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THE CHINA EFFECT ON GLOBAL INNOVATION

OCTOBER 2015

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THE CHINA EFFECT ON GLOBAL INNOVATION

OCTOBER 2015



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PREFACE

How innovative is China? How innovative does it need to be? These are the fundamental questions underlying this research. The answers are somewhat surprising. In many ways, we find, Chinese industry is more innovative than is generally acknowledged. Chinese companies have established strong positions in two types of innovation—developing new products and services that address consumer needs, and process innovations that make manufacturing more efficient. We also find that China has a growing need to innovate more broadly, across more industries, and raise innovation performance in engineering and science. China needs to evolve from an innovation “sponge” to an innovation leader to sustain GDP growth in the coming decade as other drivers of growth—an expanding labor force and capital investment—decline.

We conclude that China has the potential to meet its “innovation imperative” and to emerge as a driving force in innovation globally. The “China effect” in global innovation would be felt in several ways. As the nation with the largest population and the second-largest economy in GDP terms, China will be a growing source of innovation to serve the needs of an enormous and increasingly demanding consumer market. It is also a logical location for R&D and rapid commercialization of new ideas by global companies—for China, for other emerging markets, and for the rest of the world. Finally, the Chinese model of rapid, low-cost innovation can be applied around the world, potentially disrupting a range of industries.

This research is a joint effort by the McKinsey Global Institute and the McKinsey Greater China office. It was led by Jonathan Woetzel, an MGI director based in Shanghai; Jeongmin Seong, an MGI senior fellow based in Shanghai; Yougang Chen, a partner based in Shanghai; James Manyika, an MGI director in San Francisco; and Erik Roth, a McKinsey director based in Shanghai. We also thank Gordon Orr, a former McKinsey director in China, for his thoughtful guidance throughout this research effort, as well as Jacques Bughin, a McKinsey director based in Brussels.

The research team was led by Jason Lee and included Sizhe Chen, Denise Lee, Chao Li, Luke Li, Xiujun Lillian Li, Ganesh Raj, Yi Shao, Jimmy Wu, Anting Xu, and Colin Zhu. Geoffrey Lewis provided editorial support. We thank Marisa Carder and Patrick White for design, and Julie Philpot, MGI’s production manager. We also thank MGI colleagues Tim Beacom, Matt Cooke, and Deadra Henderson. We are grateful to McKinsey Greater China staff members: Bo Jiang, Glenn Leibowitz, Lin Lin, Karen Schuster, Ruwen Shen, and Rebecca Zhang.

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We thank the many business leaders, experts, investors, and entrepreneurs who shared their insights confidentially. We are deeply indebted to our academic adviser, Martin N. Baily, Bernard L. Schwartz Chair in Economy Policy Development and senior fellow and director of the Business and Public Policy Initiative at the Brookings Institution.

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

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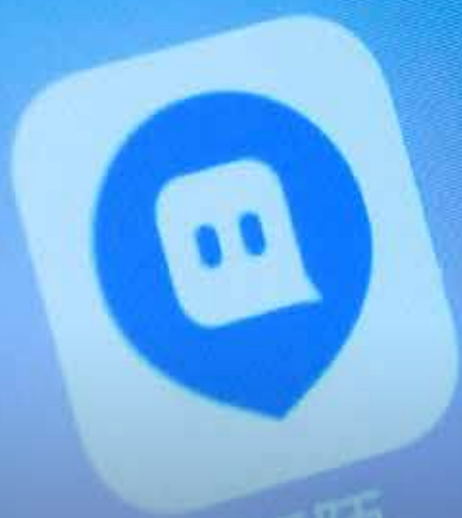
Chinese Social Media



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A complete technical appendix describing the methodology and data sources used in this research and are available at www.mckinsey.com/mgi.

IN BRIEF

CHINA CAN BECOME A GLOBAL INNOVATION LEADER

China has the potential to evolve from an innovation sponge—absorbing and adapting global technologies and knowledge—to an innovation leader. Chinese companies are performing well in some types of innovation, by filling consumer needs with better products and services and wielding the power of China’s manufacturing ecosystem to make innovations in production processes. China has yet to take the lead in more challenging forms of innovation, such as scientific discovery and engineering, but Chinese companies are using a distinctly Chinese way to nimbly accelerate experimentation and learning on a large scale.

- **China faces an innovation imperative.** As two sources of growth—labor force expansion and heavy capital investment—fade, innovation (broadly defined) will need to contribute up to half of GDP growth by 2025, or \$3 trillion to \$5 trillion in value per year. We identify opportunities to create value of \$1 trillion to \$2.2 trillion per year in 2025 through innovations to expand and raise the productivity of the service sector and further improve manufacturing efficiency through digitization.
- **Performance varies across the four “archetypes” of innovation.** We gauge innovation impact by examining 30 industries in four innovation archetypes. China performs well in customer-focused and efficiency-driven archetypes, but is catching up in engineering- and science-based archetypes.
- **China’s large and dynamic market gives it an edge in customer-focused innovation.** Chinese innovators use China’s massive consumer market (more than 100 million mainstream consumer households today) to commercialize new ideas quickly. Chinese consumers enable innovation by accepting early iterations of products and services and providing feedback for rapid refinement.
- **China’s manufacturing ecosystem enables efficiency-driven innovation.** China has the world’s most extensive manufacturing ecosystem, with more than five times the supplier base of Japan, 150 million manufacturing workers, and modern infrastructure.
- **Accelerated learning is essential for engineering-based innovation.** Purchasing by government-owned enterprises, facilitation of technology transfers, and introduction of market discipline are accelerating learning needed for engineering-based innovation in such industries as communications equipment, wind power, and high-speed rail.
- **Chinese companies are trying to catch up in science-based innovation using novel approaches.** The government push to raise R&D spending, train scientists, and file for patents has yet to give China a lead in science-based innovation. Today, Chinese companies in science-based industries are developing their own approaches to catch up—taking advantage of China’s lower cost and large pool of researchers to industrialize and accelerate experimentation and discovery.

In the next ten years the “China effect” on innovation will be felt around the world as more companies use China as a location for low-cost and rapid innovation. The overall China effect could be disruptive, bringing large-scale yet nimble innovation to serve unmet needs in emerging markets and produce new varieties of goods and services for advanced economies. Around the world consumers could benefit from better goods at lower prices.

China can become a global innovation leader

China faces an innovation imperative

Two traditional sources of growth are fading...



The labor force is no longer growing

Aging is expected to reduce the working-age population by **16%** by 2050

Return on fixed asset investment is declining

It takes **60% more capital** to generate a unit of GDP than it did from 1990 to 2010

...so to sustain 5.5–6.5% growth rates through 2025, innovation would need to contribute up to 50% of GDP growth¹

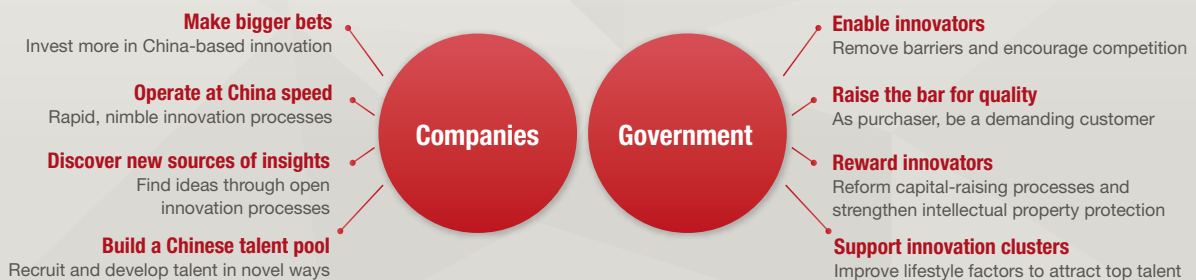


Up to 50%
\$3T–\$5T by 2025

China has opportunities in 4 “archetypes” of innovation

	EFFICIENCY DRIVEN	CUSTOMER FOCUSED	ENGINEERING BASED	SCIENCE BASED
China's advantages	Extensive manufacturing ecosystem (suppliers, labor, infrastructure)	Massive domestic market for rapid commercialization	Government creates local demand, enables learning	Rapidly increasing, low-cost R&D capacity
Current performance²	Strong <ul style="list-style-type: none"> Solar panels (51%) Construction machinery (19%) 	Rapidly improving <ul style="list-style-type: none"> Household appliances (36%) Internet software (15%) 	Mixed <ul style="list-style-type: none"> High-speed rail (41%) Commercial aviation (1%) 	Opportunities <ul style="list-style-type: none"> Branded pharmaceuticals (<1%) Semiconductor design (3%)
Future opportunity	Next-generation manufacturing (\$450B–\$780B by 2025)	Internet-enabled innovation in service sector (\$550B–\$1.4T by 2025)	Opportunities in targeted industries, including nuclear power, medical equipment	Drug discovery, genomics

Accelerating the China effect to make innovation cheaper, faster, and more global



¹ Innovation measured as contribution from multifactor productivity growth.

² % = Chinese companies' share of global revenue pool.



EXECUTIVE SUMMARY

How innovative is the Chinese economy? By some common measures of innovation, China has already become a global innovation leader. Each year it spends more than \$200 billion on research (second only to the United States) and turns out close to 30,000 PhDs in science and engineering. It leads the world in patent applications (more than 820,000 in 2013). However, when it comes to the actual impact of innovation—as measured by the success of companies in commercializing new ideas and competing in global markets—the picture is mixed. China has become a strong innovator in some industries, largely by serving domestic demand. In the more challenging types of innovation, such as creating new drugs and designing new commercial airliners, China is still not globally competitive.

In this research we have examined the state of innovation across major sectors of the Chinese economy—identifying factors that drive successful innovation in different types of industries and the policies that can advance innovation. We find that China has some unique strengths in innovation, including the largest base of consumers of any country, which enables rapid commercialization of new ideas. It also has the world's most extensive manufacturing ecosystem, enabling continuous innovations in production processes that reduce costs and improve quality. And, thanks to investments over the past three decades, China has created capacity for research with a growing number of universities and research institutions, as well as an expanding pool of talent. We also have identified obstacles to innovation, such as slow regulatory processes and weak intellectual property protections.

Our conclusion is that China has the potential to build on its strengths in innovation and become a global leader—creating a “China effect” on innovation around the world. This conclusion is based on China's momentum in consumer-facing industries and manufacturing, and its growing capacity for innovation in industries where it is not yet globally competitive. Not only can China serve as the locus of innovation for a growing number of companies that want to penetrate China and other fast-growing emerging markets, but the Chinese approach to innovation also can spread, helping companies everywhere turn ideas into products and services more quickly and for less cost.

Completing the journey from innovation sponge—absorbing and adapting existing technology and knowledge from around the world—to global innovation leader is not just a way to signal China's progress as an economy and society. The boost to productivity that innovation provides is critically important for sustaining China's growth. We also identify specific innovation opportunities in manufacturing and service industries that can contribute \$1.0 trillion to \$2.2 trillion in value by 2025, or equivalent to as much as 24 percent of total GDP growth.

**\$1.0–
2.2T**

Value of specific
innovation
opportunities in
manufacturing
and services

CHINA'S INNOVATION IMPERATIVE

As the events of 2015 have illustrated, China is in the midst of a very challenging transition to a slower-growing, more consumption-driven economy. For 30 years, from 1985 to 2015, China's GDP rose by 9.4 percent per year on average. However, two forces that helped to drive this growth—a constant flow of new workers into the labor force and massive investments in housing, infrastructure, and industrial capacity—are receding. Because of aging, China's labor force will soon peak—perhaps as soon as 2016—and begin a long decline that could reduce its size by 16 percent by 2050. And macroeconomic returns on fixed asset investments have fallen: it now takes 60 percent more capital to produce one unit of GDP in China than it did, on average, from 1990 to 2010.¹ Investment is also constrained by China's debt, which, at 282 percent of GDP, exceeds debt-to-GDP ratios in the United States and Germany.

It now takes 60 percent more capital to produce one unit of GDP in China than it did, on average, from 1990 to 2010.

Without labor force expansion and investment to propel growth, China must rely more heavily on innovation that can improve productivity. We use multifactor productivity—growth that does not come from factors of production such as labor and capital investment—as a proxy for the macroeconomic impact of innovation broadly defined (including productivity gain from catch-up). The contribution to GDP of multifactor productivity has been falling in China, from nearly half of yearly GDP growth in the 1990 to 2000 decade to 30 percent in the past five years. To reach the growth target of 5.5 to 6.5 percent per year (the current consensus view from five leading economic institutions), multifactor productivity growth will need to contribute 35 to 50 percent of GDP growth, or two to three percentage points per year of GDP (Exhibit E1).²

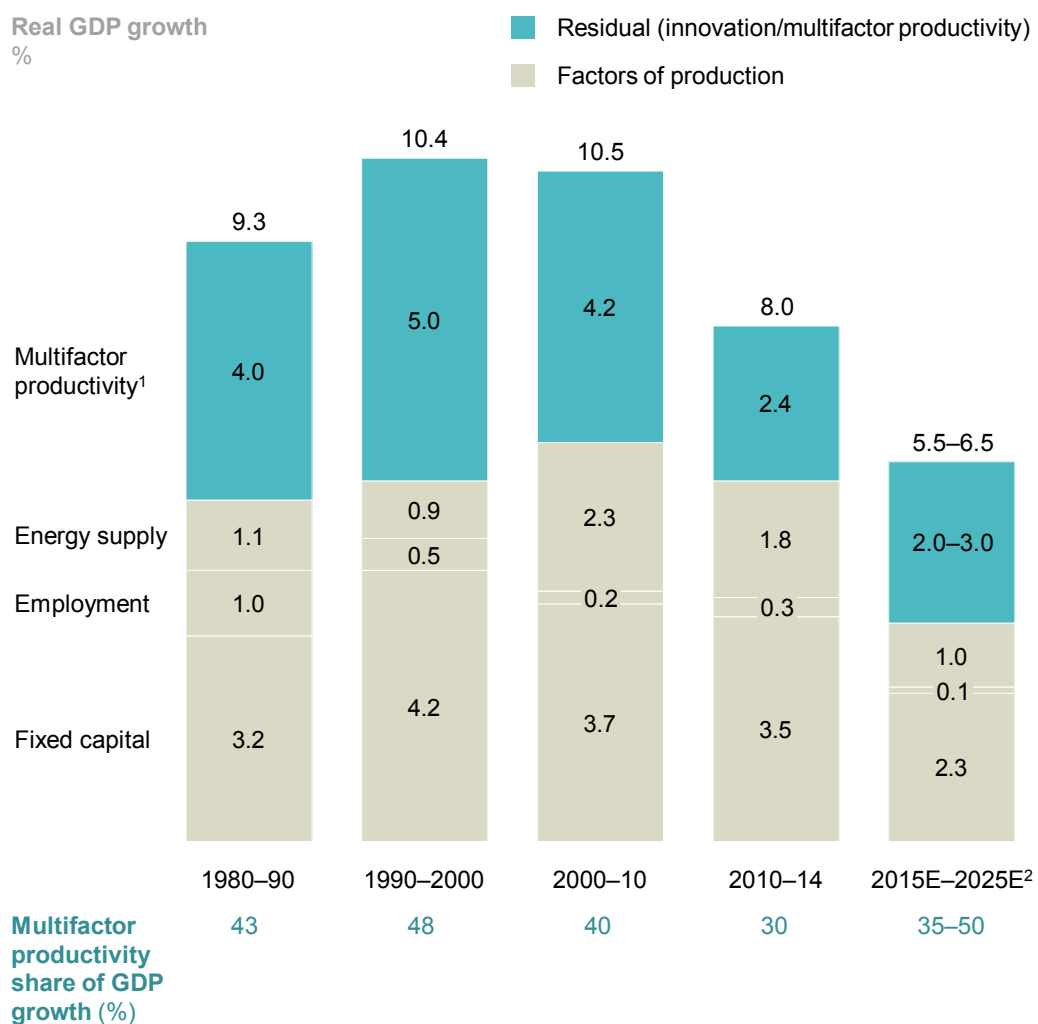
Improving innovation performance would have additional benefits—helping China's transition to a more balanced, consumption-driven economy by expanding the service sector and providing more high value-added jobs. Rising productivity is also critical for creation of the well-paying jobs that can raise living standards and employ a growing urban population.

¹ This is based on the incremental capital-output ratio (ICOR), which averaged 3.4 from 1990 to 2010 and stood at 5.4 in 2010 to 2014.

² Consensus is based on projections from The Economist Intelligence Unit, IHS Global Insight, the International Monetary Fund, the Oxford Economics Forecast, and the World Bank.

Exhibit E1

Innovation (broadly defined) can contribute 2 to 3 percentage points of GDP growth in China by 2025, accounting for 35 to 50 percent of total GDP growth



1 Calculated as total GDP growth minus three factors of production (energy, labor, and capital), multifactor productivity broadly measures the impact of innovation on the economy.
2 Baseline GDP estimate developed by regressing more than 100 variables from historical trends, assuming no major economic shocks. Key variables include demographic change, unemployment rate, interest rate, factor cost changes, depreciation, inflation, and urbanization rate.
NOTE: Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

HOW INNOVATION HAPPENS: FOUR DIFFERENT ARCHETYPES

To develop a view of the impact of innovation, we identify four archetypes of innovation: customer-focused, efficiency-driven, engineering-based, and science-based. We believe the archetype-based analysis produces a more nuanced picture of innovation performance than national-level metrics and provides more useful insights on which to base company strategies and public policy. We gauge the success of innovation in industries in these archetypes by metrics such as the share of global revenue and profits and the share of global exports that companies have achieved.

Industries that fall into the four archetypes innovate in very different ways. Household appliance and smartphone manufacturing and Internet services fall into our customer-focused archetype. For these businesses, innovation involves identifying and addressing customer needs to develop new products, services, and business models—then using market feedback for frequent modifications and updates. Efficiency-driven innovation involves improving processes in production, product design, and supply-chain management to reduce cost and accelerate time to market. In engineering-based industries such as autos and aerospace, companies innovate by solving engineering problems using accumulated know-how and integrating technologies from suppliers and partners—to engineer cars for better fuel economy, for example. Science-based innovation is about generating new discoveries and turning them into products—a new drug or a semiconductor design.

36%

Chinese share of global household appliance revenue

From the archetype analysis, we see that Chinese companies in some customer-focused and efficiency-driven industries have, in fact, performed well as innovators based on both their shares of global revenue and export markets. Exhibit E2 plots the revenue of Chinese players in the four archetypes in relation to what would be their expected share of global sales in their industries based on China's share of global GDP (12 percent in 2013). We see that in customer-focused innovation, Chinese players have captured more than their GDP-based shares in three out of seven sectors we analyzed. In some of these industries, such as appliances, Chinese companies have high shares of both global revenue and exports—36 percent of global revenue and 20 percent of global exports in appliances, for example. In Internet services and software and Internet retailing, Chinese companies have more than their share of global revenue (15 percent and 14 percent, respectively).

