. Excluding nuclear energy.

Source: IRENA Renewable Energy Statistics 2020; *World Energy Outlook*, International Energy Agency 2019; McKinsey Global Institute analysis

Exhibit 29

Solar and wind account for the majority of new capacity in Asia by 2040.

Additional renewable capacity, 2019–40, %, gigawatts



Note: Figures may not sum to 100% because of rounding.

Source: International Energy Agency; IRENA Renewable Energy Statistics 2020; McKinsey Global Institute analysis

Asian countries are among the world's top renewables suppliers, particularly in solar and onshore wind

Asian countries top global rankings on market share in four types of renewable energy: solar, onshore wind, hydrogen, and biofuels. Asia has also experienced some of the steepest drops in prices of electricity produced by renewables over the past decade, which have spurred more installation. The region—specifically China and India—is the most cost-competitive on solar, onshore wind, and hydropower. Solar and wind dominated the expansion of the region's renewable energy capacity in 2019, accounting for 90 percent of new capacity globally.[194] Global weighted average levelized cost of electricity (LCOE) for renewables have dropped around the world.[195] Between 2010 and 2019, the largest decline, 82 percent, was in solar photovoltaics (PV), followed by concentrated solar power at 47 percent, onshore wind at 39 percent, and offshore wind at 29 percent. In 2019, more than half of new renewable power capacity delivered electricity at a lower cost than coal, and 54 percent of that new capacity was in Asia.[196] The falling cost of renewable electricity partly reflects lower costs of technology and equipment—including solar modules, for instance—and partly the fact that solar and wind installations are increasingly achieving scale that enables a reduction in operations and maintenance costs and an ability to negotiate rates with equipment manufacturers. This strong position owes much to policy support from governments in the region, which have helped the industry to innovate in technology and develop competitive supply chains that have enabled players to build scale and cut costs.

Solar energy: China is the largest producer of solar PV modules, while India is the most cost-competitive in this technology

The cost of solar has been dropping around the world, but nowhere more so than in India. From 2010 to 2019 India experienced the largest decline of 85 percent in LCOE for utility scale solar PV to achieve the lowest LCOE in the world at $0.045 per kilowatt hour—or 34 percent lower than global average. The next two countries with the lowest cost are China and Spain at $0.054 and $0.056, respectively.[197] China has played a major role in reducing the price of equipment and technology. Between 2008 and 2013, global prices for solar panels dropped by 80 percent, mainly because of plunging costs in China.[198]

In 2019, China produced more than 70 percent of the global supply of solar PV; it remains the world's single largest supplier. The next most significant supplier is South Korea, which had a 7 percent market share in 2019.[199] China's position reflects strong support for the industry's development from the government, which has implemented more than 100 policies since 2000. Those policies are rooted in meeting national goals for renewable energy that the government sets in successive five-year plans, which then cascade down into regional plans and market and fiscal support. This sustained policy support has helped China to pivot from focusing on solar power in rural areas in the 1990s to becoming the world's largest producer, serving both domestic and international demand. Policy support has included mandatory renewable energy targets, feed-in tariffs, and other market and financial incentives. These have helped Chinese companies to be sufficiently competitive to serve soaring international demand. Policy support was particularly important in the mid-2000s, when demand accelerated and smaller markets outside Europe had trouble sourcing modules. With timely policy support, China's share of global shipments increased from 1 percent in 2004 to 38 percent in 2010 and 72 percent in 2017.[200]

[194] *Renewable capacity insights*, International Renewable Energy Agency, March 31, 2020, irena.org.
[195] Levelized cost of electricity represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and use cycle. LCOE is often used to gauge the overall competiveness of different energy generating technologies.
[196] *Renewable power generation costs in 2019*, International Renewable Energy Agency, June 2020, irena.org.
[197] Ibid.
[198] Will Doig, *How China sold us a solar-powered world*, Reasons to Be Cheerful, August 19, 2019.
[199] Yukinori Hanada, "China's solar panel makers top global field but challenges loom," *Nikkei Asian Review*, July 31, 2019.
[200] Paula Mints, *How China came to dominate solar manufacturing*, ALT Energy Stocks, November 4, 2018.

In March 2020, China announced plans to lower or discontinue subsidies of wind and solar. The main reason behind this policy shift was the government's aim to let these renewable energy sources compete with conventional sources and achieve grid parity.[201] Solar and wind construction costs dropped by 45 and 20 percent, respectively, from 2012 to 2017.[202] In some regions, these renewables have already achieved grid parity and can operate without subsidies. Newly built solar energy sources in China are now almost on par with the running cost of coal power plants.[203] The government was also motivated by a desire to ease the fiscal burden on the public purse as well as to discourage excess capacity, which has developed in some remote areas and in locations where renewable sources are abundant. In those areas, capacity has been added, but there has been a shortage of long-distance grid transmission capacity, resulting in energy waste.[204]

Onshore wind energy: China has the largest market share among the top ten global onshore wind manufacturers and is the most cost-competitive on this technology

Onshore wind power is now often less expensive than any fossil fuel as a way to generate electricity. Installation costs have been falling consistently as the capacity of turbines rises. Between 2010 and 2019, the global weighted-average LCOE from onshore wind projects fell by 39 percent, from $0.086 per kilowatt hour to $0.053 per kilowatt hour. During the same period, cumulative installed capacity grew from 178 gigawatts to 594 gigawatts.[205]

Two notable reasons for these trends are size and rotor diameters, which have both increased, thereby ensuring that more wind is captured and more electricity generated. The largest increase in average rotor diameter in the period from 2010 to 2018 was in Canada at 78 percent; the second largest—60 percent—was in China.[206] The weighted-average LCOE for onshore wind in 2019 for China and India were $0.046 and $0.049 per kilowatt hour, respectively. This compares with $0.051 in North America, $0.067 in Europe, $0.099 in other Asia, and $0.048 in Brazil.[207] In Asia, the average size of wind turbines increased by 55 percent from 2010 to 2017, compared with an increase of 32 percent in North America; today, the average size in Asia is 2.39 megawatts, compared with 2.36 megawatts in North America. In Europe, the average size is over 3.00 megawatts, largely driven by offshore wind.[208]