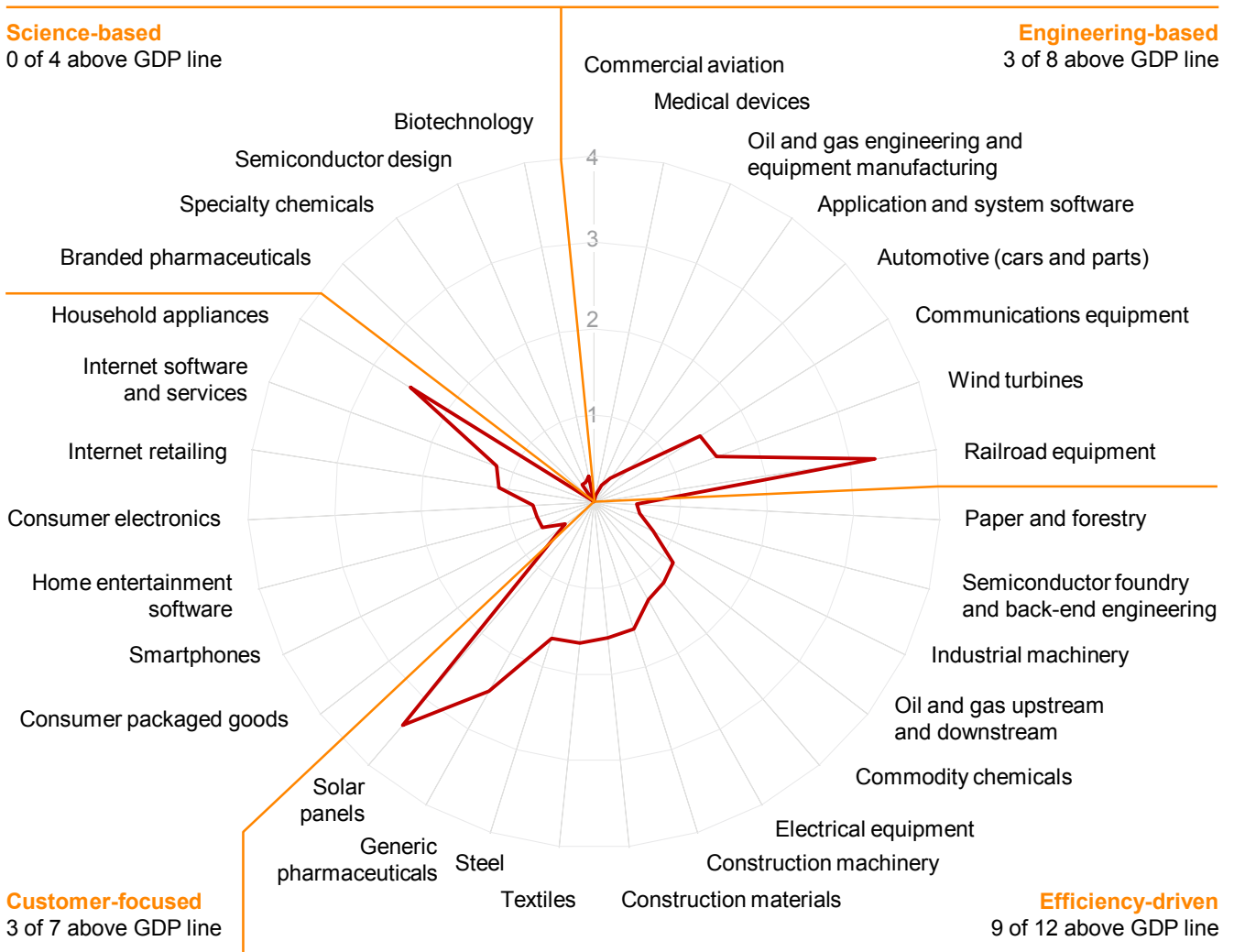
In efficiency-driven industries, China has more than its GDP-based share of global revenue in nine of 12 sectors we analyzed, including in solar panel production, where Chinese players have 51 percent of global revenue. Chinese players in efficiency-driven industries are also increasingly successful in higher value-added segments, such as construction machinery and electrical equipment, where they had 19 and 16 percent of global revenue in 2013, respectively. They are also competing more effectively in global markets, capturing 9 and 6 percent of global exports in 2013, respectively, up from just 1 percent in 2005.

In engineering- and science-based innovation, the picture is mixed. Chinese companies get far more than their share of global revenue in engineering-based businesses such as railroad equipment (41 percent) and wind power (20 percent), but less than their GDP-based share in others, such as autos and commercial aviation. In autos, Chinese manufacturers have only 8 percent of global revenues and 2 percent of exports. In the four industries we analyze in science-based innovation—branded pharmaceuticals, biotechnology, semiconductor design, and specialty chemicals—Chinese players have less than 3 percent of global revenue.

Exhibit E2

China has established strength in efficiency-driven and customer-focused innovation, but lags in science- and engineering-based innovation

Revenue fair share of Chinese companies, 2013¹
 Index: 1 = GDP share



1 This is the ratio of a country's share in the global revenue pool to its share of global GDP.

SOURCE: International Data Corporation; McKinsey Corporate Performance Analysis Tool; company annual reports, IHS Global Insight; iSuppli; McKinsey Global Institute analysis

HOW CHINESE COMPANIES ARE INNOVATING TODAY AND HOW INNOVATION IS EVOLVING

Looking at innovation across the Chinese economy, we see not only that companies in certain archetype industries are doing better than others, but we also see that their success often relies on their ability to take advantage of certain characteristics of the Chinese economy. Internet services and other constituents of our customer-focused archetype, for example, benefit enormously from the sheer size of China's consumer market, which enables rapid and large-scale commercialization of new ideas. Indeed, in China, a niche market such as online gaming is bigger than a major industry such as autos in other countries. For industries that depend on efficiency-driven innovation, China's unique advantage is its extensive manufacturing ecosystem, which provides an unmatched environment for process innovation, with the world's largest supplier base, a massive manufacturing workforce, and a modern supply-chain infrastructure. In the engineering-based group, government policy has played an important role—accelerating innovation by creating local demand in high-speed rail and wind power, for example. And while the massive government push to raise research and development (R&D) spending, train more scientists, and file for more patents has not yet led to leadership in science-based innovation, we see that Chinese companies are taking advantage of China's unique characteristics to catch up. In biotech, for example, companies are using massive scale to speed up the process of drug discovery.

Here we look at the state of Chinese innovation in the four archetypes and consider what's next for innovation for players in each archetype industry.

Customer-focused innovation: The Chinese commercialization machine

As China's consuming class has grown (it now numbers more than 100 million households and is expected to reach more than 200 million by 2025), Chinese companies have learned to read the needs of a rapidly urbanizing nation and quickly scale up new products and services to meet those needs.³ The first wave of customer-focused innovators were manufacturers of appliances and other household goods whose innovations were “good enough” products—refrigerators or TV sets that had perhaps 80 percent of the features and quality of products made by global players, but that sold for a fraction of the price.

Lately, consumer expectations have been rising along with incomes, and for a growing segment, good enough products no longer suffice. Now companies such as Xiaomi are responding with “cheaper and better” products that are intended to be as good as the models of global brands but are still priced for the Chinese market (Exhibit E3). Xiaomi also exemplifies another trait of customer-focused innovators in China—it uses consumers as collaborators in innovation. Chinese consumers are willing to buy 1.0 versions of products and give feedback that helps manufacturers (or service providers) refine their offerings. Xiaomi relies on more than one million “fans” who vote online for new features that then appear in weekly software updates.

Internet services have been a major source of customer-focused innovation in China. In addition to Alibaba, companies such as Tencent and Baidu have become global leaders in online services simply by serving the Chinese market. These companies have found new ways to meet the needs of the Chinese market. With its online bazaar, for example, Alibaba addressed the need for better retail options for Chinese consumers, particularly those residing in smaller cities and rural areas. Among its innovations to make the online market work in China was Alipay, a service that holds vendor payments in escrow until goods are delivered. Tencent has built a very different model than other social media platforms use for monetizing traffic to its sites. Rather than depending on advertising, which is a relatively

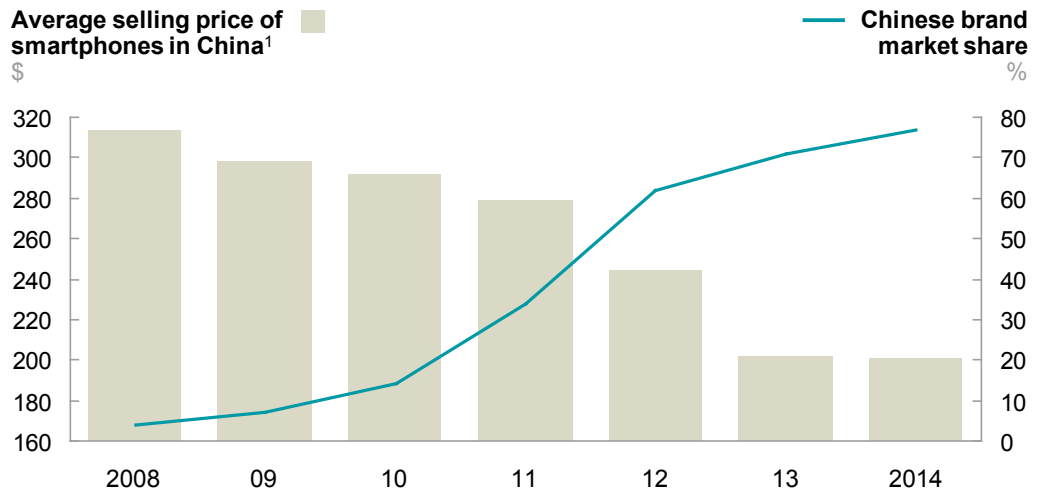
³ We define the mainstream consuming class as households with disposable annual income of 103,000 to 222,000 renminbi (\$16,000 to \$34,000).

200M+
Mainstream
consumer
households by
2025

small business in China, Tencent makes 90 percent of its revenue from sales of virtual goods to online gamers, payments, and e-commerce. In 2014, this innovative business model allowed the company to generate \$6 more revenue per user than Facebook did.

Exhibit E3

“Cheaper and better” innovation is helping Chinese brands gain share in smartphones



1 Real value, using 2013 constant prices.

SOURCE: International Data Corporation; Euromonitor; McKinsey Global Institute analysis

**\$550B—
1.4T**

Potential value per year from service sector innovations by 2025

In the coming decade, we see an enormous opportunity for customer-focused innovation to reshape large swaths of China’s service sector, where productivity is just 15 to 30 percent of the average for service businesses across Organisation for Economic Co-operation and Development (OECD) economies. The government is pushing modernization of traditional businesses through the “Internet Plus” initiative announced in March 2015. Innovations are needed to expand access to services (through remote health monitoring using Internet of Things technology, for example), improve quality (more choices and better customer experiences), and optimize operations (higher asset utilization). We expect more platforms and apps to connect online consumers to services in the physical world (cab hailing via smartphone, for example). We estimate that innovation in service-sector businesses could generate value of \$550 billion to \$1.4 trillion per year by 2025, equivalent to 11 to 29 percent of service-sector growth. These innovations would not only raise Chinese productivity, but growing the service sector would also help make the economy more consumption-driven, while also benefiting consumers with better services, greater convenience, and lower cost.

Another opportunity for Chinese companies is to use their skills in customer-focused innovation to take the lead in emerging markets. The experience of Chinese consumer goods suppliers in their home market and China’s cost advantages give these companies a potential edge over other global players in defining and meeting the needs of new middle- and low-income consumers in developing economies. In Myanmar, Huawei already dominates the mobile phone market with a 50 percent share, and in Brazil, Midea has almost 35 percent of the air conditioner market. There are many similar opportunities in emerging markets for Chinese players—if they can build the sales and marketing skills to turn innovation into market share.

To achieve the potential growth in customer-focused industries in the next ten years, companies will need to build new capabilities. For the most part, Chinese companies have enjoyed unusually favorable circumstances—serving rising domestic demand from a rapidly expanding consuming class and, in many industries, facing no foreign competition. As Chinese consumers become more demanding, more markets open, and Chinese companies compete abroad, success in customer-driven innovation will be more difficult.

Efficiency-driven innovation: The ecosystem advantage

In becoming the “factory to the world,” China also became a leading innovator in efficiency-driven innovation. No longer simply a source of low-cost labor, Chinese manufacturing companies are gaining in knowledge-intensive manufacturing categories such as electrical equipment (16 percent of global revenue and 9 percent of global exports) and construction equipment (19 percent of revenue and 6 percent of exports). This progress has been enabled by the vast scale of China’s manufacturing ecosystem. China has more than five times the supplier base of Japan, 150 million factory workers, and modern transportation. The combination of supply-chain advantages from this ecosystem and large scale gives Chinese solar panel manufacturers a cost advantage of 22 cents per watt, or about 15 to 20 percent, over foreign peers, according to a Massachusetts Institute of Technology study.⁴

Chinese companies are driving efficiency in a variety of ways, including agile manufacturing, modular design, and a flexible approach to automation. Everstar, an apparel manufacturer, has invested in automated equipment and online design and e-commerce systems that allow consumers to customize clothing and receive finished goods within 72 hours. Modularization saves money by breaking products down into subassemblies. This approach is even being used to industrialize construction. Broad Construction assembled a 57-story hotel in Changsha in 19 days from prefabricated components to demonstrate its innovations. And, while China has become the number one purchaser of robots, companies such as Chint, a maker of electrical equipment, have found that semiautomation—selectively mixing robots and other machinery with labor—provides greater efficiency and flexibility than full automation.

An important development in efficiency-driven innovation is the evolution of open manufacturing platforms. The “maker” movement has taken off in China, and the ecosystem that supports individuals and small entrepreneurs can also work on a global scale. In Shenzhen, a network of component suppliers, design services, business incubators, and outsourced assembly capacity is enabling rapid prototyping and scaling up of manufacturing businesses. HAX Accelerator operates incubators in Shenzhen and San Francisco and brings startup teams from around the world to Shenzhen when they are ready for prototyping.

Open manufacturing platforms are made possible by the rich Chinese manufacturing ecosystem, which is exemplified by Shenzhen itself. The city has 2,000 electronic component and product manufacturers, more than 1,000 makers of electrical parts and equipment, 300 apparel makers, and a labor force of nine million (Exhibit E4). Design firms in Shenzhen can turn ideas into prototypes in as little as one-fifth the time and at half the cost for doing such work in-house. The city’s modern infrastructure then speeds goods to world markets.

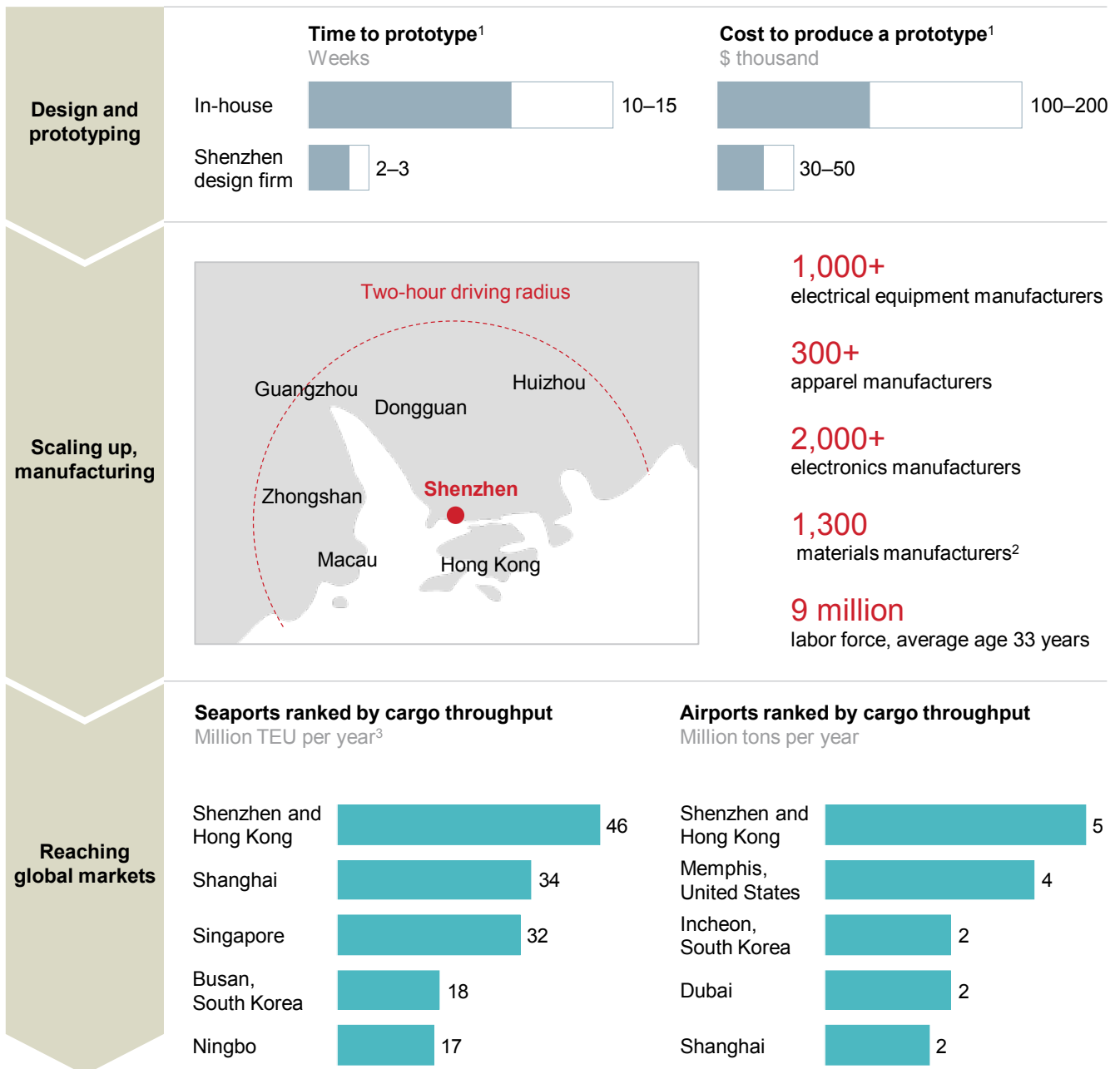
Chinese companies will have to innovate in new ways to retain China’s lead in manufacturing. Not only are rising wages in China making it a less competitive site for labor-intensive work such as low-end apparel manufacturing, but there is also a worldwide shift in the manufacturing sector to the “Industry 4.0” model in which major processes of

⁴ Alan C. Goodrich et al., “Assessing the drivers of regional trends in solar PV manufacturing,” *Energy & Environmental Science*, issue 10, October 2013.

manufacturing and logistics are digitally linked. Next-generation manufacturing promises significant gains in asset utilization, supply/demand matching, and quality control. It also has the potential to shift the basis of competition in manufacturing, providing an opening for advanced economies to take back some lost ground. Germany, the United States, and other advanced economies are using policy and investment to seize the lead in the Industry 4.0 era. China has announced a series of programs to support its bid for leadership, too, starting with “Made in China 2025,” unveiled in March 2015.

Exhibit E4

Shenzhen has a strong ecosystem advantage in manufacturing



1 Low-tech electronics example.

2 Chemicals, rubber, minerals, metals, textiles.

3 Twenty-foot equivalent unit, a measure of cargo ship capacity.

SOURCE: Shenzhen Statistical Yearbook 2014; Drewry Container Market; Airport Council International; McKinsey Global Institute analysis

**\$450B—
780B**

Potential annual value of next-generation manufacturing approaches in 2025

As Chinese companies move to the next-generation manufacturing model, the nation's manufacturing ecosystem can provide additional advantages—extending benefits beyond individual factories and across a digitally linked ecosystem that can enable a new level of rapid, flexible manufacturing, and mass customization. With a massive supplier base, factories can be adapted to many types of manufacturing, modern logistics, and digital links to customers around the world. Chinese companies can become virtual manufacturing resources, offering manufacturing as a service to companies around the world and even filling custom orders for individual consumers. We estimate that if China can prevail in the Industry 4.0 era, manufacturing could create value of \$450 billion to \$780 billion per year in 2025, equivalent to 12 to 22 percent of GDP growth in manufacturing by 2025.

Engineering-based innovation: Succeeding in “learning” industries

Engineering-based innovation is part science, part art, and it almost always requires deep experience and learning. For developing economies that are trying to catch up with global competitors in engineering-based industries such as autos, high-speed rail, and wind turbines, gaining knowledge and experience is critical. China has had mixed success in engineering-based innovation. The best performers have been in markets where government has supported an infant industry by providing local demand, while also facilitating technology transfer agreements with foreign partners. This formula has been used most successfully in high-speed rail, where China now has 41 percent of the global market, as well as in wind power (20 percent) and communications equipment (18 percent). Learning and innovation have been slower in automotive manufacturing, where exploding demand and strong profits from joint ventures have limited the need for state-owned enterprises to learn and innovate. Chinese automakers have relied on platforms contributed by their global partners or designs that they have commissioned from outside design firms to get products to market more rapidly. As a result, even though China has become the world's largest car market, Chinese companies have only an 8 percent share of global revenue.

Chinese companies that have succeeded in engineering-based innovation have acquired the knowledge they need in a variety of ways. In wind power, for example, the government's Wind Power Concession Project, launched in 2003, sparked a massive investment in wind generation and a rapid transfer of knowledge to Chinese players. The plan required 50 percent local content, which led foreign suppliers to establish joint-venture plants in China. This helped spread knowledge. In high-speed rail, the Ministry of Railways launched a 3 billion renminbi (\$470 million⁵) program in 2008 to develop a new generation of high-speed trains. The Chinese high-speed rail initiative has driven 86 percent of global growth in the market since 2008, while technology transfers from overseas partners have helped Chinese companies build the knowledge to innovate on their own. The CRH380, the first locomotive designed by the Chinese industry, has a top speed of 380 km/hour.

Telecom equipment maker Huawei set out to systematically acquire “end-to-end” engineering knowledge when it realized that its foreign partners were not likely to share cutting-edge technology. Through a painful trial-and-error process, Huawei began creating increasingly sophisticated designs of its own; it spends 12 percent of revenue on R&D and operates 19 innovation centers around the world with joint-venture partners.

In the next ten years, Chinese players are likely to catch up in other forms of engineering-based innovation. The government has identified several industries for policy support, including nuclear power, medical equipment, and electric vehicles. Based on recent history, the success of government interventions will depend on two core elements—creating local market demand and ensuring that Chinese companies gain knowledge they need to

⁵ Renminbi to US dollar conversion is for reference. We use average exchange rate in 2014 throughout the report (1 USD = 6.14 RMB).

innovate on their own. Of the targeted industries, nuclear power has progressed furthest on the learning curve, thanks to an ambitious government plan to build 58 gigawatts of capacity by 2020 to help meet the goal of getting 30 percent of energy from renewable sources by 2030. Construction of the Hualong One, China's Generation III reactor design, is underway and export agreements have already been signed.

Progress is also being made in medical equipment. A new crop of players, such as Mindray and United Imaging, are making inroads against foreign suppliers in categories such as CT scanners and MRI machines, thanks in part to government subsidies of hospital purchases of Chinese-made equipment. Both are strengthening R&D capabilities, and both are pushing into overseas markets. Mindray spends 10 percent of its revenue on R&D and makes 55 percent of its sales outside of China.

30%

goal for supply of energy from renewable sources by 2030

Other industries have not had similar opportunities to gain engineering know-how. Commercial aircraft are massively complex—even global leaders are challenged to manage the millions of components that go into a plane—and China's nascent industry has fallen behind schedule in delivering its first commercial passenger jets. In electric vehicles, the government has invested 37 billion RMB (\$6 billion) in research, subsidies, and recharging infrastructure, but electric hybrids and fully electric vehicles (plug-ins) still represent a far smaller share of auto sales in China than in advanced economies. Barriers include high tariffs on imports and buyer subsidies that apply only to cars produced in China—limiting competition and learning.

Science-based innovation: Catching up, using novel Chinese approaches

China has made science-based innovation an important priority and has invested substantially in building the institutions and capabilities needed for discovery and invention. Chinese companies are making progress in science-based businesses such as biotechnology, but China is not yet a top global competitor: it has less than a 1 percent share of global revenue in branded pharmaceuticals, 3 percent in biotech, semiconductor design, and specialty chemicals. However, we also find that Chinese companies are taking distinctively Chinese approaches to speeding up science innovation.

In our research we identify a number of reasons for slow progress in science-based innovation, not least of which is that this type of work takes a long time to pay off: it might be 10 to 15 years before an idea moves from a laboratory to a bottle of pills in a hospital dispensary. Among the issues that are seen to inhibit science-based innovation in China are slow regulatory processes, questions about intellectual property protection, inefficient allocation of government research funding, and underinvestment by private-sector players. And, despite the large numbers of Chinese students being trained in scientific and technical fields, companies still struggle to find capable talent. The government is addressing some of these obstacles. Reforms to the drug approval process could reduce the time it takes to get a new drug to patients by two years. Also, efforts such as the Thousand Talents program are helping to bring overseas Chinese scientists home to work in industry and universities and to launch companies.

In the meantime, Chinese drug companies are taking innovative approaches to speed up drug development. BeiGene has created an approach to accelerate drug discovery by using a proprietary system to test substances on human tissue (cancerous tumors, for example) to get an early indication of potential issues during human trials. WuXi AppTec, a contract research organization, uses an industrial approach to accelerate drug discovery by deploying massive scale. It employs 7,500 researchers and is expanding the scope of its service scope from preclinical testing through clinical trials. In genomics research, BGI, a biotech company, is also using massive scale—more than 2,000 PhDs and more than 200 gene-sequencing machines—to power through science problems.

THE CHINA EFFECT ON GLOBAL INNOVATION : CHEAPER, FASTER AND GLOBALLY CONNECTED

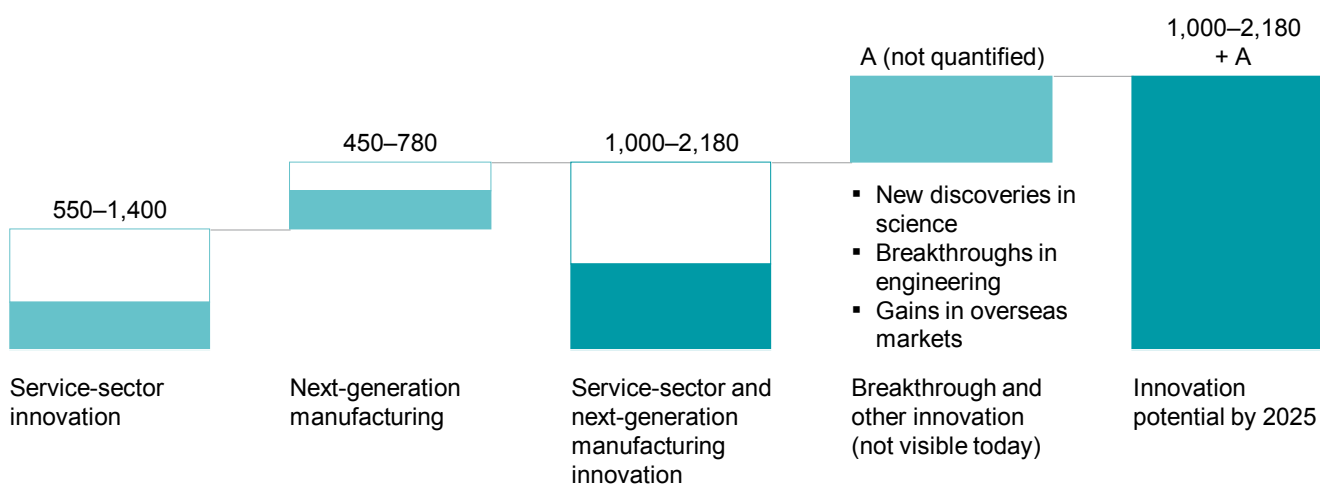
Based on the recent performance of Chinese industries, the investments made to build innovative capacity, and the opportunities for greater innovation success we outline above, we believe that China can not only meet its innovation imperative, but can also emerge as a dominant force in innovation globally. We estimate that progress in service- and manufacturing-sector innovation can contribute \$1.0 trillion to \$2.2 trillion per year in value to the Chinese economy by 2025. Additional value can arise from innovations in science- and engineering-based innovations, which we do not estimate (Exhibit E5). Equally important, we would expect to see a “China effect” on innovation globally, which could disrupt markets and industries. China can become a platform for accelerated innovation, not just for Chinese companies, but also for foreign multinationals that want to take advantage of Chinese cost and speed to produce innovations for China, emerging markets, and the world. Moreover, the Chinese model for rapid, low-cost, and nimble innovation can be adapted for use around the world. The overall effect could be accelerated innovation globally, challenges to market leaders from new innovators, and new, lower-cost products and services that fill unmet needs of emerging-market consumers and keep up with the shifting demands of consumers in advanced economies.

Exhibit E5

Innovation in services, manufacturing, and other areas can help China meet its innovation imperative

Potential value in 2025¹

2014 \$ billion



¹ Value includes increased output and company profit as well as consumer surplus (benefits such as lower prices and higher quality).

NOTE: Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

What companies can do to accelerate innovation in China

Companies can start by making a larger commitment to innovation in China. For foreign companies, this could mean locating more R&D activity in China, as Microsoft has done with the 3,000 scientists and engineers in its Asia-Pacific Research and Development Group in Beijing, which does global research. Or, as Phillips and GE have done, companies might relocate global headquarters of entire business units to China to take advantage of low-cost R&D talent and get closer to Chinese customers. Similarly, Chinese companies can strengthen innovation capabilities by adding R&D facilities in other markets or using overseas R&D joint ventures. Lenovo executives credit having dual headquarters in Beijing and North Carolina with helping the company achieve global leadership in PC sales.

Both domestic and foreign companies in China can adopt the rapid development and commercialization processes—“China speed”—that have helped China’s innovation leaders. Chinese companies can speed up innovation by flattening hierarchical organizations and empowering all workers to suggest ideas for products or process improvements. Organizational changes to accelerate decision making and innovation processes in China can also benefit global companies. All companies operating in China can discover new ideas and commercialize them faster by tapping into China’s emerging open innovation ecosystem. Some are already crowdsourcing ideas internally and externally through competitions and incentives.

What Chinese policy makers can do to support innovation

For Chinese policy makers to support and accelerate innovation, it will be important to continue to craft coordinated, coherent policies that set the conditions for innovation by market competitors. Broadening access to funding for entrepreneurs and small and medium-sized enterprises, for example, can help more Internet innovators commercialize their ideas and more small manufacturers innovate process improvements. Small manufacturing companies also can benefit from programs that provide free or subsidized training in innovation skills, which countries such as the Netherlands have used.

Government can raise the bar for innovation by being a demanding purchaser and as an educator for end consumers. Market creation in high-speed rail and wind-turbine industries certainly helped local innovation, but “guaranteed” markets for local players can impede innovation in the future. Government can raise the bar for innovation by requesting challenging tasks, as the National Health Service in the United Kingdom did with its purchasing policies to encourage innovations in medical products. At the same time, the government can educate the public to speed the acceptance of innovation. Fuel-economy and energy labeling standards have helped drive innovations in motor vehicles and appliances in advanced economies.

Continuing market reforms that open up more areas of the economy to competition will lead to more innovation, too. And reforms to the initial public offering process (simpler and more predictable listing based on clear rules) and stronger intellectual property enforcement can ensure that innovators enjoy the rewards of their labors—and encourage more Chinese to pursue their creative ideas.

Finally, in addition to providing enabling infrastructure, government can help make China’s innovation clusters more attractive to top talent. The success of an innovation cluster depends heavily on the quality of talent it can attract, and top talent can afford to be picky about quality-of-life issues such as housing costs, cultural diversity, and pollution. In these “soft” factors, Chinese cities are currently at a disadvantage.



China has reached a point where innovation is no longer a conceptual idea—an aspiration that would reflect the rising power and sophistication of the Chinese economy. In the coming decade, innovation will be a vital tool for China to raise productivity and sustain growth. Innovation will be key to retaining and extending China’s competitiveness in global markets. At the same time, China can become a global center of innovation and its rapid, nimble approaches could be adopted around the world. A decade from now, the world may acknowledge a “China effect” on innovation.



1. CHINA'S INNOVATION IMPERATIVE

As we write this, China is in the midst of a challenging transition. After three decades of rapid growth that has transformed the nation and made China the second-largest economy in the world (by GDP), growth is slowing. The population is aging, and the labor force will soon start to shrink. Debt has been rising rapidly to fund investment in infrastructure, but returns on fixed asset investment are declining. Therefore, China can no longer count on additions to the labor force and fixed asset investment to sustain GDP growth, even at the more moderate rates (compared with the past 30 years) predicted for the coming decade.

Like the United States, Japan, and the mature economies of Europe, China must now rely increasingly on rising productivity to drive GDP growth. This, then, is China's innovation imperative: to raise productivity sufficiently to make up for the loss of momentum from labor and investment. China has the potential to complete the evolution from an innovation "sponge" that absorbs knowledge and technologies from abroad to a leader in all forms of innovation (see Box 1, "The challenge to define and measure innovation"). The contribution of innovation (measured as multifactor productivity growth) will need to rise to 35 to 50 percent of GDP, or \$3 trillion to \$5 trillion, by 2025.

Our analysis suggests that China could realize about 40 percent of its innovation imperative through further gains in manufacturing, mostly driven by digitization, and innovation in service industries, particularly the use of the Internet to expand access to services, improve quality, and raise efficiency. The remainder of the productivity growth would come from productivity gains in other industries as well as from innovations in science and engineering.

The contribution of multifactor productivity to growth would need to rise to 35 to 50 percent of GDP, or \$3 trillion to \$5 trillion, by 2025.

The innovation imperative is not news to Chinese policy makers. The government has long recognized the need to expand the economy's innovative capabilities so that more output will come from higher value-added products and services and more Chinese workers can be employed in high-paying, high value-added work. Government programs have focused on raising R&D spending, training scientists and engineers, and building research institutions. However, these investments have not yet translated into the successfully commercialized innovations that can substantially raise productivity in the economy. Indeed, the growth contribution of multifactor productivity has declined since 2000, despite these investments.

For China to reverse that trend and seize the opportunity to lead in global innovation, policy makers should think about policies that enable innovation, rather than continuing to focus on inputs such as numbers of PhDs and patents. More productive approaches would include ways to increase access to funding for entrepreneurs, ensure that innovators receive their full rewards (by protecting intellectual property, for example), and support innovation clusters. These measures are discussed in depth in Chapter 7.

Box 1. The challenge to define and measure innovation

Innovation can be defined and quantified in many ways. In 1911, Joseph Schumpeter identified five types of innovation: new products, new methods of production, the exploitation of new markets, new sources of supply, and new methods of organizing business.¹ Since that time, other researchers have introduced different approaches. Clayton Christensen of Harvard University has focused on the nature of the innovation, looking at whether innovation is sustaining (new models, for example) or disruptive (advances that can displace established players).²

Similarly, there is no single best way to measure innovation. One challenge is simply identifying whether something is an innovation: must it be truly novel, or can it be an incremental change? Another challenge is obtaining data that enable standardized comparisons across economies. As a result, innovation at the national level is often measured by inputs and intermediate outputs—the number of patents or PhDs an economy produces every year, for example—rather than actual impact.

In this report, we apply a broad definition of innovation, encompassing both “frontier” and “incremental” innovation. We define frontier innovation as the implementation of substantially new products, processes, or business models to solve problems for customers and create new value, while incremental innovation refers to smaller improvements. In developing economies, there are also catch-up activities, which involve the absorption and adoption of existing technologies or approaches for local applications—such as adapting cars or mobile phones to meet the needs of consumers in emerging markets.³ The way an economy innovates changes over time as developing economies evolve from adapters and incremental innovators to frontier innovators.

To assess the impact of innovation, we look at both national and firm-level data. At the national level, we use multifactor productivity as a proxy for innovation. Multifactor productivity measures the growth of the economy that is not explained by the addition of more inputs. It is often the result of the new technologies, better processes, and greater know-how associated with innovation. We assess innovation at the firm level by looking at such metrics as a share of global industry revenue, profits, and exports. We believe these metrics capture the impact of innovation; ultimately, the proof of successful innovation is the ability of companies to expand revenue and raise profits with new products and services and with improvements in design, manufacturing, or business models. Competitiveness of companies can be affected by non-innovation factors such as industry structure and factor costs, but we believe innovation is a primary contributor to revenue and profit growth.⁴

¹ Joseph A. Schumpeter, *The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle*, Transaction Books, 1983 (translated from the original German, *Theorie der wirtschaftlichen Entwicklung*, 1911, by Redvers Opie).

² Clayton M. Christensen and Michael E. Raynor, *The innovator's solution: Creating and sustaining successful growth*, Harvard Business School Press, 2003.

³ Chris Freeman and Luc Soete, *The economics of industrial innovation*, 3rd ed., MIT Press, 1997.

⁴ For further reading on innovation's impact on competitiveness, also see Michael Porter, “The competitive advantage of nations,” *Harvard Business Review*, March-April 1990, and John Cantwell, “Innovation and competitiveness,” in *The Oxford handbook of innovation*, Jan Fagerberg, David C. Mowery, and Richard R. Nelson, eds., Oxford University Press, 2006.

AN ECONOMY IN TRANSITION: WHY THE INNOVATION IMPERATIVE IS INCREASINGLY URGENT

After 30 years of record-setting growth—GDP rose by 9.7 percent on average from 1985 to 2014—China is transitioning. Growth is moderating, and the economy is evolving to a more consumption-driven model, in which more GDP and employment will come from services. At the same time, the forces that have driven GDP growth in the past—a constant surge of workers into the labor force and massive investments in fixed assets such as infrastructure—are losing their power. Today, the labor force is no longer expanding because China's population is aging and returns on fixed asset investments have declined.

After labor and investment, the only other major source of growth for the economy is productivity improvement, which is why the innovation imperative grows more urgent. However, the contribution to growth from multifactor productivity in China (our key metric of the impact of innovation at the macroeconomic level) has been declining.⁶ From 1990 to 2000, multifactor productivity contributed nearly half of GDP growth. But in the past five years, its share dropped to 30 percent, or about 2.4 percentage points of GDP per year, which is the lowest level in 35 years. To make up for the loss of momentum from labor and investment and maintain GDP growth of 5.5 to 6.5 percent per year through 2025, productivity growth will need to contribute 35 to 50 percent of GDP growth, or two to three percentage points per year (Exhibit 1). Rising productivity is also essential for creating the high value-added jobs that will be needed to sustain rising living standards and employ a growing urban population.