Low cost and rising domestic demand have helped increase the global share of Chinese wind manufacturing companies in onshore wind turbine manufacture. In 2019, China accounted for more than 44 percent of global market share of the top ten global manufacturers that together account for 85 percent of the onshore market. Thus, China had the largest share, followed by the United States with 27 percent and Denmark with 21 percent.[209] China's growing use of wind energy has been recent and rapid. Since 2010, the deployment of wind energy generation has grown at a compound annual rate of 27 percent. By 2018, China had established the largest installed onshore wind capacity, for the first time overtaking Europe. China now accounts for nearly one-third of global capacity.[210]

[201] *China to slash solar subsidies by 50% in 2020 – report*, Renewables Now, March 12, 2020.
[202] "China launches subsidy-free solar, wind power after project costs fall," *Reuters*, January 10, 2019.
[203] "Scale-up of solar and wind puts existing coal, gas at risk," *Bloomberg New Energy Finance*, blog, April 28, 2020.
[204] "China launches subsidy-free solar, wind power after project costs fall," Reuters, January 10, 2019; and Jay Ze, Yang Wang, and Michelle T. Davies, *China: Wind and solar energy in China – issues and regulatory regime*, Mondaq, June 1, 2020.
[205] *Renewable power generation costs in 2019*, International Renewable Energy Agency, June 2020, irena.org.
[206] Ibid.
[207] China had the lowest weighted-average LCOE in 2019 among countries or regions whose costs were specified. See *Renewable power generation costs in 2019: Latest trends and drivers*, International Renewable Energy Agency, June 9, 2020, irena.org.
[208] *Wind turbines continue to grow in size*, Power Technology, July 2, 2018.
[209] *Vestas still rules turbine market, but challengers are closing in*, Bloomberg New Energy Finance, February 18. 2020.
[210] *Future of wind*, International Renewable Energy Agency, October 2019.

In addition to setting overarching targets for use of renewable energy, the government introduced several policies that have helped China's wind-power industry to expand. In 2002, the government introduced concession tendering that required 70 percent domestically produced content to be used in the manufacture of turbines, helping to boost domestic manufacturing capacity for this type of renewable and more investment by foreign firms in manufacturing facilities in China. That catalyzed growth in domestic turbine manufacturers. In 2007, China had 40 wind turbine manufacturers; by 2008, there were 70. Between 2008 and 2011, the government explicitly began selecting provinces best suited to wind power. In 2009, it introduced feed-in tariffs for wind power that covered the entire period of turbine operations (usually 20 years); this also expanded capacity. In 2017, China's National Energy Administration issued requirements aimed at accelerating the construction of distributed wind power projects. So successful have government efforts to expand wind power been that there is a now a danger of overcapacity in the industry, and the government is planning to discontinue feed-in tariffs.[211]

Biofuels: Indonesia is the world's largest producer of biofuels, but widespread concern for the environment calls for innovation of more sustainable biofuel feedstocks

The cost of bioenergy is determined by two major and highly variable factors: the type of feedstock and the type of technology used in producing a particular form of biofuel. Thus far, the cost of bioenergy is lower in non-OECD countries largely because of their low-cost technologies used for the combustion of feedstock. The total weighted-average LCOE of bioenergy projects in the latest International Renewable Energy Agency Renewable Cost Database is $0.057 per kilowatt hour in India and $0.059 per kilowatt hour in China, compared with $0.08 in Europe and $0.099 in North America.

Biofuels are made from different raw materials or feedstocks. Brazil and the United States, the two largest biofuel producers, use soybean oil. Indonesia, the world's third largest biofuel producer in 2019, uses palm oil.[212] Palm has more than ten times oil yield per hectare and costs less than soybean. Indonesia's biofuel industry has expanded rapidly due to aggressive domestic mandates and incentives. In 2015, government made the use of B15—a fuel blend with 15 percent biodiesel—mandatory for industries reliant on diesel. It increased this mandated share over time to B20 and, in January 2020, to B30, or 30 percent biodiesel. This is the highest requirement for biodiesel in a fuel mix in the world. The scope of Indonesia's mandate has spread and now covers almost all economic sectors.[213] The government eventually plans to raise the biocontent requirement to 100 percent and recently piloted the production of 100 percent palm oil diesel (B100) in the state oil company, Pertamina.

However, the cost of both palm and soybean does not reflect the true cost to society. Both have been responsible for high rates of deforestation and loss of habitat in Latin America and Southeast Asia. Palm oil is, in fact, one of the most efficient feedstocks for biofuel by land use. Rapeseed requires nearly five times as much land, and soy nearly eight times as much, to produce the same yield, one study found.[214] Nevertheless, palm oil can cause up to three times more greenhouse gas emissions than diesel, and soy oil biofuel doubles the emissions of diesel. One study found that converting one hectare of rainforest land into oil palm plantation land led to the loss of 174 tons of carbon, most of which is released into the atmosphere as carbon dioxide—that's the equivalent of 530 people flying from Geneva to New York in an economy class as per the study.[215] For this reason (and loss of biodiversity), the European Commission has designated palm oil high risk and is phasing out its use.[216]

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[211] *30 years of policies for wind energy: lessons from 12 wind energy markets*, International Renewable Energy Agency, January 2013.

[212] Ian Tiseo, *Global biofuel production by select country 2019*, Statista, July 23, 2020; and Khairul Azly Zahan and Manabu Kano, "Biodiesel production from palm oil, its by-products and mill effluent: A review," *Energies*, August 2018, Volume 11, Number 8.

[213] Kiki Siregar, "Indonesia's B30 biodiesel plan a boost to domestic palm oil consumption," *Channel News Asia,* November 22, 2019, and *Indonesia produces maiden batch of biodiesel made of 100% palm,* Advanced Biofuels USA, July 16, 2020.

[214] E. Meijaard et al., *Oil palm and biodiversity: A situation analysis by the IUCN Oil Palm Task Force*, International Union for Conservation of Nature and Natural Resources, 2018.

[215] Ecole Polytechnique Fédérale de Lausanne, "Palm oil: The carbon cost of deforestation," *ScienceDaily*, June 19, 2018; and Thomas Guillaume et al., "Carbon costs and benefits of Indonesian rainforest conversion to plantations," *Nature Communications*, 2018, Volume 9, Number 2388.

[216] *Palm oil: Fuelling bioeconomy controversy?*, NNFCC, June 10, 2019, nnfcc.co.uk.