Aging will reduce China's labor force

China's large population has been an asset in its economic ascent, providing a constant supply of labor as the nation has urbanized and industrialized. In the past three decades, hundreds of millions of people migrated to cities and took up more productive work. Urbanization itself became a driver of growth. However, China's population is aging rapidly, and population growth is slowing. The share of the population over the age of 65 is expected to increase from 9 percent in 2015 to 25 percent in 2050, while the share of the population of prime working age (15 to 64) is expected to fall to 61 percent from 72 percent today. As early as 2016, the Chinese labor force is expected to peak and then begin a long decline that could reduce its size by 16 percent by 2050. China's dependency ratio—the population that is not in the labor force (mostly the elderly and children) divided by the working-age population—is projected to reach 43 percent in 2020 and 47 percent by 2030 (and 63 percent by 2050), up from about 38 percent today.

Returns on fixed asset investment are declining

Along with labor, investments in fixed assets have been critical to the rapid growth of the Chinese economy over the past 30 years. Capital investment, often funded with debt, went into factories, highways, transit systems, airports, and other assets. In the past ten years, China has channeled nearly \$40 trillion into fixed asset investments, including \$10 trillion in real estate and another \$10 trillion in infrastructure, accounting for 45 to 50 percent of total GDP. These investments drove demand across the economy and created jobs.

However, today China has reached a point of diminishing returns on such investments. Returns on investment in fixed assets, as measured by the incremental capital-output ratio (ICOR) have declined. From 1990 to 2010, the ratio was 3.4, meaning that 3.4 units of investment were needed for every unit of GDP. Since 2010, that ratio has risen to 5.4, meaning that it takes 60 percent more capital to generate a unit of GDP in China today. On that trajectory, by 2030, China's ratio could be 17 percent higher than the current ratio

61%
Share of population
that is working age
(vs. 72% now)

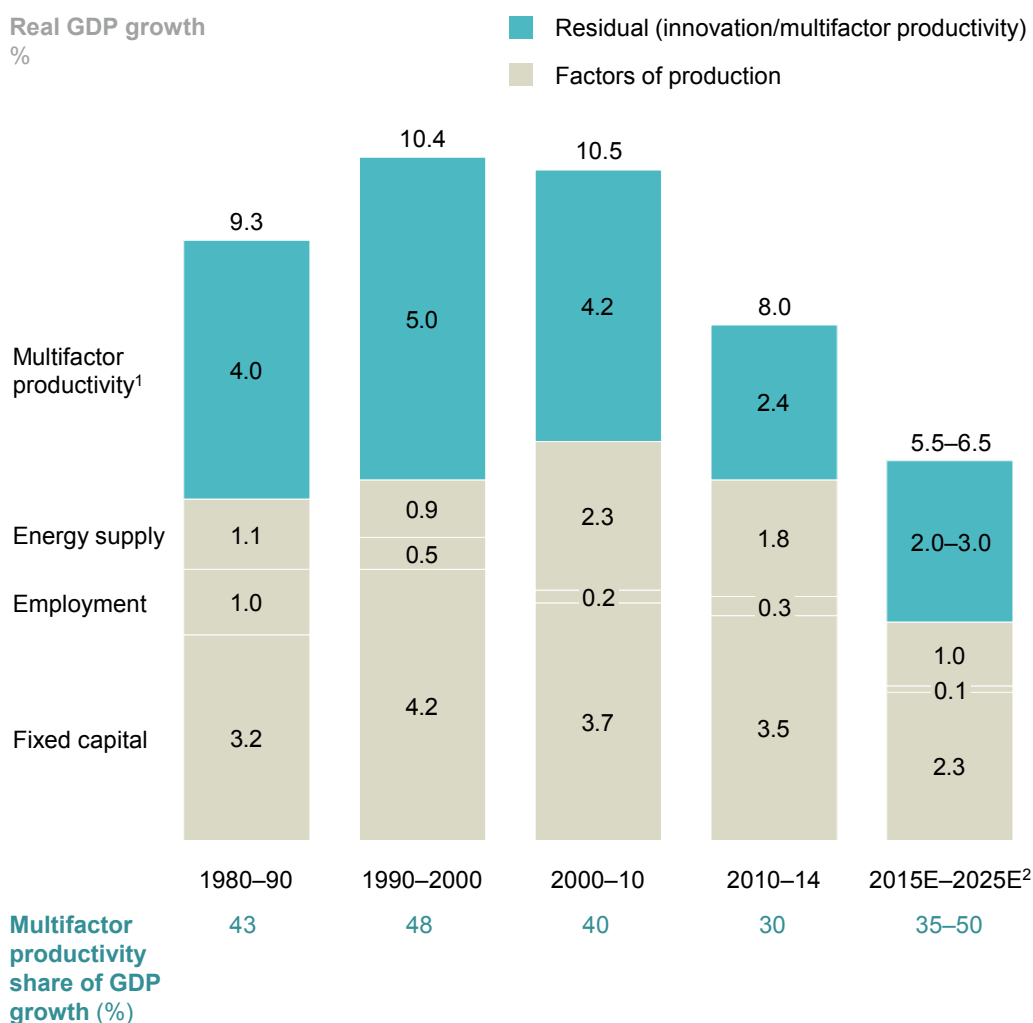
⁶ On the macroeconomic level, we use multifactor productivity as a proxy for innovation. Multifactor productivity is the incremental growth of the economy that is not explained by the addition of more factors of production. It is often the direct result of innovation in products and services that allow companies to charge more or sell more, or it can be innovations in processes that allow companies to operate more efficiently.

for the other BRIC countries (Brazil, Russia, and India) and near the current level of more advanced economies such as the United States and South Korea (Exhibit 2).

Decades of investment have left China with high levels of debt in the private sector and in the funding vehicles used by local governments to pay for infrastructure and housing projects. China's overall debt ratio jumped from 158 percent of GDP in 2007 to 282 percent of GDP in mid-2014, leaving it with a higher debt burden relative to GDP than the United States or Germany and less borrowing capacity to fund future investment.⁷ About a third of this new debt is concentrated in real estate and related industries.

Exhibit 1

Innovation (broadly defined) can contribute 2 to 3 percentage points of GDP growth in China by 2025, accounting for 35 to 50 percent of total GDP growth



1 Calculated as total GDP growth minus three factors of production (energy, labor, and capital), multifactor productivity broadly measures the impact of innovation on the economy.

2 Baseline GDP estimate developed by regressing more than 100 variables from historical trends, assuming no major economic shocks. Key variables include demographic change, unemployment rate, interest rate, factor cost changes, depreciation, inflation, and urbanization rate.

NOTE: Numbers may not sum due to rounding.

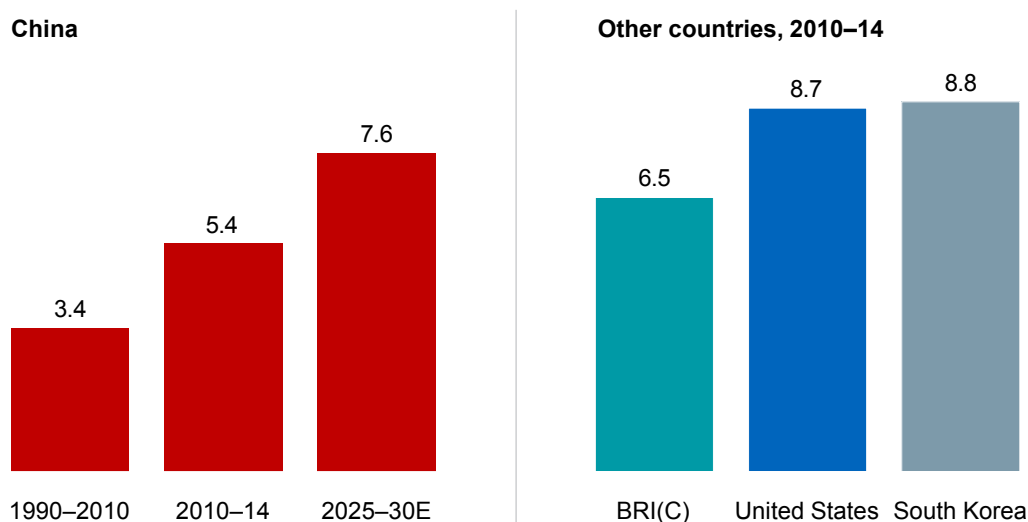
SOURCE: McKinsey Global Institute analysis

⁷ *Debt and (not much) deleveraging*, McKinsey Global Institute, February 2015.

Exhibit 2

Returns on fixed investments in China have declined: it takes 60 percent more capital to produce a unit of GDP growth

Capital cost to produce 1 unit of GDP
%



SOURCE: IHS Global Insight; McKinsey Global Institute analysis

11%
Annual wage
increase between
2009 and 2014

Rising wages and urbanization require more high value-added jobs

China also will need to find new ways to create higher value-added employment as incomes rise, citizens continue to migrate to cities, and the share of employment in manufacturing declines. From 2009 to 2014, average wages rose by 11 percent per year; in manufacturing they grew by a 12 percent compound annual rate. An estimated 100 million more Chinese are expected to migrate to cities by 2020, and these workers will need employment that can support higher costs of living in China's cities. It is estimated that China will need to create ten million urban jobs every year to keep up with the growing urban population.

Providing high-wage jobs in sufficient numbers is a particular challenge for countries that are transitioning from low- to middle-income status, as China is doing. As countries grow wealthier, consumption patterns change and more GDP and job growth come from services, while hiring in manufacturing—often a key source of well-paid jobs—slows. Typically, manufacturing employment rises rapidly as economies develop and demand expands for manufactured goods for domestic use and for export. According to our analysis of six advanced economies, manufacturing GDP tends to peak when per capita GDP reaches \$7,000 to \$10,000 (adjusted for purchasing power parity, using 1999 dollars). At that point, manufacturing typically contributes 35 to 40 percent of GDP and 25 to 35 percent of employment.⁸ In advanced economies, service sectors generate 60 to 80 percent of GDP and account for up to 80 percent of employment.

Today, China is at an early stage of the shift from manufacturing to a more service-based economy: in 2015, services accounted for just 49 percent of GDP and 40 percent of employment. The Chinese government's goal is to raise service-sector output to 55 percent of GDP by 2020. China's service sector is not only relatively small, but it also has low productivity compared with global norms—15 to 30 percent of the OECD average, depending on the service industry (Exhibit 3).

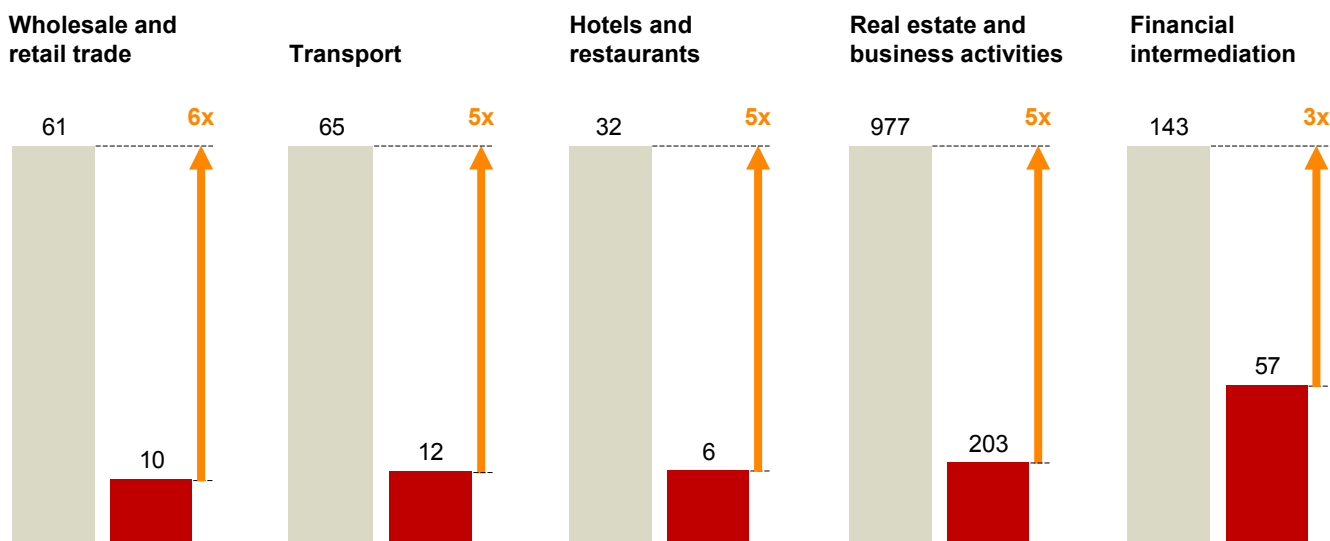
⁸ *Manufacturing the future: The next era of global growth and innovation*, McKinsey Global Institute, November 2012.

Exhibit 3

China's services sector is underdeveloped, and has approximately 15 to 30 percent of the productivity of service businesses across the OECD

Productivity comparison, 2011
2011 \$ thousand (nominal) per employee

■ OECD average ■ China **Factor gap between China and OECD average**



NOTE: Not to scale.

SOURCE: IHS Global Insights; China Bureau of Statistics; World Input-Output Database; McKinsey Global Institute analysis

CHINA HAS THE POTENTIAL TO EVOLVE FROM AN INNOVATION SPONGE TO INNOVATION LEADER AND MEET THE INNOVATION IMPERATIVE

Innovation already plays a critical role in China's economy. Like other developing economies, China has been an innovation sponge, absorbing and adapting existing technology and knowledge from around the world. Indeed, China may be the most successful innovation sponge in history, systematically mastering technologies and acquiring know-how as it has industrialized. As a result, over the past three decades, China has come further and industrialized faster than any other economy in history. In China, industrialization raised GDP per capita to \$8,000 from \$1,000 in just 30 years—a third of the time it took Japan and about one-sixth of the time it took the United States. In the process, China has lifted more than 400 million people out of poverty and started to climb the global value chain: China ranks second in the world in knowledge-intensive flows—the movement of knowledge-intensive goods and services and foreign direct investment.⁹

The next step is to progress from innovation sponge to innovation leader. From our sector-based analysis of innovation in the Chinese economy, which is the focus of Chapter 2, we see that China already has strong positions in industries such as Internet services and appliances, where innovation involves solving consumer problems. In serving consumer needs, Chinese companies have created a unique innovation model that takes advantage of the size and speed of the Chinese market. China also has had success in efficiency-driven innovation in manufacturing, based on its ecosystem advantages. In engineering-based industries, such as telecommunications equipment and autos, the picture is mixed, and the most progress is needed in science-based innovation. The government has invested heavily in building capabilities in engineering and science, which have created a strong foundation for future innovation (see Box 2, "China's innovation policy approach").

⁹ *Global flows in a digital age*, McKinsey Global Institute, April 2014.

Box 2. China's innovation policy approach

Chinese policy makers have long been aware of the innovation imperative and have devoted substantial resources to building capacity for innovation. China's total investment in R&D has risen from \$30 billion in 2005 to more than \$200 billion in 2014. That makes China the No. 2 nation for R&D spending (in absolute terms), behind the United States, which spent about \$500 billion in 2014. China now spends about 2 percent of GDP on R&D, which is comparable to the level of the Netherlands and the United Kingdom, but below the levels of South Korea (4.4 percent), Japan (3.3 percent), and Austria (2.9 percent). Chinese policy and public investment have built a solid foundation of innovation institutions and talent. Chinese universities confer 28,700 PhDs in science and engineering per year, the largest number in the world. Chinese researchers published more than 420,000 scientific papers in 2013, second only to the United States.

Based on metrics of innovation prowess such as patent awards, the government's investments should have put China well on its way to becoming a global innovation leader. Yet these input-based approaches have not produced the commercial successes that raise productivity. Moreover, while the magnitude of the effort is impressive, there are some questions about quality (Exhibit 4). For example, the number of claims per Chinese patent—a widely regarded sign of a patent's strength—is 30 to 50 percent less than for US patents. Also, only 998 of 650,000 Chinese patents filed in 2012 were triadic, meaning that they were filed in the United States and Japan and with the European Patent Office. Triadic filing is another indicator of patent quality; US and Japanese companies filed more than ten times as many triadic patents as China.

The government has continued to expand innovation policies in recent years, such as the “mass entrepreneurship and innovation” initiative, announced by Premier Li Keqiang as a way to counter China's slowing growth. The State Council followed with a series of policies to improve the environment for entrepreneurship by offering funding and streamlining administrative processes to lower barriers to starting a business. The moves are aimed at encouraging college students, scientists, and engineers to start new businesses.

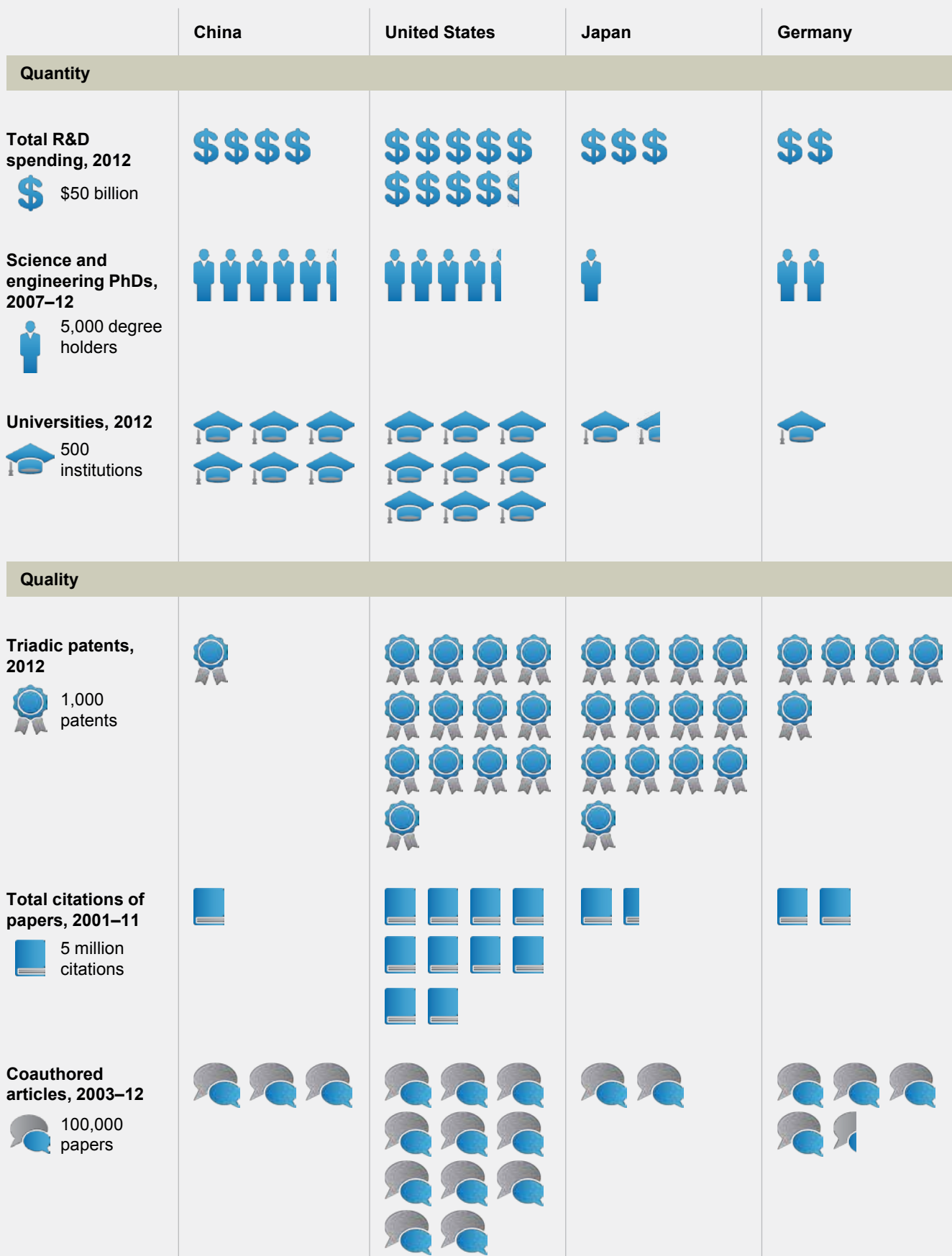
In March 2015, Li announced the “Internet Plus” plan to boost the economy through digitization. It calls for greater adoption of the mobile Internet, cloud computing, big data, and the Internet of Things to encourage e-commerce, industrial networks, and Internet banking, and to help Internet companies increase their international presence. These initiatives could prove very helpful in efforts to raise service-sector productivity by providing the connectivity to make businesses more efficient.