Given the climate risk faced by Asia, the onus is on governments, companies, and innovators to use technology to find more sustainable alternative biofuels. Innovation is under way, but thus far more sustainable biofuels formulated with genetic engineering are far from being commercialized because costs are not yet competitive. A few companies are producing genetically engineered microbes to create fuel for the aviation and marine industries.[217] In the United States, biochemicals and biofuels company Gevo has developed aviation fuel that synthesizes hydrocarbons to create renewable jet fuels in a process that the company calls "alcohol-to-jet, oil-to-jet, syngas-to-jet, and sugar-to-jet."[218] Making biofuels using algae, largely found in freshwater and marine environments in great quantities and with a CO_2 fixation efficiency estimated at up to 50 times higher than that of terrestrial plants, is one option. French companies Fermentalg and SUEZ have designed genetically engineered algae capable of capturing CO_2 and transforming it into biofuels.[219] Bio innovation such as this could represent a new frontier for Asian companies.

Hydropower: Asia accounts for the highest installed capacity of hydropower in the world but is increasingly switching to more sustainable renewable energies

Hydropower is the largest source of renewable energy and often the cheapest way to generate electricity in resource-abundant regions. Asia has the highest share in total installed capacity, with several countries in the global top ten. China has the largest installed capacity in the world, India ranks sixth, and Japan and Vietnam are also among the top countries in the world. In a number of Asian countries, namely Afghanistan, Bhutan, Myanmar, Nepal, and Tajikistan, hydro is a dominant source of electricity, especially for rural areas; it accounts for almost all renewables in these countries. Their governments have provided the necessary support to help scale hydropower. In India, the government launched additional policies in 2019 to support the sector. It approved a series of measures including granting renewable energy status to large hydroelectric projects (above 25 megawatts) and new funding. For instance, it devoted 1.5 crore rupees ($205,000) per megawatt to infrastructure projects of up to 200 megawatts, and 1.0 crore rupees ($136,000) for projects above 200 megawatts. With that support, the government aims to add 45 gigawatts of hydropower capacity to India's renewable energy portfolio.[220]

However, over the years hydropower has been losing share of new renewable capacity installations. Solar and wind have dominated, with 90 percent of new capacity in 2019.[221] The share of renewable hydropower in total renewable installed capacity fell from 78 percent in 2009 to about 43 percent in 2019 and is expected to fall even further, to 24 percent, by 2040.[222] This expected decline reflects the fact that most suitable Asian locations for hydropower have already been explored, and exploitation of new sites could involve challenging civil engineering conditions, driving costs higher. China's cost of installation was $1,062 per kilowatt from 2010 to 2014 and then rose to $1,264 per kilowatt—still low. For large hydropower projects China's cost is the lowest worldwide, trailing $1,349 per kilowatt in India and $1,460 in Brazil 2015 to 2019. The cost is highest in Oceania and in Central America and the Caribbean.

[217] Peggy Hollinger, "Greener biofuels battle for take-off to cut aviation emissions," *Financial Times,* March 30, 2020; and *Innovation outlook: Advanced liquid biofuels*, International Renewable Energy Agency, 2016.
[218] *Sustainable aviation fuel*, Gevo, December 2019.
[219] *Transforming CO2 into green energy*, SUEZ and Fermentalg, September 25, 2017.
[220] "Cabinet approved renewable status for large hydro power projects," *Economic Times*, March 7, 2019.
[221] *Renewables account for almost three quarters of new capacity in 2019*, International Renewable Energy Agency, April 6, 2020.
[222] *Renewable capacity statistics 2019*, International Renewable Energy Agency, 2019.

Efforts to make hydropower more sustainable have emerged in response to concerns about environmental impact related to land use, the loss of homes and natural habitat, and the disruption to river flow and ecosystems, including in the case of the Mekong.[223] These environmental issues serve to reinforce the popularity of solar and wind. Addressing environmental concerns is important because, in absolute terms, hydropower will continue to play an important role in the energy transition. New technologies are already emerging that are more sustainable and efficient. For instance, hybrid plants are being built that install floating solar panels on a dam's water surface, a cost-effective strategy that combines solar and hydro in one plant. This helps reduce the land taken up by solar plants, and, in the case of hydro, helps to protect the dam from insulation, increasing power generation by reducing evaporation losses, minimizing erosion of the bank, and reducing the buildup of algae.[224] Floating panels can help increase the capacity factor of hydropower plants by 50 to 100 percent. Asia is at the forefront in deploying this technology. The world's first floating solar plant was built in Japan, which has 73 of the 100 largest floating solar plants. These plants are particularly well suited for Southeast Asian countries where, as in Japan, land is scarce and there are many hydroelectric plants.[225] Currently Vietnam has the largest plant in the region, and overall, Southeast Asia is expected to witness a 100-fold increase in floating solar plants in the next five to 15 years.[226]

Hydrogen energy: South Korea and Japan are the strong players

Using hydrogen for fuel is appealing due to its abundance in nature, its wide applications, and its low impact on carbon emissions—it does not emit CO_2 during power generation. Hydrogen power can be produced from diverse resources including fossil fuels, biomass, and water electrolysis with wind, solar, or grid electricity. The environmental impact and energy efficiency of hydrogen depend on how it is produced. When produced with renewable electricity (green hydrogen), it has the potential to decarbonize sectors. Currently, however, 95 percent of hydrogen is produced from fossil fuels—but it is more efficient than conventional power technologies. With advances in technology and commercialization driving down cost, hydrogen is being looked at as an important area by many countries.

Of 14 countries at the forefront of hydrogen innovation and adoption, Bloomberg ranked South Korea and Japan as the top two economies scored against five sectors.[227] The government of South Korea has set ambitious targets for developing a hydrogen economy in the period to 2040. Those targets include producing 6.2 million fuel cell EVs, 15 gigawatts of fuel cell power generation, and 2.1 gigawatts of stationary fuel cell applications in buildings. The South Korean company Hyundai developed the world's first commercial fuel cell EV in 2013. Japan's Toyota and Honda are also producing fuel cell EVs at scale. Japan is also one of the most advanced markets for green hydrogen. The recently completed Fukushima Hydrogen Energy Research Field is the world's largest plant for production of hydrogen from renewable energy. Hydrogen can be further processed into hydrocarbon or ammonia that can be used as fuel for shipping to achieve zero emissions. Japan is one of the few countries moving this idea from theory to the design phase. Japan's Green Ammonia Consortium is an industry body dedicated to demonstrating the successful use of ammonia in developing supply facilities.[228] In early 2020, Japan's NYK presented plans for ammonia and next-generation marine fuels to realize decarbonization.[229] The primary goal of Japan's hydrogen economy strategy is also to make hydrogen cost competitive; the government aims to reduce the price by 90 percent by 2050 to make it cheaper than natural gas. Today, Japan is the world's largest importer of natural gas and pays the highest price per imported

[223] See, for example, Shaoqing Chen, Bin Chen, and Brian D. Fath, "Assessing the cumulative environmental impact of hydropower on river systems based on the energy network model," *Renewable and Sustainable Energy Reviews*, October 2014, Volume 42; and Chin Luu and Jason von Meding, *Hydropower development and environmental impact assessments in Vietnam: Current practice and shortcomings*, Proceedings of the 37th WEDC International Conference, Sustainable Water and Sanitation Service for All in a Fast Changing World, Hanoi, Vietnam, September 2014.

[224] Emanuele Quaranta, "Floating solar + hydropower hybrid projects can benefit both technologies," *Solar Power World*, May 28, 2020.

[225] Douglas Bloom, *How Japan became the world leader in floating solar power*, World Economic Forum, March 22, 219.

[226] *Southeast Asia to see 100-fold increase in floating solar PV plants: Rystad Energy*, ET Energy World, September 9, 2019.

[227] *H_2 economy today*, Bloomberg, October 2019.

[228] Trevor Brown, *Maritime ammonia: Ready for demonstration*, Ammonia Energy Association, May 7, 2020.

[229] *NYK introduces concept of using ammonia as marine fuel*, NYK Line, February 26, 2020.

unit.[230] The Japanese government has dedicated $1.5 billion toward hydrogen technology R&D.[231] The governments of both Japan and South Korea are actively supporting the hydrogen economy using a combination of financial incentives, the creation of domestic markets, and instruments.

Energy companies of the future can consider striving toward carbon neutrality

It is almost imperative that the energy company of the future adapt to sustainable forms to remain relevant and to be seen as part of the solution to carbon emissions. There is a high share of state-owned enterprises in Asia's energy sector, and these may adapt to new circumstances and changing market dynamics relatively slowly. This implies that the region's energy sector may need to start thinking proactively about the implications of energy transition to their businesses, and how to make big and bold decisions in order to continue to survive and thrive. Energy companies today can therefore consider two broad choices. They can diversify their portfolios toward cleaner energy forms or, if they choose not to shift away from fossil fuels, remove carbon from their value chains. These directions will entail a major shift, a large amount of financing, and investment in R&D and technologies. One analysis puts the investment needed by 2050 at about $50 trillion if the global goal of zero net emissions is to be met.[232] It is not easy to raise such funds given that capital markets have no obligation to reward sustainable behavior. Long-term transition costs may be outside of the scope of investors' time horizon. Even though instruments such as green bonds first launched in 2008 have become mainstream in many countries, they have been unable to stimulate significant investment by lowering the cost of capital. We look briefly at the two directions:

— **Diversify current portfolios toward renewable or clean forms of energy.** This shift will require a significant reallocation of capital, but there are examples of companies that have successfully executed this change. In 2008, Orsted announced plans to transform itself from a black to a green energy company. It began to phase out coal and sell off its oil and gas business, and it made large investments in wind energy. In a decade, Orsted has changed from being Denmark's largest fossil-fuel energy company responsible for one-third of Denmark's carbon footprint to being one of the largest renewable energy companies in the world. The company in 2017 also changed its name from Danish Oil and Natural Gas company (DONG Energy) to Orsted to reflect its new identity. The company plans to end its use of coal by 2023 and be carbon neutral by 2025.[233] Finnish energy company Neste (once Neste Oil) had been an oil refinery company, but in the 2000s it shifted also to producing biofuels, investing heavily in R&D and increasing capital expenditure. It is now the leading global producer of renewable diesel.[234] Fossil fuel giants such as BP, Shell, and Total are all including cleaner energy forms in their portfolios in a bid to cut their carbon footprint.[235] India's Reliance Industries Limited aims to become carbon neutral by 2035. Although Reliance intends to continue to use crude oil and natural gas, the company plans to also invest in clean and affordable energy sources including wind, solar, and hydrogen. Australia's coal mining giants BHP and Rio Tinto are adding renewables and battery storage to their mining sites to reduce energy sourced from gas and diesel.

[230] Robin Harding, "Japan's hydrogen dream: Game-changer or a lot of hot air?" *Financial Times*, June 17, 2019.
[231] Monica Nagashima, *Japan's hydrogen strategy and its economic and geopolitical implications*, IFRI Centre for Energy, October 2018.
[232] *Decarbonization: The race to zero emissions*, Morgan Stanley, November 25, 2019.
[233] Adele Peters, "How this Danish energy company is transitioning from oil and gas to all renewables," *Fast Company*, May 2, 2020.
[234] *Neste 70 years: From a Finnish oil refiner to the world's largest producer of renewable diesel*, Neste, January 9, 2018.
[235] Simon Flowers, *Jam today versus jam tomorrow*, Wood Mackenzie, January 23, 2018.

— **Remove carbon from value chains.** Not all energy companies can completely transform their portfolios. Doing so may not offer a reasonable return on large, upfront investment, or companies may face a lack of supporting storage or grid infrastructure. These companies could opt to remove carbon from their value chains through carbon capture and storage (CCS) technologies that trap carbon, preventing it from entering the atmosphere. Alternatively, they could reduce their carbon emissions through energy efficiency measures and digital technologies. Both BP and Shell target zero net emissions by 2050 at the latest through CCS, digital energy efficiency technologies, and expanding their portfolios to include more clean and renewable energy. BP is expanding its investment in CCS and is considering building a zero carbon cluster at its UK industrial complex of oil refineries and chemical factories; the company plans to inject the carbon into rock formations in the North Sea. This project could help capture 2 percent of the United Kingdom's annual emissions.[236] BP has also invested in digital and AI companies such as Grid Edge and R&B, which design systems that predict and control energy use in buildings.[237] Shell's Quest Project in Canada is a fully integrated CCS facility designed to capture, transport, and store underground more than a million tons of CO_2 annually.[238] CCS technologies could be important for meeting global climate targets, but they have limitations and have not lived up to their full promise. CCS can only be applied to processes that are large-scale emitters. Currently, only 21 large CCS facilities are operational, of which 14 are in North America (ten in the United States and four in Canada). Only two facilities are in Asia (in China and Australia). However, momentum is growing, with 40 facilities at different stages of development; of these, ten are in Asia, including one each in New Zealand and South Korea. However, more will be needed.[239] Digital technologies can be applied faster and on a larger scale. Technologies such as smart grids and smart meters are already being adopted rapidly in Asia, as we have discussed. These technologies are relatively easy to adopt and are expected to spread rapidly across electricity utilities.