The government also has launched a comprehensive blueprint to maintain the nation's lead in manufacturing. The effort includes three ten-year plans that are expected to culminate in 2049, the centennial of the People's Republic of China. It is aimed at driving further efficiencies in manufacturing while raising the value added of Chinese manufacturing output by encouraging companies to move into goods such as numerical control machine tools for automation, robotics, and aerospace equipment.

Many of these initiatives can be characterized as enablers of innovation and are not focused as intensely on inputs as earlier top-down policies were. Policies to create enabling infrastructure such as cloud computing and programs to encourage mass innovation and entrepreneurship are aimed at unleashing innovation at the grass roots. In Chapter 7, we discuss additional policy considerations that would clear obstacles to innovation.

Exhibit 4

China has invested heavily in science-based innovation but has not yet seen commensurate results



SOURCE: UNESCO Institute of Statistics; 2014 Global R&D Funding Forecast Report, Battelle; China National Bureau of Statistics; Report on the Survey on Research and Development (2013); Essential Science Indicators, UK National Endowment for Science, Technology and the Arts; World Market Monitor; OECD; McKinsey Global Institute analysis

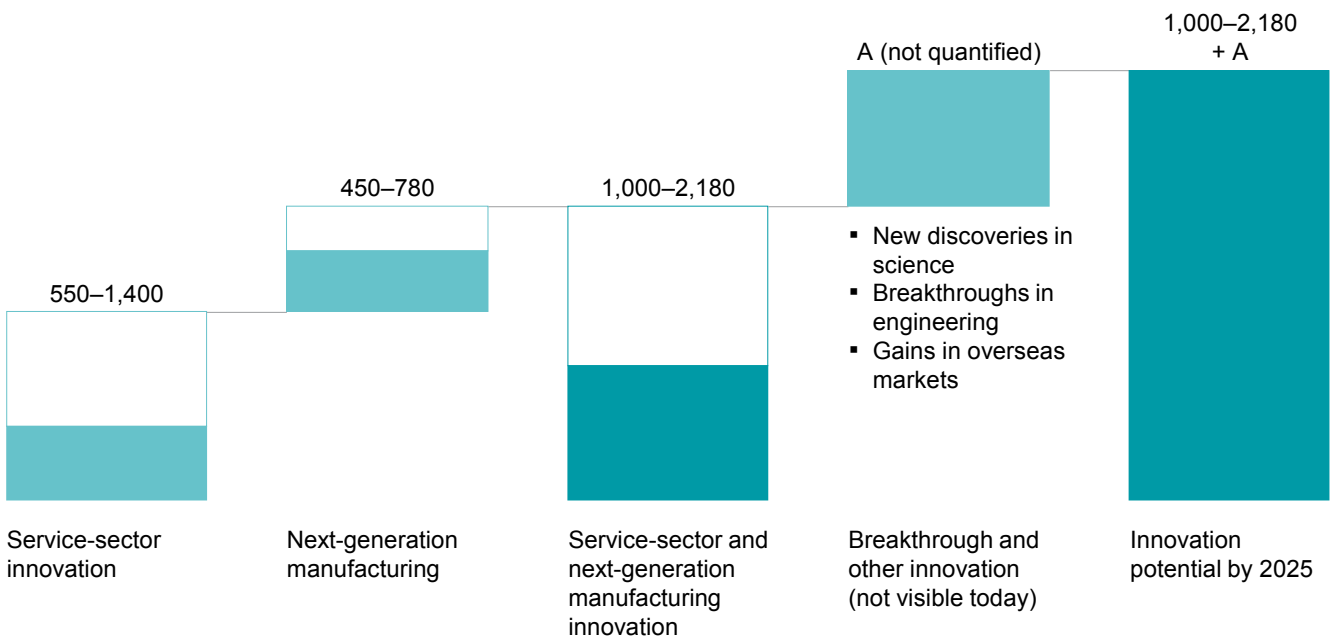
Innovation in services and manufacturing can create value of \$1.0 trillion to \$2.2 trillion by 2025, up to 24 percent of GDP growth

Innovation in services, manufacturing, and other areas can help China meet its innovation imperative. Based on our estimates, China can create \$1.0 trillion to \$2.2 trillion in value from innovations in manufacturing and services by 2025, equivalent to 13 to 24 percent of total GDP growth by 2025 (Exhibit 5). The value from innovation that we estimate would include both direct contributions to GDP and consumer surplus, such as time savings from better services and better health from new drugs. If this value can be fully realized, it can account for 40 percent of the contribution to GDP growth that China needs from multifactor productivity, which we estimated to be \$3 trillion to \$5 trillion per year in 2025. In addition, China will need to continue to raise productivity broadly throughout the economy, including by adopting best practices in all types of businesses.¹⁰ Additional gains would come from accelerated progress in science- and engineering-based innovation.

Exhibit 5

Innovation in services, manufacturing, and other areas can help China meet its innovation imperative

Potential value in 2025¹
2014 \$ billion



¹ Value includes increased output and company profit as well as consumer surplus (benefits such as lower prices and higher quality).
NOTE: Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

We focus here on certain types of opportunities in service-sector and manufacturing innovation because of their large potential to raise productivity. In services, where Chinese companies are only 15 to 30 percent as productive as peers in OECD countries, there are many opportunities to raise efficiency and expand the reach of service industries—Internet-based services are particularly promising. In manufacturing, China has the opportunity to build on its current strengths as global industry shifts to a next-generation, digitized manufacturing model, known as Industry 4.0. We also consider opportunities for innovation in life sciences, engineering industries (nuclear, medical equipment), and other areas, but we do not quantify potential impact.

¹⁰ For further details on catch-up productivity, see *Global growth: Can productivity save the day in an aging world?* McKinsey Global Institute, January 2015.

- **Services.** We see three broad categories of innovation opportunity in China's service sector, which together can create \$550 billion to \$1.4 trillion in value, or the equivalent of 11 to 29 percent of service-sector growth over the next ten years. First, China can further expand the service sector, which today accounts for only 49 percent of GDP (compared with 60 to 80 percent in advanced economies). It can do so by providing greater access to services such as education and health care, which are concentrated in larger urban areas, and by increasing funding for small and medium-sized enterprises. Second, Chinese companies can improve quality of services through a range of innovations that offer more choices and better customer experience. Internet-based business models, including "online-to-offline" platforms, can improve service for customers and drive growth of offline services ranging from hair styling to personal security. Finally, innovation can optimize service-sector operations. For example, in logistics, Chinese companies are using the Internet to crowdsource last-mile package delivery and messenger services. We discuss the opportunities for service-sector innovation in detail in Chapter 3.
- **Manufacturing.** Manufacturing may not be as large a force in Chinese GDP growth or employment in the coming decade as in the past. However, it will continue to be a large share of the economy, around 27 percent by 2025, and is expected to continue to contribute to growth. More important, manufacturing can make outsized contributions to innovation and competitiveness, especially if China can make the transition to the next-generation manufacturing model by embracing Industry 4.0, a model for more extensively digitized and connected operations within a factory and across the manufacturing value chain. We estimate that innovations in manufacturing can create \$450 billion to \$780 billion per year in value by 2025, or 15 to 22 percent of manufacturing-sector growth. The new manufacturing model, including using Internet of Things sensors and tags on machinery, inventory, and physical assets, can raise the productivity, quality, and agility of Chinese manufacturing. With a digitally linked manufacturing ecosystem, Chinese players can deliver manufacturing as a service to small businesses and even to individual consumers (mass customization). China is already building an open manufacturing platform that is expanding access to manufacturing for entrepreneurs in China. For large-scale manufacturers, a flexible combination of robotics and skilled labor (hybrid automation) can raise productivity. We discuss these opportunities in detail in Chapter 4.
- **Emerging opportunities.** In addition to the opportunities we have sized, China has other ways to innovate and add value. For example, Chinese companies can apply the skills they have developed in customer-focused innovation at home to capture growth in emerging markets. Chinese companies also have the opportunity and, increasingly, the ability to compete against global brands in areas such as packaged foods and personal care products, where foreign brands still dominate. We discuss these opportunities in Chapter 3. We also see opportunities in engineering-based innovation in areas such as electric vehicles and aerospace, which we describe in Chapter 5. In Chapter 6, we discuss opportunities in life sciences. If China can successfully reform regulations and processes for awarding and managing research grants and if it can continue to build a talent pool in life sciences, successful drug discoveries and commercialization will follow.



With slowing growth, aging, and falling returns on capital investment, China faces an innovation imperative. Innovation can raise multifactor productivity and help China reach its growth goals. To do this, China must evolve from innovation sponge to innovation leader. In the following chapters we will look at the challenges and opportunities China faces across four industry archetypes that innovate in different ways and the policies that will be needed to unleash innovation.





2. THE CURRENT STATE OF CHINESE INNOVATION

To better understand how innovation in China works and assess whether China can meet its innovation imperative, we set out to measure the impact of innovation in different sectors of the economy. We developed an archetype-based view that shows how innovation works in different industries and allows us to see where Chinese innovation is succeeding today and where further improvements are needed.

CREATING A MODEL THAT CAPTURES THE ACTUAL IMPACT OF INNOVATION

When assessing an economy's capacity for innovation, it is common to use a macro view that focuses on metrics of capabilities. The most common metrics focus on data such as R&D spending, numbers of PhDs granted, annual patent applications, and research papers published. While these metrics may indicate increasing capacity and capabilities, they do not address innovation in its broadest sense, which includes not only scientific inventions, but also successful commercialization of ideas and technologies, novel business models, and innovations in production processes. Nor do these measures of capacity provide any information about how successful a nation is at innovation. For example, China scores highly on R&D spending, PhDs, and patents, but Chinese companies in fields where innovation involves lengthy research efforts and scientific breakthroughs—where R&D spending and PhDs matter—are not yet globally competitive.

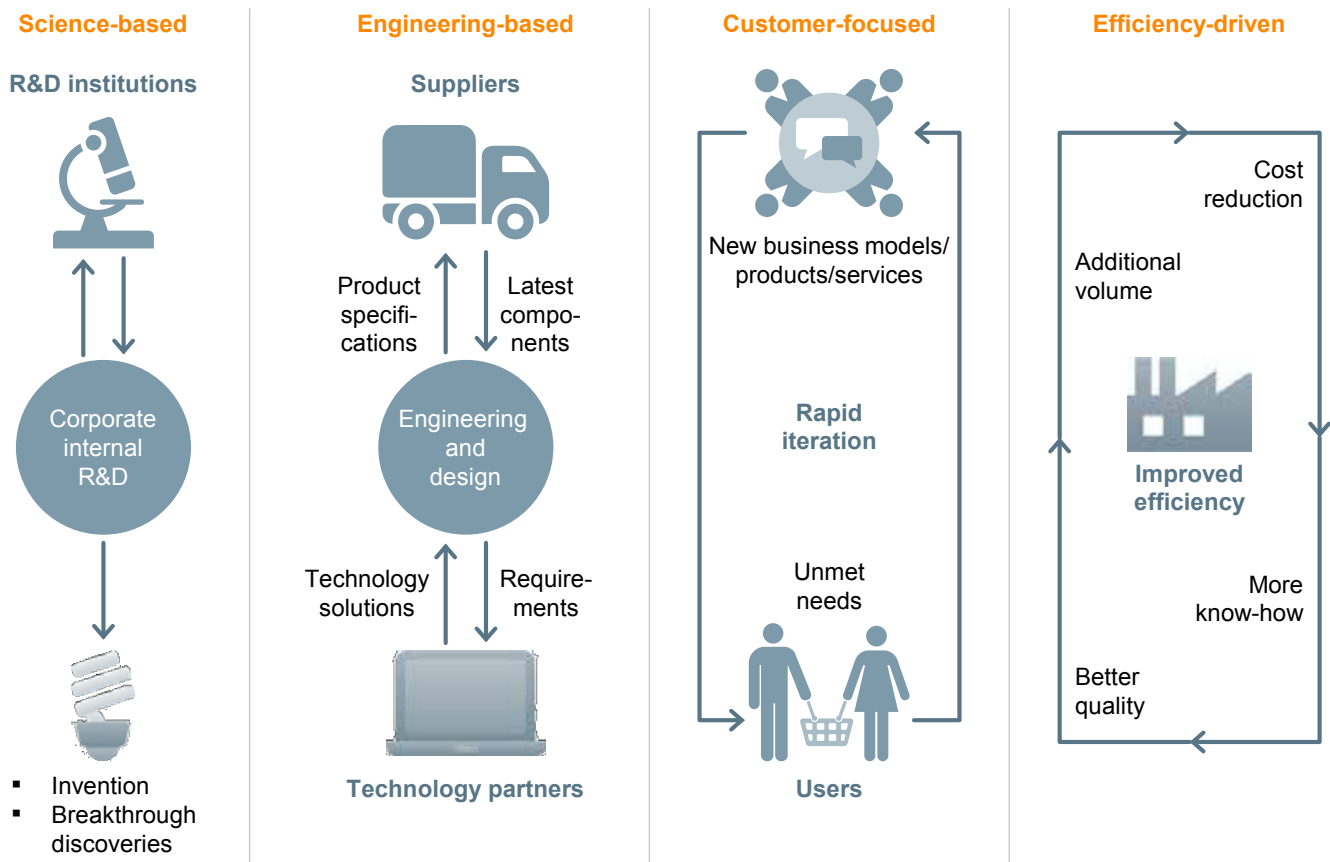
We also wanted a model that could generate actionable insights for business leaders and policy makers by determining the requirements for innovation in specific industries. We began by looking at more than 30 industries and analyzing what constitutes innovation in each and how innovation determines the success of firms in these industries. The result was four archetypes of innovation: customer-focused, efficiency-driven, engineering-based, and science-based. Depending on the industry, factors such as R&D intensity, understanding of customer needs, and capital and labor intensity are of greater or lesser importance.

THE FOUR ARCHETYPES OF INNOVATION

The four innovation archetypes have different innovation processes and different requirements for success. For example, in the science-based innovation archetype, innovation involves the commercialization of basic research, conducted by companies and academic institutions, often in collaboration (Exhibit 6). Industries in the science-based archetype spend heavily on R&D (they have high “R&D intensity”). By contrast, industries that fit the efficiency-driven archetype are more labor- and capital-intensive. The innovation process in efficiency-driven industries involves scaling up quality improvements or cost reduction techniques. Customer-focused innovation requires a deep understanding of consumer needs and behavior. As Exhibit 7 shows, industries that fall into the archetypes share certain characteristics as well as having common sources of innovation.

Exhibit 6

We define four archetypes of innovation



SOURCE: McKinsey Global Institute analysis

Exhibit 7

Industries in the four archetypes share certain characteristics, such as high R&D or labor intensity

■ High ■ Medium-high ■ Low-medium ■ Low

		R&D intensity ¹	Capital intensity ²	Labor intensity ³	Marketing intensity ⁴	Trade intensity ⁵	Source of innovation
Science-based	Semiconductor design	16	45	5	2	14	<ul style="list-style-type: none"> Company research Academic research
	Biotechnology	33	28	3	2	41	
	Branded pharmaceuticals	15	27	3	5	41	
Engineering-based	Communications equipment	13	12	5	1	48	<ul style="list-style-type: none"> Suppliers, technology partners Engineering know-how
	Auto manufacturing	4	29	1	3	41	
	Railroad equipment	3	23	3	2	22	
	Commercial aviation	4	17	5	<1	67	
Customer-focused	Internet software and services	13	25	3	5	n/a	<ul style="list-style-type: none"> Consumer insights Identifying unmet needs
	Household products	2	27	n/a	7	38	
	Household appliances	2	16	6	3	40	
	Consumer electronics	6	17	7	4	70	
Efficiency-driven	Commodity chemicals	2	48	1	1	33	<ul style="list-style-type: none"> Production know-how Ecosystem
	Textiles	1	48	8	1	40	
	Electrical equipment	3	25	8	<1	45	
	Construction machinery	3	33	5	<1	42	

1 R&D expenses as a percentage of revenue.
 2 Plant, property, and equipment divided by revenue.
 3 Hours worked per \$1,000 value added, in 2014 dollars.
 4 Marketing expenses divided by revenue.
 5 Exports divided by global production value, 2010–14 average.

SOURCE: McKinsey Corporate Performance Analysis Tool; IHS Global Insight; US Bureau of Labor Statistics; McKinsey Global Institute analysis

- **Science-based innovation** involves the development of new products through the commercial application of basic research. Industries such as branded pharmaceuticals, biotechnology, semiconductor design, and specialty chemicals rely on scientific innovation and may spend 15 to 33 percent of revenue on R&D. The innovation process can involve basic research—discovering a new drug molecule or material, for example—and might take ten to 20 years from initial investigation to commercialization. Science-based innovation often involves collaboration among companies and academic researchers within a nation or across borders. Having a supportive environment for the long-term efforts that scientific innovation require is essential. This includes tax policies that reward long-term investments in R&D (through incentives, for example), and rigorous intellectual property protections to ensure that innovators reap the profits generated by their discoveries. High-quality universities play a central role in science-based innovation by conducting basic research, training talent, enabling academic collaboration and exchange, and spawning new companies. Nations that are strong in science-based innovation generally provide government funding for basic research and fund science education as “public goods.” Global competition plays a significant role in shaping science-based innovation. Products such as semiconductor chips are heavily traded, and incumbents have accumulated large patent portfolios that help them retain market share and enter new markets.
- **Engineering-based innovation** involves the design and engineering of new products and often involves the integration of technologies from suppliers and partners. Industries that rely on engineering-based innovation include commercial aviation, auto manufacturing, and communications equipment. These industries have moderate to high R&D intensity, typically spending 3 to 13 percent of sales on R&D, and can have product life cycles of five to ten years or longer. Engineering innovations are often protected by patents. Knowledge in these industries is typically based on accumulated learning that is acquired over time through experimentation and learning by doing. Knowledge can be transferred via employee-to-employee interaction within an organization and through dealings with component suppliers and technology partners. For companies to succeed in engineering-based innovation, they need access to professionally trained talent and a supportive environment that provides strong intellectual property protection. Engineering-oriented companies (autos, for example) benefit from strong industry clusters, and policies that increase access to global sources of technology, talent, and knowledge.
- **Customer-focused innovation** involves solving consumer problems through advances in products, services, and business models. Industries in this category include Internet software and services, appliances, and consumer packaged goods. These industries are characterized by high marketing intensity (typically spending 3 to 7 percent of sales on marketing) and short development cycles, with rapid iterations of new concepts. Because many products and services in these industries tend to be tailored to local needs and regulations, local innovators often have advantages. However, some customer-focused businesses, such as appliances, are globally traded. The innovation process in customer-focused industries depends on understanding and addressing consumer “pain points” and needs, and identifying underserved markets and niches. Access to large consumer markets is important for understanding customer needs as well as for scaling up innovations rapidly (and for refining designs and service offerings after introduction). Companies in customer-focused industries benefit from large local demand, easy access to capital, and policies that support entrepreneurship.