In this section, we discussed four types of opportunities in Asia that can overcome current challenges and thereby open up new vistas for progress: accelerating consumer digital adoption, building on manufacturing strengths, growing digital services based on a strong endowment of talent, and making a strong contribution to the energy transition. In the final section, we explore how business leaders and policy makers around the world can capture the opportunities and accelerate innovation in Asia.

[236] Akshat Rathi, *BP expands carbon capture capabilities to meet 2050 climate goals*, World Oil, February 13, 2020.
[237] *BP invests in Chinese AI energy management tech specialist R&B*, BP, January 9, 2020.
[238] *Carbon capture and storage projects*, Shell, shell.com.
[239] Facilities database, Global CCS Institute, co2re.co.

4. Speed, collaboration, and resilience can deliver success

Innovation today matters even more than ever—it is potentially the key that unlocks post-pandemic growth and addresses challenges Asia faces. In a McKinsey survey of more than 200 organizations across industries, nearly three out of four executives agreed that changes brought about by COVID-19 can be a large opportunity for growth. This number was even higher in the technology industry, with 85 percent of executives expecting the crisis to present a big opportunity.[240] In the COVID-19 era, three attributes appear to be vital to corporate success. The first is speed. The pace of technology innovation and adoption by Asian companies and consumers is fast and, indeed, unmatched by other regions. The second is collaboration. There is a strong case for corporations to work in partnership with governments, particularly in Asia where policy makers have been an integral part of technological development. The third is resilience. The pandemic in 2020 amply demonstrated the fragility of supply chains in the case of a global shock; making those supply chains more resilient in what could be a more explicitly multipolar world in innovative technologies and geographies is a priority if companies and investors are to access the full variety of opportunities. Asian firms can build on these three attributes to tackle challenges and prepare for future success.

Speed: Continually adapt to the rising pace of innovation

Asia has accounted for the majority of growth in technological capabilities over the past decade, as we noted in the first section of this paper. Innovation forced on many companies and consumers as a consequence of the COVID-19 pandemic appears to have accelerated this process. Consider, for instance, that South Korean biotech firm Seegene used an AI-based big data system to design a diagnostic test for the virus within two to three weeks, a process that would usually take two to three months. Many companies moved all employees to remote work in a matter of days.[241] Chinese mass beauty brand Perfect Diary quickly moved offline makeup experts online and used its more than 10,000 WeChat groups for private-domain social engagement and commerce.[242] Such developments suggest a new era of disruption, new forms of competition, and radical changes to business models. Companies that adapt to the accelerated pace of innovation will thrive; those that don't may struggle. Considerations for companies include the following:

— **Continually take the pulse of rapidly changing consumer preferences.** Customer experiences are already powered by technology. In Asia, technology adoption is happening quicker than it is elsewhere, and this pace is set to continue. Successful companies will be those that are responsive and cater to consumers' thirst to have technology baked into the shopping experience, from incorporating electronic payments to offering big data-based recommendations. In China, for example, Burberry partnered with Tencent to launch a luxury concept store, which gives shoppers access to exclusive content and personalized experiences through a WeChat program and lets them share experiences on their social media networks.[243] The concept store is regarded as a unique place to conduct trials of innovations that can be expanded to the rest of Burberry's

[240] Jordan Bar Am, Laura Furstenthal, Felicitas Jorge, and Erik Roth, *Innovation in a crisis: Why it is more critical than ever,* McKinsey & Company, June 17, 2020.
[241] Ivan Watson et al., "How this South Korean company created coronavirus test kits in three weeks," CNN, March 13, 2020.
[242] Johnny Ho, Daniel Hui, Aimee Kim, and Yuanyuan Zhang, *Cautiously optimistic: Chinese consumer behavior post-COVID-19,* McKinsey & Company, March 31, 2020.
[243] "Burberry and Tencent team up for concept stores," BBC News, July 31, 2020.

network in China. As Asia becomes the first region to adopt some of the newest technologies, it may also become the "test lab" for pioneering commerce models.

— **Enhance organizational agility.** During the COVID-19 crisis, companies fast-tracked innovation, partly because governments reacted faster on regulation and approvals in a bid to compress the timeline of vaccine development. But this new agility can now be applied more comprehensively—quick reactions have been proven to be possible and can now become the norm. Organizations can consider flattening their structures and delegating decision making to enable faster choices and implementation. Ubiquitous digital technology means that companies can move away from co-located, full-time employees to a mix of gig workers, flexible contract employees, and full-time employees who can work remotely and flexibly. For example, Indian IT services firm TCS has set a target of having only 25 percent of its workforce present in the office to deliver 100 percent of productivity by 2025.[244] New working models mean that organizations have a much greater opportunity to access talent anywhere, anytime.

— **Further build the talent and skills pool.** Advanced Asia and China have strong positions in owning patents, India and China have robust talent pools, and the rest of Asia is building strength in manufacturing. However, given automation that is radically changing the skills that will be in demand—and those that will be less so—and significant shifts in digitization, business models, and consumer behavior during the COVID-19 pandemic, even more complexity awaits.[245] Employee skills and companies' talent acquisition must evolve and be as agile as possible.

Collaboration: Forge partnerships with ecosystem players

Collaboration is vital given heightened complexity. Collaboration includes horizontal ecosystems, public-private partnerships, research-based collaborations, and scenario-based strategy relative to understanding government and other players:

— **Explore opportunities for public-private collaboration.** As noted, Asian governments have played a key role in facilitating the development and adoption of technology—and an even more central role during the COVID-19 crisis. Corporate Asia needs to be aware of, and keep pace with, this burst of government activity, and it might consider how to align its strategy with the direction of government policy. In all instances of successful development of technological capabilities, the hand of government has been evident. Governments have catalyzed technological development and funding research in the background through enabling regulation—as Singapore did in cultivating the fintech sector—or played a more central role, actively creating ecosystems in which companies can thrive. Efforts to encourage renewable energy in China and India are an example of this higher-profile government approach. If anything, the COVID-19 pandemic deepened existing collaboration between Asian governments and companies. Examples of governments working closely with technology companies during the pandemic range from facilitating data sharing to conducting contact tracing in South Korea to implementing national health QR codes in China and Singapore.[246] Government policy and strategy have substantial implications for the pace of innovation, and companies may therefore need to consider how they can effectively engage with policy makers to keep informed on policy developments at a minimum and, ideally, participate in public-private collaborations.