- **Efficiency-driven innovation** is aimed at improvements to reduce cost, shorten production time, and enhance quality in manufacturing. Efficiency-driven innovation is particularly relevant in capital- and labor-intensive industries, such as commodity chemicals, textiles, electrical equipment, and construction machinery. These industries are capital intensive, with investments in plant, property, and equipment equivalent to about 30 percent of sales, but they have low marketing intensity (consuming 1 percent of sales or less). The innovation process depends on in-depth knowledge of production processes and materials to reduce cost while maintaining or improving quality. This involves novel approaches in product development, supply-chain management, manufacturing, or service delivery. A strong cluster ecosystem promotes collaboration among suppliers, manufacturers, and customers.

We recognize the limitations of attempting to sort industries squarely into archetypes. In reality, multiple forms of innovation take place within a sector. For example, although innovation in the automotive industry depends heavily on engineering, competitive car companies must also master customer-focused innovation to keep up with consumer preferences. They also pursue efficiency-driven innovation in manufacturing to remain profitable. Nonetheless, we find that the innovation archetypes offer useful guidance to understand key drivers of innovation by industry and reveal insights that can lead to effective strategies for policy makers and business executives.

HOW THE INNOVATION ARCHETYPES SHAPE COMPETITION

The nature of the innovation process in the four archetypes and the requirements for successful innovation in the archetypes have a large influence on competition in different types of industries. In science- and engineering-based innovation, firm performance is closely correlated to strong proprietary knowledge. In Exhibit 8, we see that in branded pharmaceuticals and telecommunications equipment, companies that have successful inventions (as measured by volume of high-quality patents) outperform competitors with weaker knowledge (patents that do not attract as many challenges). In many science- and engineering-based industries, companies that have large portfolios of high-quality patents are extremely difficult to displace, making it even more challenging for economies like China to catch up.

In contrast, where industries rely on customer-focused and efficiency-driven innovation, patentable knowledge is not a key requirement for success. For example, in the smartphone and solar panel industries, we do not observe a correlation in profit or revenue to quality of knowledge. In these businesses, commercializing innovations quickly and on a large scale does more to capture industry profits than invention per se. It is the firms that get new ideas or technologies to customers first that tend to capture the larger share of industry profits. In customer-focused and efficiency-driven innovation, the end consumer captures a significant amount of the value created by innovation in the form of better offerings, lower prices, or both.¹¹

The nature of innovation in an industry can also shape industry structure. Companies that build strong patent portfolios have tremendous advantages because they can make additional innovations based on existing intellectual property and trade their patents to get access to other innovations. The effect can be observed in the semiconductor design business, where the top three global players have not changed for two decades. Sometimes, companies with strong intellectual property can use their patents to expand the market. Tesla is attempting to accelerate growth of the electric vehicle market by licensing its patents for free.¹²

¹¹ William D. Nordhaus, *Schumpeterian profits in the American economy: Theory and measurement*, NBER working paper number 10433, April 2004.

¹² Mike Ramsey, "Tesla Motors offers open licenses to its patents," *The Wall Street Journal*, June 12, 2014.

Exhibit 8

Invention correlates with performance in science- and engineering-based industries, but not in customer-focused or efficiency-driven industries

○ Size of circle =
Number of patents, 2010–14

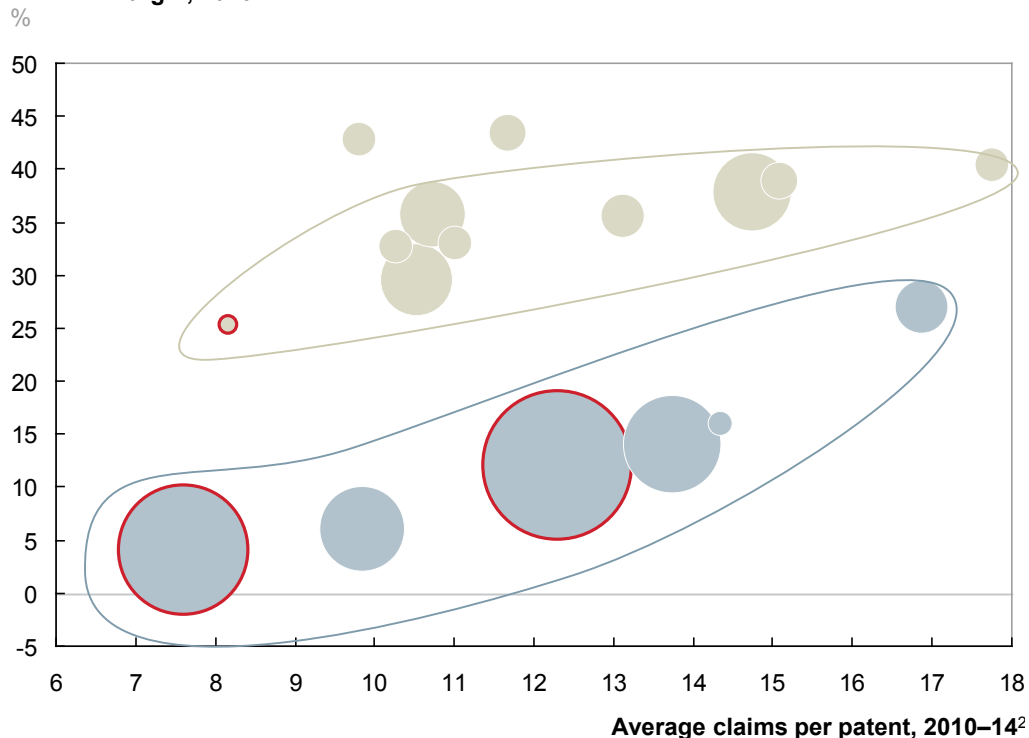
○ Chinese player

Invention, as measured by strong patents, correlates with superior firm performance in science and engineering

● Pharmaceuticals

● Communications equipment

EBITDA margin, 2010–14¹

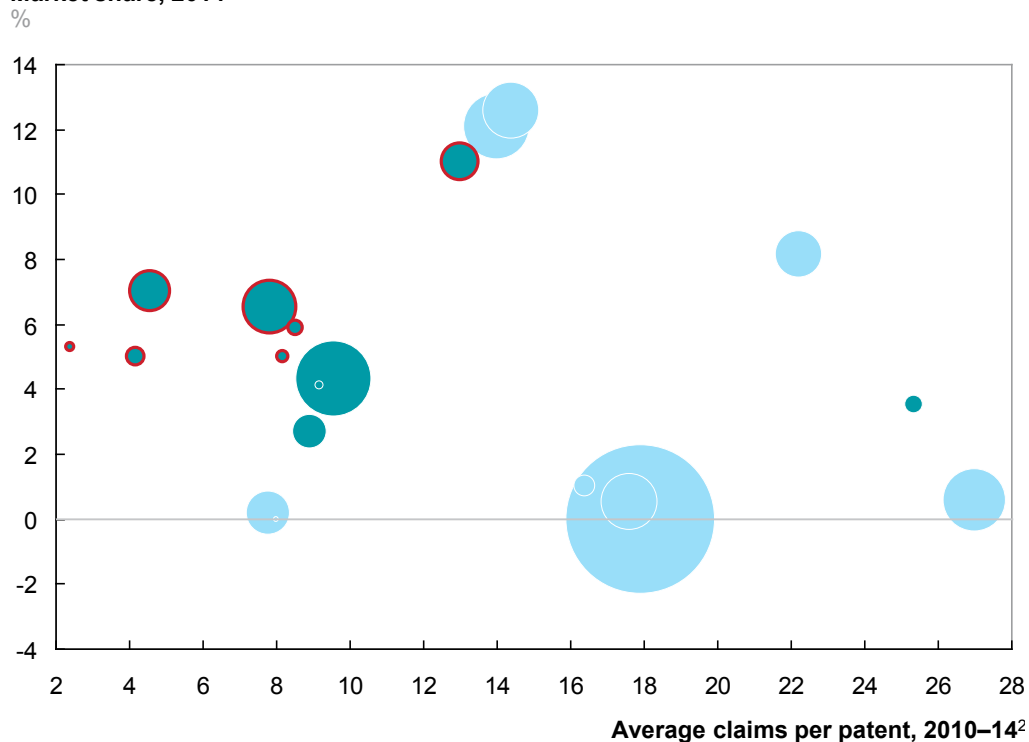


In customer- and efficiency-based industries, even companies with weak patents can be leaders

● Smartphones³

● Solar panels³

Market share, 2014³



¹ Earnings before interest, tax, depreciation, and amortization

² A patent claim specifically describes the inventions for which a patent is sought. Each patent will contain multiple claims, which define the scope and the protection conferred by a patent. Multiple claims are regarded as a metric for patent quality.

³ Market share calculated as a share of China market (units) for smartphones, as a share of global market (MW) for solar panels.

SOURCE: Innography; McKinsey Corporate Performance Analysis Tool; Strategy Analytics; McKinsey Global Institute analysis

WHERE CHINA IS SUCCEEDING—AND WHERE IT IS NOT

Ultimately, the proof of successful innovation is the ability of companies to expand revenue and raise profits with new products and services and with improvements in design, manufacturing, or business models. Although the competitiveness of companies can be affected by non-innovation factors such as industry structure and factor costs, we believe innovation is a primary contributor to the growth of revenue and profit at the company level.¹³

To gauge China's success in innovation, we look at how well Chinese companies in the four archetype industry groups compete. First we look at where Chinese companies have captured more than their "GDP-based share" of global markets—where Chinese companies have a disproportionate share of global revenue compared with China's share of global GDP (12 percent in 2013).¹⁴ While the competitiveness of companies can be affected by non-innovation factors such as industry structure and factor costs, we believe innovation is a primary contributor to the growth of a firm's revenue and profit.

For this analysis, we use a proprietary database of more than 20,000 publicly held companies from around the world, selected from major sectors that represent approximately 28 percent of the global economy. Exhibit 9 illustrates the results: Chinese companies show the greatest strengths in markets that require customer-focused and efficiency-driven innovation. For example, Chinese companies have captured more than 36 percent of global appliance industry revenue, or almost three times their GDP-based share based on China's GDP. In generic pharmaceuticals, where innovation is based on creating more efficient processes, Chinese companies also have about 30 percent of global revenue, and Chinese companies have 20 percent or higher shares in textiles and metals. One of China's greatest successes is in solar panels, an efficiency-driven industry in which Chinese companies have 51 percent of global revenue.

The chart shows that China has the most catching up to do in industries that rely on science- and engineering-based innovation. In the four industries we analyze that depend on science-based innovation, for example, China has less than a 1 percent share of global revenue in branded pharmaceuticals, and 3 percent in each of the other three: biotech, semiconductor design, and specialty chemicals. In engineering-based industries, Chinese companies have a more mixed record. While China has a disproportionately low share of global auto revenue (8 percent) and medical devices (about 3 percent), it has 41 percent of global revenue in railroad equipment and is the world's largest producer of high-speed trains. China's success in high-speed rail and its strong position in wind turbines are the result of government action in these sectors (as a purchaser and as a facilitator of access to knowledge), which we will discuss in depth in Chapter 5. China has also captured 18 percent of the global telecommunications equipment market.

Another way to gauge the success of Chinese innovation is to look at how well Chinese companies compete in export markets. Exhibit 10 shows a slightly different picture of Chinese innovation success. Chinese companies can attain significant shares of global revenue in many markets simply by filling domestic demand, but they may not be successful innovators in terms of winning in global markets (through exports).

¹³ For further reading on innovation's impact on competitiveness, also see Michael Porter, "The competitive advantage of nations," *Harvard Business Review*, March–April 1990, and John Cantwell, "Innovation and competitiveness," in *The Oxford handbook of innovation*, Jan Fagerberg, David C. Mowery, and Richard R. Nelson, eds., Oxford University Press, 2006.

¹⁴ The exhibit shows revenue share rather than profit share. Our research found that Chinese firms tend to put revenue growth and scale ahead of maximizing returns on invested capital. See *Playing to win: The new global competition for corporate profits*, McKinsey Global Institute, September 2015.

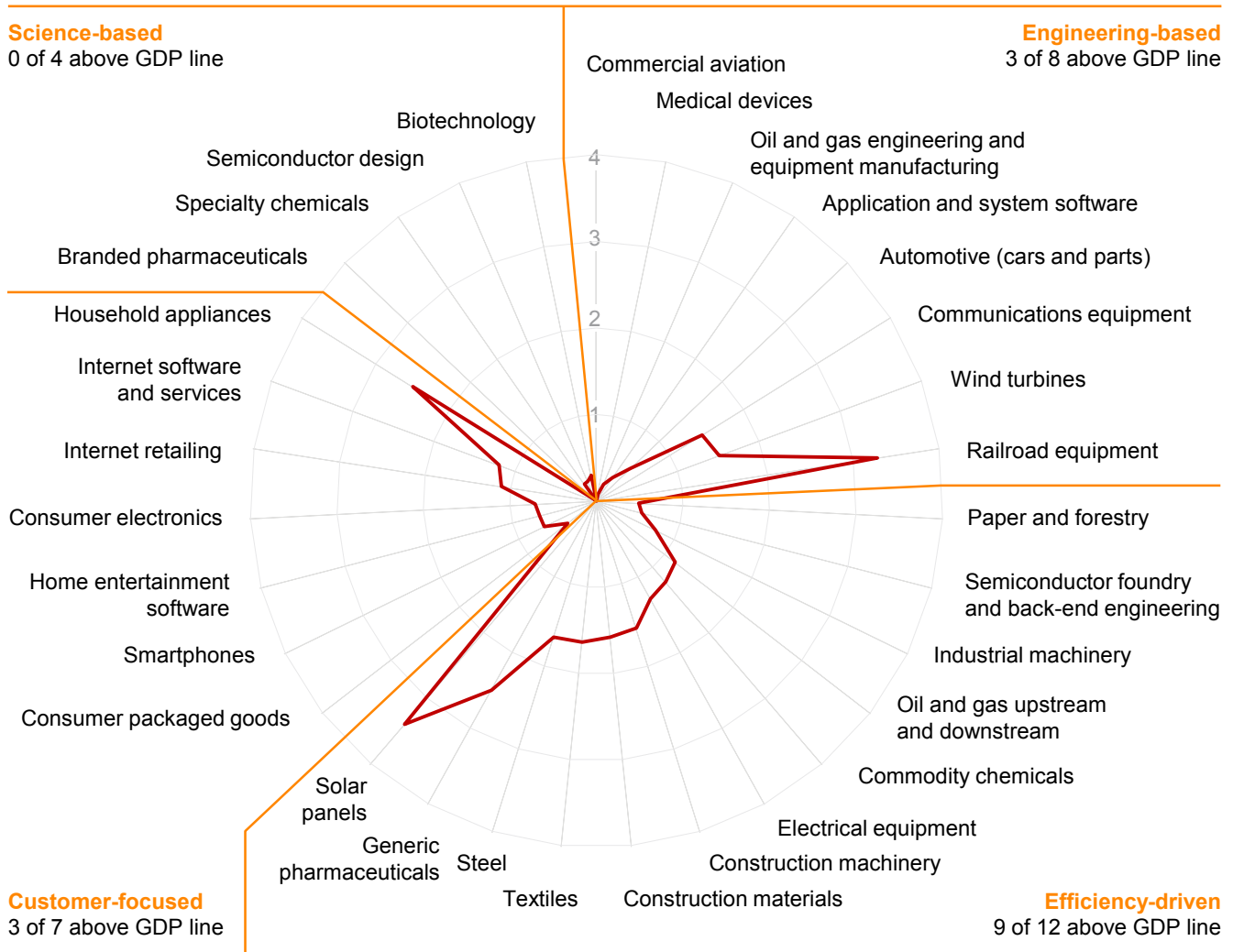
Chinese companies are winning in several export markets where competition is based on customer-focused innovation, such as appliances and consumer electronics. And Chinese companies are strong exporters in such efficiency-driven industries as textiles and construction materials. In communications equipment—an engineering-based industry—Chinese companies have 10 percent of export markets.

Exhibit 9

China has established strength in efficiency-driven and customer-focused innovation, but lags in science- and engineering-based innovation

Revenue fair share of Chinese companies, 2013¹

Index: 1 = GDP share



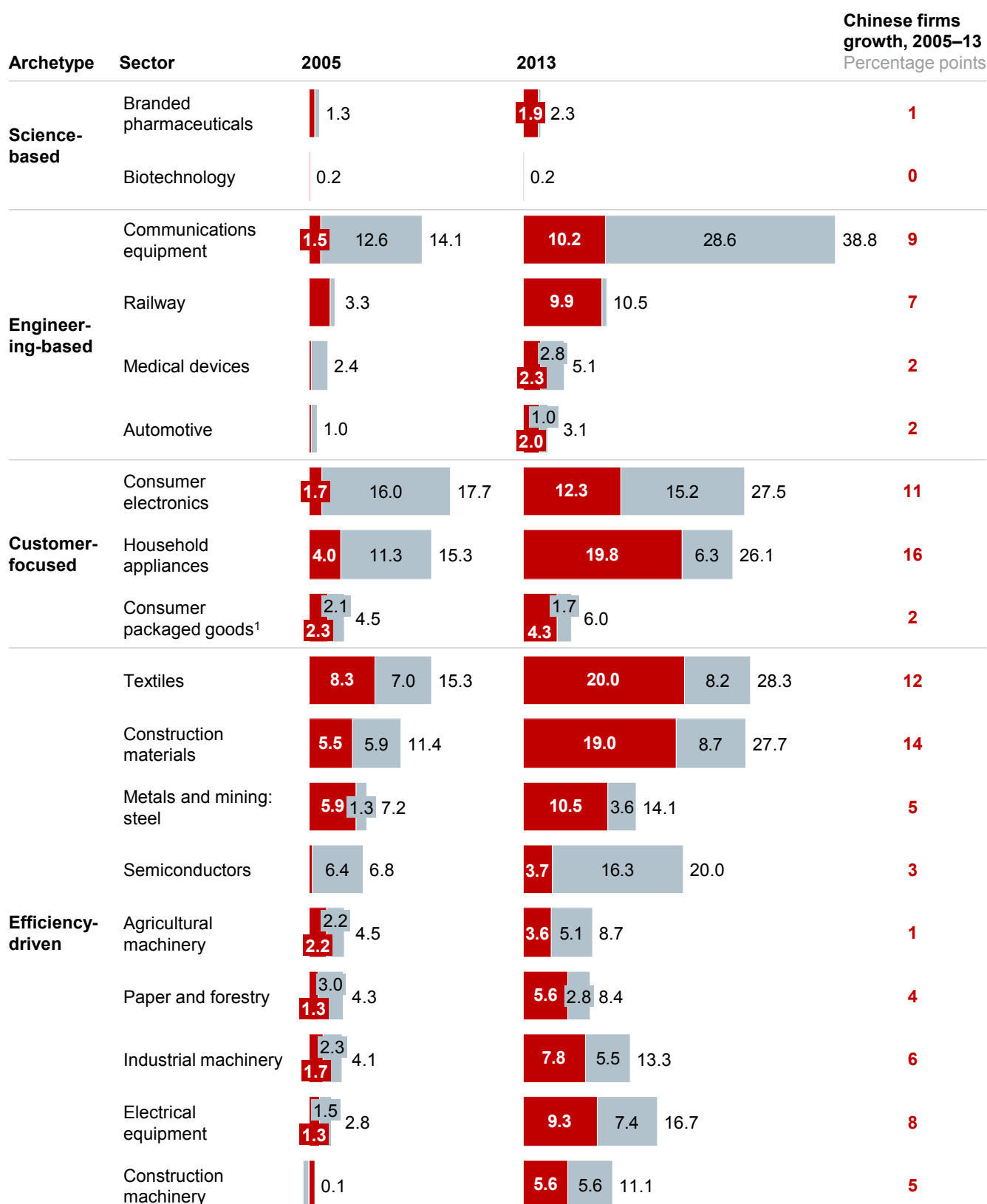
¹ This is the ratio of a country's share in the global revenue pool to its share of global GDP.