[244] *Future of WFH: TCS aims to have only 25% of its workforce in office by 2025*, Tech Gig, April 20, 2020.
[245] Sapana Agrawal, Aaron De Smet, Sébastien Lacroix, and Angelika Reich, *Stronger from the COVID-19 crisis, companies should start reskilling their workforces*, McKinsey & Company, May 7, 2020; Aamer Baig, Bryce Hall, Paul Jenkins, Eric Lamarre, and Brian McCarthy, *The COVID-19 recovery will be digital: A plan for the first 90 days,* McKinsey & Company May 14, 2020; and Kweilin Ellingrud, Rahul Gupta, and Julian Salguero, *Building the vital skills for the future of work in operations,* McKinsey & Company, August 7, 2020.
[246] Oliver Tonby, Jonathan Woetzel, Noshir Kaka, Wonsik Choi, Jeongmin Seong, Brant Carson, and Lily Ma, *How technology is safeguarding health and livelihoods in Asia,* McKinsey & Company, May 2020.

— **Use the power of data through core technology transformations.** The accelerated adoption of digital technologies, coupled with Asia's large user base, is generating unprecedented volumes of data that can be used to create new insights and deliver much greater impact. Firms are also collaborating in their use of data, which can help address market failures resulting from information asymmetries. From 2017 to 2019, the share of companies forming data-related partnerships increased from 21 to 40 percent. Even competitor companies are collaborating, and the share of these types of partnerships among business competitors has increased from 7 to 17 percent.[247] Several examples of data partnerships have emerged in China during the COVID-19 crisis. Collaboration on data helped many Chinese companies to maintain uninterrupted e-commerce during the pandemic. By sharing data, 3,000 Chinese companies were able to quickly and significantly scale up production of medical supplies and coordinate with hundreds of designers; this speed enabled China to build Huoshenshan Hospital in just ten days, for example.[248] Companies such as Alibaba and Tencent have been at the forefront of data collaboration and have adopted more open data architecture. Cainiao, Alibaba's logistics data platform, addresses back-end delivery challenges through an intricate web of horizontal partnerships, which enables faster and cheaper growth for Alibaba. In contrast, Amazon is quite reserved about sharing data with third-party vendors and often competes with ecosystem partners.

— **Develop and leverage digital ecosystems to create value.** Digital ecosystems and platforms bring businesses together just as physical proximity does in Silicon Valley and other technology hot spots, but digitization enables network effects to develop much faster. As noted, many digital ecosystems have moved beyond their original offer of convenience under one platform to offering adjacent products and services. Examples include super apps WeChat and Gojek. Value comes from designing operating models to facilitate interactions, which involves careful consideration of broad versus narrow, or open versus closed, architecture, as well as choices about whether and how extensively to share innovation and IP.[249]

Resilience: Companies can ensure that their supply chains and business portfolios are adaptable

Technology strengths spread across Asia in a multipolar landscape. Success may depend on companies ensuring that their supply chains and footprints match this dispersed model of technological excellence, as in the following examples:

— **Build resilient supply chains.** With supply chains growing more complex and globalized, it is important for businesses to strike a balance between efficiency and resilience. It is estimated that on average across industries, companies can face supply-chain disruptions that can last a month or more every 3.7 years. The COVID-19 pandemic, which disrupted supply chains across the world, has been one of largest such events. Moreover, Asia is particularly vulnerable to earthquakes, tsunamis, and typhoons, which have worsened in recent years due to climate change. Companies have several options to reduce vulnerabilities and external shocks in their sourcing strategies. They include reevaluating geographic footprints, building redundancy in supplier and transportation networks, holding more inventory, reducing product complexity, creating capacity to flex production across sites, strengthening risk management capability, and improving transparency. A May 2020 McKinsey survey of business leaders and supply chain executives found that 93 percent of respondents planned to take multiple measures, including regionalizing

[247] William Hoffman, Raphael Bick, Austin Boral, Nicolaus Henke, Didunoluwa Olukoya, Khaled Rifai, Marcus Roth, and Tom Youldon, *Collaborating for the common good: Navigating public-private data partnerships*, McKinsey & Company, May 30, 2019.
[248] Shameen Prashantham and Jonathan Woetzel, "3 lessons from Chinese firms on effective digital collaboration," *Harvard Business Review*, August 10, 2020.
[249] Michael G. Jacobides, Arun Sundararajan, and Marshall Van Alstyne, *Platforms and ecosystems: Enabling the digital economy,* World Economic Forum, February 2019.

supply chains, dual sourcing of raw materials, increased inventory of critical products, and nearshoring of production.[250]

Asia has a strong lead in technologies including AI, IoT, robotics, and analytics, and can leverage them to build resilience. Leading companies in the region are already doing so. Toyota has built a database that enables it to visualize its supply networks for each of four million components so that if disruption occurs in a certain area, the system can immediately identify parts at risk.[251] Similarly, Chinese appliance manufacturer Haier has implemented a procurement system that offers real-time data on sourcing.[252] Samsung's supply chains proved robust during the COVID-19 pandemic, but the company continues to refine its supply chain management to build resilience using the latest technology. In July 2020, the company partnered with Kinaxis to use the latter's rapid response cloud-based technology to manage its global supply chain.[253]

— **Achieve scale through regional collaboration.** In a multipolar world, businesses and countries may find it difficult to achieve economies of scale. Disrupted flows in technologies and trade could increase R&D and operational costs. Stronger regional collaboration can help to create scale at the regional level and accelerate technology development and adoption. Such collaboration is arguably more important for developing countries that may lack funding, infrastructure, or capabilities and would otherwise have to build their own technologies from scratch. Regional cooperation in Asia is well established. Regional groupings including ASEAN, the South Asian Association of Regional Collaboration, Asia Pacific Economic Cooperation, and East Asia Summit cooperate and exchange knowledge across a wide range of sectors and issues. In ASEAN, current science and technology cooperation includes nine programs that range from marine science and technology to space technology and applications.[254] The ASEAN Plus Three countries (ASEAN, China, Japan, and South Korea) are working together to promote connectivity and innovation in the region by sharing best practices to support the development of the digital economy and the building of ASEAN's open data network.[255] The Regional Comprehensive Economic Partnership is focusing on facilitating flows of essential goods and services and on enhancing cooperation in response to COVID-19, and could broaden its agenda to collaborate on technology and innovation. As regional collaboration expands, it can facilitate a flow of fresh ideas about business models, capital to fund startup activities, and knowledge of core technologies, and further accelerate Asia's pace of innovation.