SOURCE: International Data Corporation; McKinsey Corporate Performance Analysis Tool; company annual reports, IHS Global Insight; iSuppli; McKinsey Global Institute analysis

Exhibit 10

China has become more competitive in exports, particularly in customer-focused and efficiency-driven industries

Global export share % ■ Chinese firms ■ Foreign firms and joint ventures



1 Includes household products, packaged foods, and beverages.

NOTE: Numbers may not sum due to rounding. For legibility, segment labels <1 not shown.

SOURCE: UN-Comtrade; International Trade Centre; Chinese Export Yearbook; McKinsey Global Institute analysis

INNOVATION WITH CHINESE CHARACTERISTICS

In the next four chapters, we will explore in much greater detail the progress of Chinese companies in the four innovation archetypes, including examining what factors and decisions have contributed to success and what holds back innovation. Companies innovate—or struggle to innovate—not only in the context of their archetype industries, but also in the context of the national economy. Innovation is shaped by characteristics such as a nation’s approach to education and regulation or how well universities and business work together (see Box 3, “National innovation profiles”).

In China, we find that the path of innovation across the four archetypes is heavily influenced by Chinese characteristics—its large population, the speed of Chinese business, and the extensive manufacturing ecosystem. China’s size means that almost everything—consumer market niches, number of scientists graduating from universities, patients available for drug trials—is on a larger scale than in other parts of the world. And China’s dynamic business environment and ambitious, nimble organizations accelerate the speed of doing things in China. Finally, the ecosystem that has formed around Chinese manufacturing industries enables process innovations that can cut cost, improve quality, and improve flexibility. These characteristics help determine the state of innovation in the four archetypes in different ways.

- **Customer-focused.** Innovators in customer-focused industries benefit most from the commercialization advantage afforded by the size of the Chinese domestic market. These companies also benefit from speed—responding rapidly to market feedback by continuously tweaking designs and features and introducing new products and services.
- **Efficiency-driven.** China’s manufacturing ecosystem is the essential asset for innovators in efficiency-driven industries, providing access to a large labor force, a concentrated and ample base of suppliers, and services that can help manufacturers and service companies improve efficiency. The ecosystem also includes modern infrastructure for moving goods within China and out to global markets. Scale is also important for efficiency-based industries to drive down unit costs.
- **Engineering-based.** Innovators in engineering-based industries rely on accumulation of knowledge and know-how. China’s investments in education provide a large supply of trained engineers and, because China has been catching up in areas such as high-speed rail, government support and policy continue to play a large role in engineering-based industries. Government helps companies acquire critical knowledge through purchasing programs that drive local demand and by facilitating knowledge and technology transfers with foreign joint-venture partners.
- **Science-based.** Companies in life sciences and other highly technical industries in China also benefit from government policies and programs to help China catch up in science-based innovation (such as expanding higher education and R&D funding). Science-based innovation also benefits from China’s scale and speed. Chinese companies are using scale advantages—deploying thousands of scientists, for example—to accelerate and reduce the cost of discovery. Using China speed and access to the massive Chinese market, they are also speeding up commercialization.

Box 3. National innovation profiles

Every country has characteristics that help determine its success in different types of innovation (Exhibit 11). This innovation profile is shaped by attributes (natural resources, for example), decisions by business leaders and policy makers, and cultural traditions.

Germany is famous for its technical and engineering prowess and performs well in science- and engineering-based industries. The educational system turns out highly qualified (and well-paid) scientists and engineers as well as middle-skill technical workers trained in apprenticeship programs. Another characteristic of the German economy that helps drive innovation is the presence of strong small and mid-sized (*mittelstand*) companies, many of which are family-owned and known for making long-term investments.

South Korea became a successful innovator in consumer-focused and efficiency-driven industries, starting as a “fast follower” then through intensive efforts to match advanced economies. The *chaebol* conglomerates played a leading role, building massive production capacity at home, acquiring and accumulating knowledge to innovate, then competing globally in businesses such as consumer electronics, steel, and automobiles. Between 1999 and 2006, the top 20 companies accounted for more than half of business R&D and employed 30 percent of researchers.¹

The United States has long been a leader in science- and engineering-based innovation and is also strong in customer-focused innovation. Underpinning its success are factors such as its commitment to basic research (\$80 billion per year, about 60 percent of which is funded by government), as well as a tradition of letting markets develop with minimum intervention. The United States also has a strong entrepreneurial culture that encourages risk-taking, access to venture funding, and ties between business and academia that have led to the formation of thousands of companies. The United States has a strong talent pool that includes immigrants from around the world, and it is home to 83 of the world’s top 100 universities.²

¹ *OECD reviews of innovation policy: Korea 2009*, OECD, July 2009.

² *Academic ranking of world universities 2015*, Shanghai Ranking Consultancy.

Exhibit 11

China has established strength in efficiency- and customer-driven innovation, but continues to lag behind in science and engineering

% of global revenue share, 2013



NOTE: Not to scale.

SOURCE: International Data Corporation; McKinsey Corporate Performance Analysis Tool; annual reports, IHS Global Insight; iSuppli; Teal Group; McKinsey Global Institute analysis



The archetype view helps identify where China is succeeding in innovation and why. By understanding how industries that share certain characteristics innovate and by identifying the conditions that are needed for their innovation efforts to succeed, business leaders and policy makers can find more effective ways to improve innovation performance. In the next four chapters, we will examine how industries in the four archetype groups are performing today and the opportunities for them to raise their innovation performance in the coming decade.



3. CUSTOMER-FOCUSED INNOVATION

With 1.3 billion consumers, China is uniquely positioned to excel at customer-focused innovation. This large and dynamic consumer market gives innovators a huge supply of problems to solve and needs to fill, as well as a means of commercializing new ideas rapidly. Another advantage: Chinese consumers are willing participants in market testing and commercialization—happy to accept new products that are not completely refined and eager to share feedback to make them better. This is making China a hotbed of innovation for an expanding universe of Internet services and products ranging from air conditioners to smartphones.

Many of China's greatest innovation successes have come in consumer-facing industries: Chinese suppliers now account for 36 percent of global revenue in appliances and have 15 percent of revenue in Internet software, and 14 percent in Internet retailing—grabbing more than their GDP-based share in three out of seven customer-focused industries we analyze. Innovators are succeeding by addressing the diverse needs of China's rapidly evolving markets. Chinese innovators are moving from the “good enough” offerings that fit the needs of newly urbanized consumers to more sophisticated products that match the quality and features of global brands (but still sell for less). A rising cadre of entrepreneurs has built Internet-based businesses to fill unmet needs in retailing and other services. As these Chinese innovators have addressed a range of customer needs, they have created distinctively Chinese business models.

In the coming decade, customer-focused innovation can play an important part in raising Chinese productivity and supporting GDP growth by expanding the service sector and improving its performance. We estimate that growth and productivity improvements in service industries could generate \$550 billion to \$1.4 trillion of value per year to the Chinese economy in 2025. We also identify two additional opportunities for customer-focused innovation: Chinese companies can apply the skills they developed in serving China's consumers—identifying local needs and preferences and quickly introducing new products at competitive prices—to serve consumers in emerging markets. And in some consumer categories, Chinese companies can also become strong brand players that can compete with global brands.

To realize the full potential for customer-focused innovation, Chinese companies will need to invest in new capabilities and work harder to keep up with the rising demands of consumers in the next decade. While consumer-facing companies have built strong momentum in the past 20 years, they have done so under extremely favorable circumstances. First-time consumers were hungry for all kinds of products and services. In many industries, Chinese players have had little exposure to global competition at home—top global players in some Internet businesses are largely absent from China, for example. In only a few industries, such as appliances, have Chinese companies yet ventured abroad. At the same time, the growing sophistication of Chinese consumers is starting to strain existing capabilities, putting increasing pressure on both local companies and multinationals to improve the way they innovate for the China market.

THE POWER OF THE CHINESE MARKET

The scale and dynamism of the Chinese consumer market provides a powerful advantage for Chinese innovators. Since 2000, more than 100 million Chinese households have joined the mainstream consuming class (defined as households with disposable income of 103,000 RMB to 222,000 RMB, or \$16,000 to \$34,000). Each year, tens of millions of new households that need appliances and consumer electronics products are appearing in China's cities.¹⁵ Disposable income has risen by 10 percent per year in real terms over the past decade, and the number of households in the mainstream consuming class is expected to reach 200 million by 2025, according to MGI estimates.

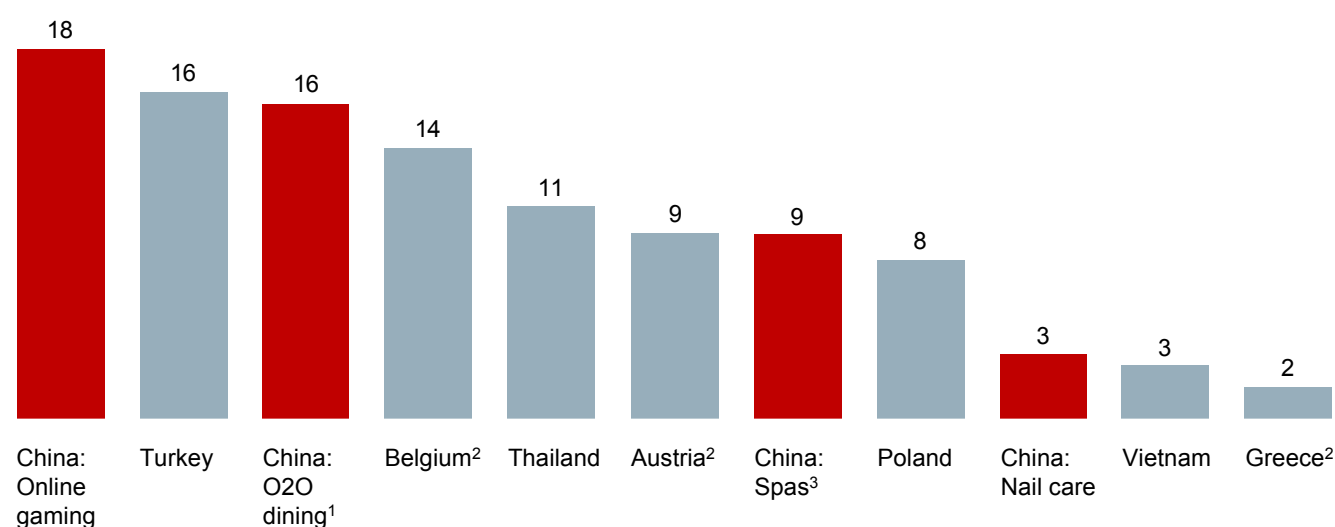
The Chinese consumer market is so large that in many segments domestic leaders are, by definition, global market leaders—without even having to venture into overseas sales. Only in consumer electronics and household appliances do Chinese companies capture more than 10 percent of global exports. And a niche market in China—online gaming or nail care, for example—is larger than major industries such as auto manufacturing in other nations (Exhibit 12). The scale advantage applies to customer-focused innovation in B2B markets, too. China had more than 40 million registered small and medium-sized companies by the end of 2014, employing over 500 million people.¹⁶ They are mass consumers of supplies and components and big users of services such as payment systems and logistics. Some ten million companies use the Alibaba platform to run online stores.

Exhibit 12

A niche in China can be larger than a major industry in another economy

Niche markets in China vs. passenger vehicle markets in other economies, 2014

\$ billion



¹ Offline-to-online services that deliver food for consumers who order online.

² Market size is estimated using 2014 volume multiplied by 2013 average selling price.

³ Including spa treatments (facial and body) and product sales through spa channel.

SOURCE: 2014 China Gaming Industry Report; International Organization of Motor Vehicle Manufacturers; iResearch; Turkish Statistics Institute; International Council on Clean Transportation Pocketbook 2014; McKinsey Global Institute analysis

¹⁵ 2011 annual Chinese consumer study: The new frontiers of growth, McKinsey China, March 2011.

¹⁶ Climate index report of Chinese SMEs, Zhejiang University, 2014.

CUSTOMER-FOCUSED INNOVATION IS SOLVING DIVERSE PROBLEMS IN CHINA TODAY

Over the past three decades, Chinese companies have learned to adapt products from around the world to the needs of a rapidly urbanizing nation. They have learned to be very agile—moving goods into production quickly, then tweaking designs afterward to better address consumer needs. The first wave of Chinese innovators to address the unique needs of Chinese consumers were makers of goods such as home appliances, television sets, mobile phones, and personal computers. Innovation meant creating designs that were “good enough”—very low cost, with adequate functionality. Now innovators are addressing the rising expectations of an increasingly affluent Chinese population. Another group of innovators, including Alibaba, has focused on unmet needs in Chinese retailing, where a highly fragmented brick and mortar retail sector offered limited choices in all but the largest cities.

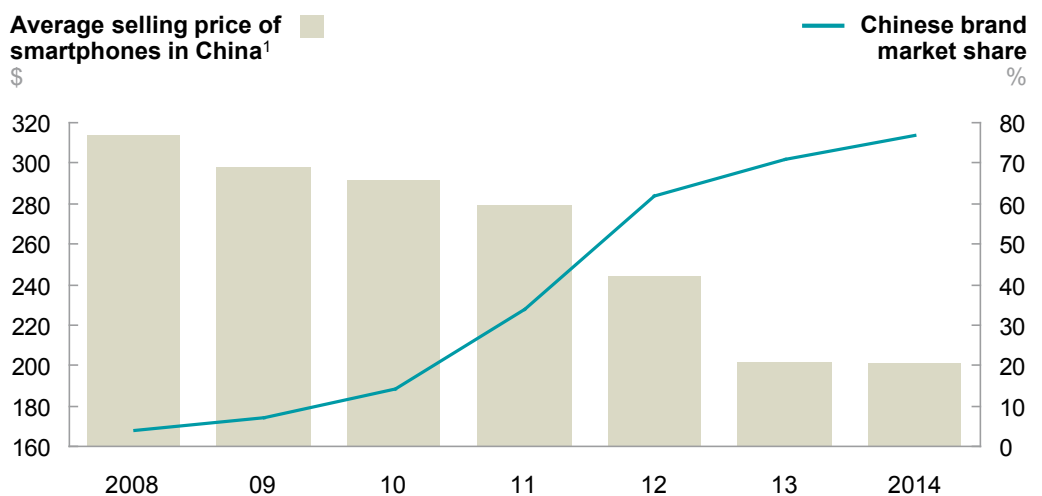
Meeting rising customer expectations: Moving beyond “good enough”

For many Chinese consumers today, the “good enough” products that were designed for consumers buying their first appliances or consumer electronics gear are no longer good enough. Companies such as Midea and Haier used the “good enough” formula (products that sold for a fraction of what global brands charged and delivered about 80 percent of the functionality) in China and then took it to export markets (Brazil, India, Indonesia, and Vietnam are among the largest), raising their combined share of global appliance sales from 5.5 percent in 2005 to 15 percent today, according to Euromonitor. In China, “good enough” products still work for lower-income consumers, but a growing segment of more affluent Chinese consumers demand products that are “cheaper and better.”

The market share gains of Chinese players in the domestic smartphone market are evidence of the appeal of “cheaper and better” innovation (Exhibit 13). Xiaomi, for example, now sells smartphones that are priced for the Chinese market but include hardware features that are intended to meet or exceed the quality of components used in phones sold by some foreign companies. As a result, in just four years, Xiaomi has become the largest smartphone player (by shipments) in China with more than a 12 percent share. It is now entering foreign markets.

Exhibit 13

“Cheaper and better” innovation is helping Chinese brands gain share in smartphones



1 Real value, using 2013 constant prices.

SOURCE: International Data Corporation; Euromonitor; McKinsey Global Institute analysis

A critical part of Xiaomi’s innovation process is keeping in close touch with consumers on social media and through direct online polling to determine what innovations they would like. With this input, the company has released new versions of its operating system weekly since 2010. Xiaomi became one of the world’s most valuable startups when it raised more than \$1 billion in December 2014, giving it a valuation of \$46 billion.¹⁷ In order to build a long-term customer base, Xiaomi promoted its products on a wide range of online forums and eventually amassed more than ten million active “Mi fans” on Weibo, a microblogging platform.¹⁸ Since 2012 the Mi fans have attended more than 60 promotional events in over 30 cities and areas based on the fan platform named “Mipop.”

Lenovo, the largest PC maker in the world, is another example of how Chinese innovators are moving from “good enough” to “cheaper and better.” Lenovo’s Yoga line combines tablet and PC functionality in a laptop design. The Yoga PC, an ultralight laptop, is one of Lenovo’s early forays into the mid-high-end segment. In 2014, Lenovo shipped 1.9 million hybrid ultralight laptops globally, capturing 25 percent of the market, up from 11 percent in 2013. In 2015, PC Magazine rated the ThinkPad Yoga 12 highest in its category for its price to performance ratio for business users. Lenovo, which acquired IBM’s PC division in 2005 and has retained IBM researchers, spends an estimated \$1.2 billion per year on R&D—about 3 percent of sales—and employs 5,000 product developers globally.¹⁹

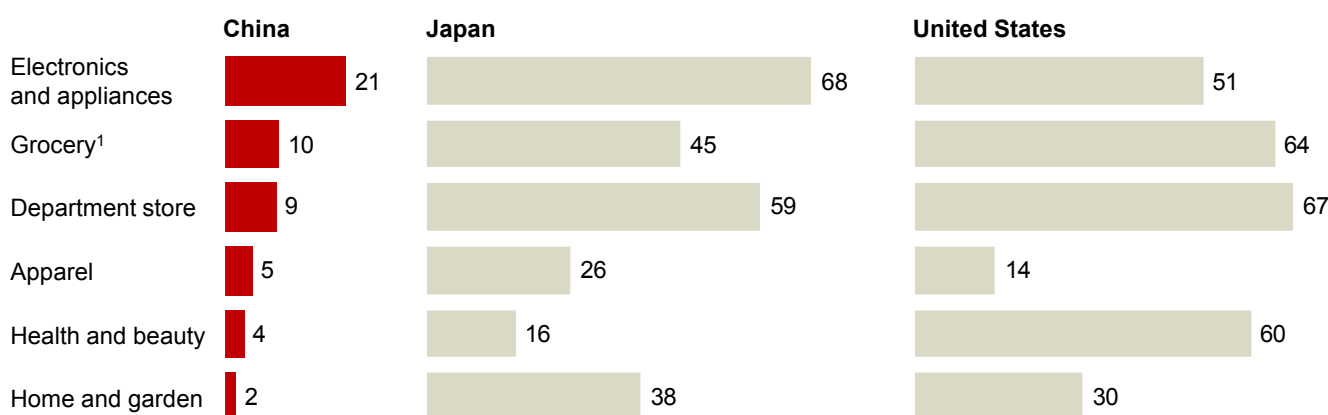
Using e-commerce to deliver choices that were unavailable from a fragmented retail industry

One of the biggest challenges facing Chinese consumers is the nation’s highly fragmented retail industry, which severely limits choice for consumers who do not live in the largest cities. Across major retail categories, the Chinese industry is far less concentrated than in other economies, which means that consumers in many places have access only to local stores that typically carry a more limited variety of merchandise than large chains (Exhibit 14).