[250] *Risk, resilience, and rebalancing in global value chains*, McKinsey Global Institute, August 2020.
[251] "Toyota looks to develop ways to disaster-proof its supply chains," *Chunichi Shimbun via Japan Times*, July 26, 2019.
[252] Raymond Chou, *How customers transformed Haier sourcing through digitalization and modularization,* Chain.net, September 17, 2018.
[253] Dale Benton, "Samsung smartens up its supply chain with Kinaxis," Supply Chain, July 29, 2020; and *How Samsung kept its supply chain intact even during the pandemic*, SamMobile, May 8, 2020.
[254] *ASEAN health sector efforts on COVID-19*, ASEAN, asean.org.
[255] "ASEAN Plus Three countries pledge to enhance regional connectivity," Xinhua, November 4, 2019.

— **Rethink business portfolios and capital allocation.** To remain resilient, companies can rethink their business portfolios and capabilities from a technology perspective. Capital allocation is the most critical means of translating business strategy into implementation. Several companies have begun to pivot electricity generation from coal and oil to renewable energy sources. As noted, NESTE and Orsted have made effective portfolio shifts to cleaner forms of energy, and there are many other examples of companies reallocating capital to new technology products and building capability through investments in intangibles including R&D. As innovation speeds up, those decisions are likely to be more frequent, and CEOs should be prepared. To remain relevant, companies may need to reconsider sinking money into old businesses that are not evolving. Disruptive technologies and products have the proven power to turn market share around and, indeed, change markets entirely. For example, smartphones have not only replaced simple mobile phones, but also are competing with other devices such as cameras, portable music players, calculators, and even laptops. Lithium-ion batteries are making lead and acid batteries obsolete. Reallocations of capital need to take into account cost resilience, and the COVID-19 pandemic is a good time to focus on cost. Businesses may prefer to buy technology on a pay-as-you-go model, varying the cost according to conditions and need. Cloud services, for instance, are a good way to reduce capital expenditure on IT as companies shift away from in-house data centers that require space, equipment, software, and personnel, adding cost.

Asia has been through a rapid technological transformation over the past decade and still offers tremendous leapfrogging opportunities over the coming decades. Innovation in the region can enhance quality of life for the region's more than four billion citizens, create exciting opportunities for the commercialization of new ideas, and advance productivity growth. In a post-COVID world, the pace of innovation may accelerate even further. Business leaders and policy makers in the region can catalyze that innovation, creating benefits for all.

Technical appendix

This technical appendix focuses on our methodology for summarizing the potential economic impact of disruptions to global flows of technology. We collected and reviewed the external research, academic literature, and other MGI publications that can serve as reference information to gauge the economic impact of disruptions to technology-related flows. For each of the seven drivers, we derived the range of potential value at stake as follows:

— **Interrupting data flows.** In 2016, MGI's digital globalization report estimated that data flows account for 3 percent of global GDP.[256] Assuming that barriers to trade cause a 10 percent disruption to data flows, the GDP impact could be minus 0.3 percent. The European Centre for International Political Economy calculates losses resulting from data localization requirements and from related data privacy and security laws that discriminate against foreign suppliers of data in seven territories.[257] The losses estimated are 0.8 percent for Brazil, 1.1 percent for China, 1.1 percent for the EU, 0.8 percent for India, 0.7 percent for Indonesia, 1.1 percent for South Korea, and 1.7 percent for Vietnam. Assuming these seven territories represent global data flow restrictions, we used the percentage GDP losses, multiplied them by projected GDP figures from McKinsey's Global GDP Model, and calculated that the total amount as a percentage of global GDP would be approximately equal to minus 1 percent. Therefore, the range of GDP impact from interrupting data flows could be between minus 0.3 and minus 1 percent.

— **Increasing cost due to tariffs.** A number of global organizations and research institutes have sought to simulate the potential impact of rising tariffs on trade and GDP, especially in the context of US-China trade disputes.[258] In 2019, the OECD estimated that trade disputes could reduce the level of global GDP by 0.6 percent by the end of 2021, and the International Monetary Fund (IMF) forecast similar impact of 0.8 percent of global GDP.[259] A Banque de France paper assessed the short-term impact of higher trade tariffs on the global economy using the IMF's global integrated monetary and fiscal model.[260] The calculation takes into account the direct impact of tariff increases on the global economy, as well as indirect effects such as a fall in productivity, higher financing costs, and an increase in uncertainty. The model assumes a full trade war scenario, modelling a 10 percent increase in tariffs on imports from all trading partners, and highlights the costs of a generalized global trade war. It estimates that a trade war could cause a direct negative impact on global GDP of about 1 percent and, taking direct and indirect impact together, as much as 2.5 percent of global GDP after three years.

— **Divergence in standards.** A study in the *Journal of Competition Law & Economics* concludes that the development of complex technologies often requires firms to coordinate their innovation activity and R&D, ensure interoperability, and streamline standards development.[261] Competition in standardization generates duplication in R&D

[256] *Digital globalization: The new era of global flows*, McKinsey Global Institute, March 2016.
[257] Erik van der Marel, Hosuk Lee-Makiyama, and Matthias Bauer, *The costs of data localization: A friendly fire on economic recovery*, European Centre for International Political Economy, May 2014.
[258] *OECD Economic Outlook*, Volume 2018, Issue 2, OECD, 2018; *Making trade an engine of growth for all: The case for trade and for policies to facilitate adjustment*, International Monetary Fund, World Bank, and World Trade Organization, April 10, 2017.
[259] *OECD Economic Outlook, Interim Report*, OECD, September 2019; *World Economic Outlook*, IMF, October 2019.
[260] Antoine Berthou et al., "Costs and consequences of a trade war: A structural analysis," *Rue de la Banque*, Banque de France, December 2018, Issue 72.
[261] Justus Baron and Tim Pohlmann, "Who cooperates in standards consortia—rivals or competitors?" *Journal of Competition Law & Economics*, December 2013, Volume 9, Issue 4.

activities and delays. One UK study found that technological change from all sources contributes to 1 percent of GDP, and that standards growth accounts for more than a quarter of this.[262] ETSI, the European standards organization, cites research that estimated the contribution of standards to GDP to be within a similar range.[263] We therefore derived the range of the negative impact on GDP of a divergence in standards of between 0.25 percent and 1 percent.

— **Establishing export controls.** MGI research on value chains in 2020 estimates that losses due to disruption to global supply chains over a decade are equal to about 7 percent of annual company profits.[264] Using gross domestic income as a proxy for GDP, we calculated that corporate profits average 28 percent of gross domestic income globally—34 percent in the United States, 28 percent in China, and 20 percent in Japan. We therefore estimate that export controls could have a negative impact on GDP of 0.3 percent to 2.0 percent (7 percent of annual corporate profits multiplied by the average share of gross domestic income of 28 percent).[265]

— **Banning research collaboration**. A National Science Board report finds that the proportion of worldwide articles produced through international collaboration (authors from at least two countries) grew to 23 percent in 2018.[266] We assume that R&D spending has a positive impact on GDP and that the value at stake is equivalent to a global ban on all cross-border R&D collaborations. We also assume that R&D collaboration results in the dissemination of knowledge and creation of inventions, which in turn is a marker of technical progress, or total factor productivity. McKinsey's Global GDP Model estimates that the total factor productivity contribution to GDP growth is about 30 percent. Given annual global GDP growth is between 2 and 3 percent, we estimate the total value at stake from the ban in collaboration research could be between 0.1 and 0.2 percent.

— **Forced technology transfer.** A body of literature describes the importance of technology flows and IP protection. Studies have found that multinational firms and their global R&D activities can result in a faster rate of technology transfer within multinational firms and increase long-run consumer welfare in both regions.[267] Studies also argue that strengthening intellectual property (IP) rights protection induces a large technology transfer and narrows the wage gap between developed and emerging nations.[268] We have not summarized quantitative impact as the impact varies by individual cases.

— **Non-tariff barriers (NTB) to market access.** Several studies indicate the impact of non-tariff barriers on market access. One study finds a statistically significant negative effect of compliance measures which reduces the number of exporting countries by as much as 35 percent, compared with the situation where no compliance requirement is imposed.[269] Another study based on empirical analysis shows that implementation of at least one NTB by a country reduces imports of affected products from targeted exporters by 4 to 12 percent.[270] The magnitude of impact varies widely by the size of countries, sectors, the degree of changes required, and methodologies used. Various methodologies can also lead to different outcomes.[271] We have not summarized the quantitative impact as the impact varies by individual cases.

[262] G. M. Peter Swann, *The economics of standardization: An update*, Report for the UK Department of Business, Innovation and Skills Innovative Economics Limited, 2010.
[263] Nizar Abdelkafi et al., *Understanding ICT Standardization: Principles and Practice*, Hamburg, Germany: Tredition, 2019.
[264] *Risk, resilience, and rebalancing in global value chains*, McKinsey Global Institute, August 2020.
[265] These estimates are for 2018 or later. US Department of Commerce, CEIC (data for China), and Government of Japan cabinet office.
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Acknowledgments

This paper is part of a series on the future of Asia, prepared in collaboration with the Asia offices of McKinsey & Company, which will all be available at mckinsey.com/featured-insights/future-of-asia.

The research was led by Oliver Tonby, McKinsey senior partner in Singapore and chairman, McKinsey Asia; Jonathan Woetzel, McKinsey senior partner and a director of the McKinsey Global Institute in Shanghai; Noshir Kaka, senior partner in Mumbai and leader of the McKinsey Analytics Practice; Wonsik Choi, McKinsey senior partner and managing partner, Korea, based in Seoul; Anand Swaminathan, McKinsey senior partner in Singapore; Jeongmin Seong, MGI partner in Shanghai; and Brant Carson, a McKinsey partner in Sydney. We are indebted to MGI senior partner and MGI chairman James Manyika and to MGI partners Michael Chui, Susan Lund, and Sree Ramaswamy for their guidance. Lily Ma led the project team, which comprised Takakazu Doi, Ted Jeon, Haemin Jeong, Jinesh Lalwani, Cady Liang, Arting Luo, Snigdha Manukonda, Jyotsna Mehta, Belinda Ong, and Raye Qin. We are grateful to Arjun Chandrasekhar, Ziad Haider, and Meng Liu in McKinsey's risk team.

We thank our academic advisers, who challenged our thinking and provided valuable guidance. We thank Rakesh Mohan, a senior fellow at the Jackson Institute for Global Affairs at Yale University and distinguished fellow at Brookings India; Gordon Orr, director emeritus and senior adviser to McKinsey; Andrew Sheng, distinguished fellow of the Asia Global Institute; Matthew Slaughter, Paul Danos Dean of the Tuck School of Business and the Earl C. Daum 1924 Professor of International Business at Dartmouth College; and Christopher Thomas, member of the board of directors and chair of the audit committee of Velodyne LIDAR.

We thank Parv Aggrwal, Stefan Burghardt, Abhinav Chanakya, Frank Chu, Mahima Chugh, Johannes Deichmann, Michael Ellis, Karel Eloot, Akshay Goenka, Hari Govindahari, Rahul Gupta, Shivanshu Gupta, Thomas Hansmann, Sven Heiligtag, Sheng Hong, Daniel Hui, Anuj Kadyan, Peter Kenevan, Dymfke Kuijpers, Dhiraj Kumar, Shruti Kumar, Nimal Manuel, Saurabh Mishra, Himanshu Pandey, Alpesh Patel, Aparajita Puri, Benjamin Sauer, Jigar Shah, Gourav Sharma, Ishprateek Singh, Jan Paul Stein, Godart van Gendt, Zi Wang, Simon Wintels, Susan Zhang, Tiankai Zhu, and Daniel Zipser.

We thank MGI senior editor Janet Bush for producing this paper; Cathy Gui, head of MGI external relations in Asia; Lauren Meling, MGI's digital editor; MGI senior editor Stephanie Strom; Marisa Carder, MGI senior graphics specialist; and Julie Philpot, MGI editorial production manager. We are grateful to Kathryn Haynes, Debbi Cheong, and Samantha Hayden in McKinsey's Asia external relations team.

This paper contributes to MGI's mission to help business and policy leaders understand the forces transforming the global economy and prepare for the next wave of growth. As with all MGI research, this work is independent, reflects our own views, and has not been commissioned by any business, government, or other institution. We welcome your comments on the research at MGI@mckinsey.com.

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McKinsey Global Institute
December 2020

Designed by the Sydney Design Studio

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