Exhibit 14

China’s retail industry is still relatively fragmented

2014 market share of top five retailers by category
%



¹ Includes convenience stores, supermarkets, and discount store grocery departments in the United States.

SOURCE: Euromonitor; McKinsey Global Institute analysis

¹⁷ Scott Austin, Chris Canipe, and Sarah Slobin, “The billion-dollar startup club,” *The Wall Street Journal*, February 18, 2015.

¹⁸ Eva Dou, “Xiaomi: The secret to the world’s most valuable startup,” *The Wall Street Journal*, April 6, 2015.

¹⁹ Lenovo 2015 annual report.

As they addressed the gaps in Chinese retailing, Chinese entrepreneurs built a world-leading e-commerce industry.²⁰ From its start in 1999, Alibaba has grown into the world's largest online marketplace, with a 2014 gross merchandise value of \$394 billion. Alibaba's innovations include Alipay, an escrow-based payment system. Alipay was initially promoted as the payment platform for the Taobao shopping site, allowing customers to keep their money in Alipay until confirming the receipt of goods from sellers and guaranteeing refunds to customers who lost money in insecure transactions. Today, Alipay has 400 million users.²¹

THE UNIQUE REQUIREMENTS OF CHINESE MARKETS HAVE INSPIRED INNOVATIVE BUSINESS MODELS

An entire body of innovation in China's consumer-facing industries has involved the creation of uniquely Chinese business models, including ways to monetize online businesses such as social media and games. Tencent, China's leading Internet service, has developed a wide range of revenue streams to monetize traffic to its sites. It developed these different streams in part because advertising is a much smaller industry in China than in places such as the United States, so depending heavily on ads, as US companies such as Facebook and Google do, was not a viable option.

Tencent generates 90 percent of its revenue from non-advertising sources such as sales of virtual items to gamers on social platforms, e-commerce, and online payments. Facebook, by contrast, derives 93 percent of revenue from advertising; its revenue per user was \$9 in 2014, compared with \$16 per user for Tencent (Exhibit 15). Similarly, YY.com, a video-based Chinese social communication platform, also has several revenue streams, including a virtual currency. In 2014, YY generated 57 percent of its revenue through sales of virtual goods that viewers on entertainment and music sites purchase to give to performers they like. Top performers on YY can earn more than 20,000 RMB (\$3,300) a month, seven times what the average factory worker earns.²²

In many areas, Chinese online services have become leaders in business model innovation. WeChat, a social media platform, has added e-commerce, allowing users to shop for everything from stickers and games to groceries. WeChat members can also book taxis and flights. WeChat added mobile payments in 2013. Facebook announced plans for an online payments system in March 2015.²³ WeChat allowed subscribers to set up online stores in 2014; in July 2015, Facebook announced a test of a new feature to allow retailers to sell from their Facebook pages.²⁴ Chinese taxi hailing apps were established in 2012 and appeared on social platforms in 2014; Kakao Talk, a South Korean messaging platform, introduced Kakao Taxi on its platform in March 2015.²⁵

²⁰ For further details, see *China's e-tail revolution: Online shopping as a catalyst for growth*, McKinsey Global Institute, March 2013.

²¹ Shai Oster, "A hundred apps bloom in China as millions bank on their phones," *Bloomberg Markets*, August 19, 2015.

²² Tomio Geron, "YY.com; China's unique real-time voice and video service with a virtual goods twist," *Forbes*, June 11, 2012.

²³ Vindu Goel, "Facebook announces a payments feature for its Messenger app," *The New York Times*, March 17, 2015.

²⁴ Karissa Bell, "Facebook will let you buy products from retailers' pages," *Mashable.com*, July 16, 2015.

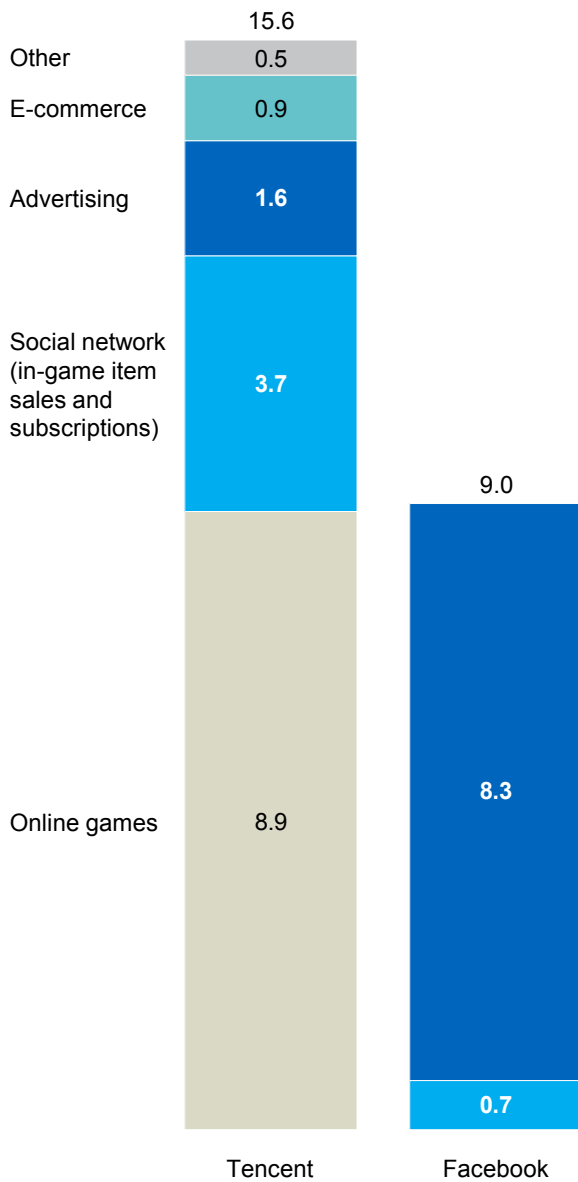
²⁵ Catherine Shu, "Daum Kakao debuts Uber rival Kakao Taxi in South Korea," *TechCrunch*, March 30, 2015.

Exhibit 15

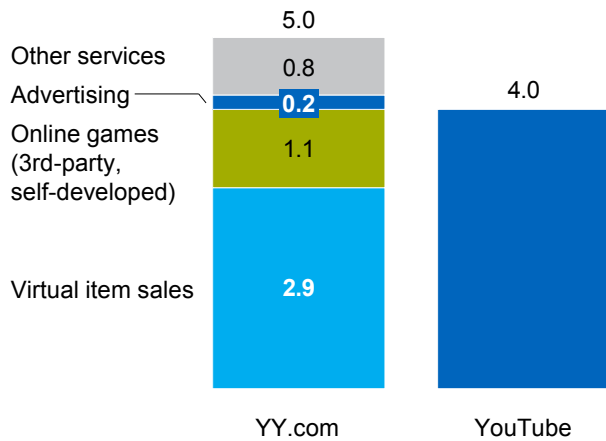
Chinese companies have developed innovative ways to monetize Internet traffic, which generate higher revenue per user

Breakdown of revenue per user, 2014¹
\$

Social network/gaming



Internet video



¹ User numbers based on monthly active users.
NOTE: Numbers may not sum due to rounding.

SOURCE: Company annual reports; McKinsey Global Institute analysis

WHAT'S NEXT FOR CUSTOMER-FOCUSED INNOVATION

The next decade will bring fresh opportunities for customer-focused innovation in China. Increasingly, innovation will be focused on Internet-based businesses and the use of Internet technologies to extend access to services such as health care and improve the performance of service businesses. The digital revolution will continue to sweep China, creating new businesses and transforming existing businesses as they “digitize.”

Here we look at three opportunities for customer-focused innovation in the next ten years: expanding and improving the performance of China’s service sector; helping Chinese companies lead in the competition for emerging-market customers; and enabling Chinese players in select market segments to build globally competitive brands.

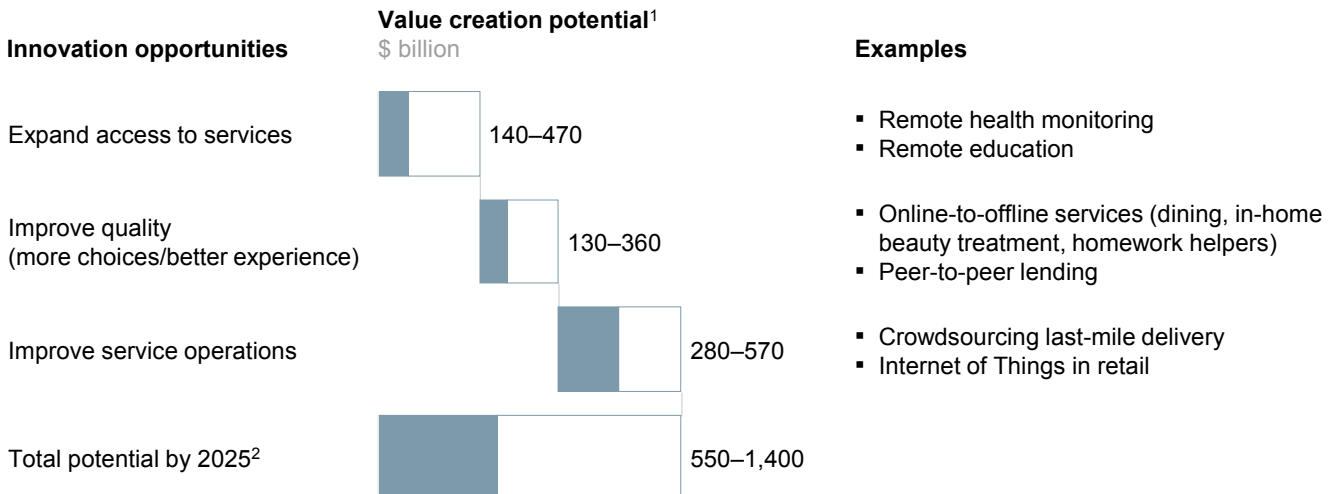
Expanding the service sector and improving service-sector productivity

Today China’s service industries are neither efficient nor globally competitive. In key Chinese service-sector industries, such as retailing, real estate and construction, health care, education, and transportation, productivity is just 15 to 30 percent of the average level in OECD economies.

Service-sector performance is held back by structural barriers that limit competition and by business models that limit productivity. China can expand the service sector by improving access to services, and improve quality and efficiency by using technology and proven best practices. We analyzed seven segments that represent 83 percent of service-sector value added in China: real estate and business activities (20 percent of service-sector GDP), wholesale and retail trade (20), transportation/storage/communications (16), financial intermediation (13), education (7), hotels/restaurants (4), and health and social services (3). We estimate that these measures could generate value of \$550 billion to \$1.4 trillion per year in 2025 (Exhibit 16). An expanded and better-performing service sector would have additional benefits for the Chinese economy—more efficient logistics for manufacturers, better choices and prices for consumers, and better access to vital services such as health care and education, for example.

Exhibit 16

Service-sector innovations can add value of \$550 billion to \$1.4 trillion per year by 2025



¹ May not be direct addition to GDP as some values can be passed to consumers as lower price or time saving.

² Scope includes retail and wholesale trading, transportation, health care, finance, hotels and restaurants, education, and real estate.

SOURCE: McKinsey Global Institute analysis

Tackling structural issues—such as reforming the hukou registration system, can enable better citizen mobility and improve access to education and health care. But these reforms could take many years. In the meantime, companies can raise productivity by digitizing business processes, and entrepreneurs can be counted on to introduce new services and business models (see Box 4, “A new generation of entrepreneurs”).

Box 4. A new generation of entrepreneurs

A new wave of entrepreneurs is emerging and starting to drive customer-focused innovation. Increasingly Chinese youth aspire to launch businesses: in 2013, 12 percent of Peking University graduates said they had launched a company or were self-employed, compared with 4 percent in 2005. In a 2015 survey of college students on Renren, a social networking service, 56 percent said they would be willing to become entrepreneurs while in college.

Another source of entrepreneurial talent is returning students who have studied overseas. More and more students are returning to China, and in the Zhongguancun technology hub near Beijing, an estimated 3,400 startups have been founded by some 8,000 returnees. Top Internet companies are another source. ITJuzi, a media company that covers new ventures, found that more than 400 of the 3,000 companies it follows were founded

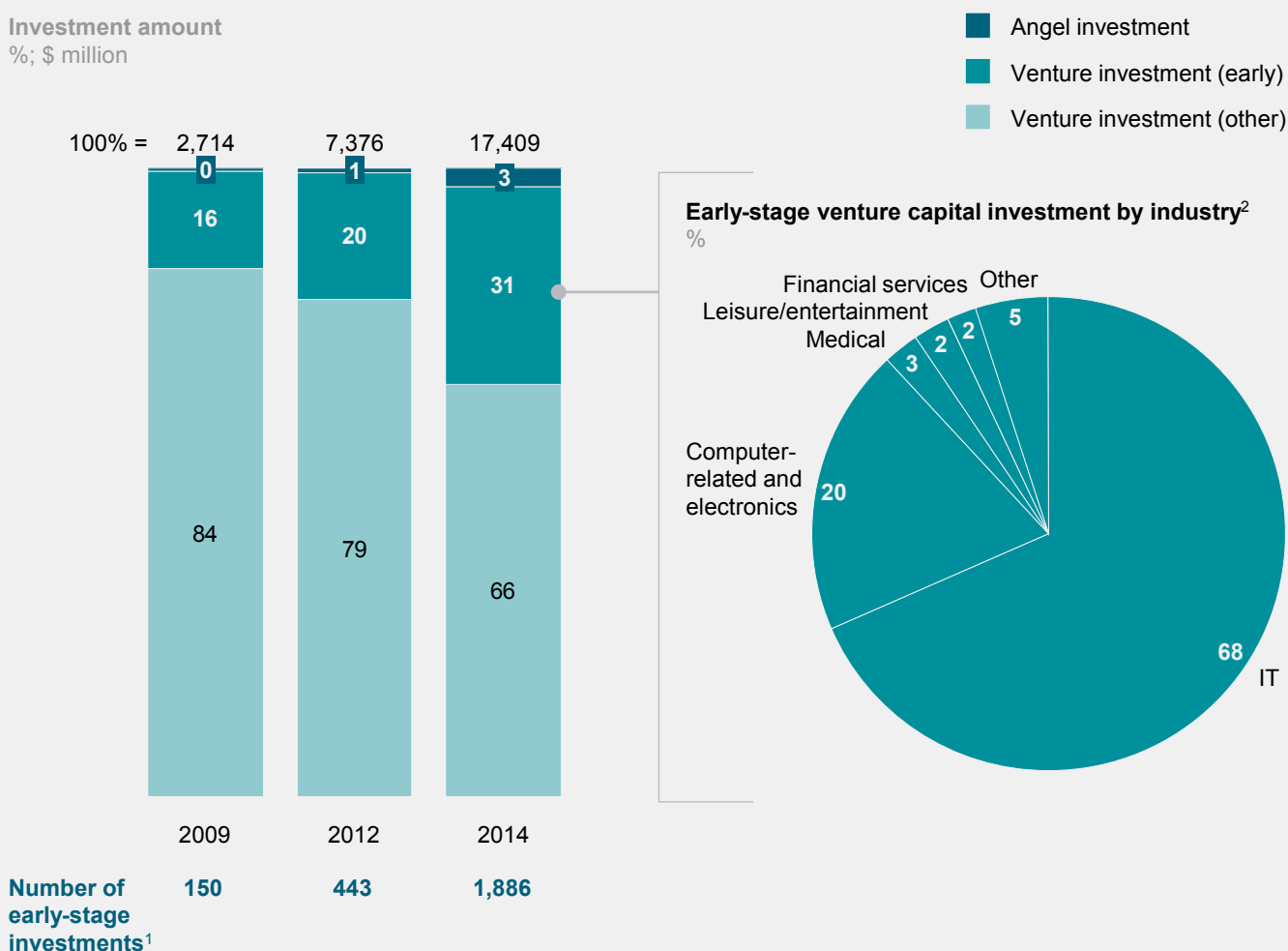
by ex-employees of Alibaba, Tencent, and Baidu. First-generation Internet entrepreneurs are also developing the next generation. Alibaba founder Jack Ma helped create a program to teach established entrepreneurs business skills, and Richard Li, founder of JD.com, another e-commerce player, has announced plans for a program at Zhongguancun College.

Finally, access to early-round funding has improved dramatically (Exhibit 17). Funding by angel investors and early-stage venture funds grew by a factor of 14 between 2009 and 2014, rising to about \$6 billion. Almost 70 percent of early-stage investment was in Internet- and IT-related businesses. Alibaba, Baidu, and Tencent have invested more than \$11 billion in approximately 100 ventures, looking for both investment returns and to fill strategic needs of their businesses.

Exhibit 17

Early-stage investing has risen 14-fold since 2009, dominated by computer and IT deals

Investment amount
%; \$ million



1 Including angel and early-stage investment.
2 Based on investment amount of disclosed deals.
NOTE: Numbers may not sum due to rounding.

Expanding access to services

One reason behind the slow development of some service industries in China is uneven distribution of resources across the country, limiting access for poorer consumers and residents in rural areas. Improving access to services can expand markets and, we estimate, could create value of as much as about \$150 billion to \$470 billion by 2025.

- **Expanding access to residential care services for the elderly.** Aging is the most powerful demographic force in the Chinese economy. About 25 percent of the Chinese population will be 65 or older in 2050 and even now there is a lack of appropriate housing and residential care facilities for aging and ailing Chinese. An estimated 37 million of the 200 million Chinese who are older than 60 have disabilities, and 100 million suffer from chronic conditions.²⁶ Half of this population lives alone, and the continuing migration of younger workers to cities will likely raise this ratio substantially. Current facilities for the old and infirm emphasize housing over providing services, which can discourage families from using such facilities. Technology and business model innovation can substantially improve service delivery in residential facilities and make them more popular. For example, with remote health monitoring and telemedicine connections, offsite physicians and caregivers can manage the care of the elderly and patients with chronic conditions. Other Internet of Things technology can be used to track residents for security and safety (detecting a fall, for example). Housing operators can also introduce community-building and rehabilitation services, which are common in Western assisted living complexes.
- **Expanding access to banking for SMEs.** China's small and medium-sized enterprises (SMEs) badly need better access to funding. These companies account for 97 percent of registered industrial companies, 65 percent of employment, and 60 percent of GDP. Yet, they received only 23 percent of bank loans in 2013 and just 4.7 percent of short-term loans, which are typically used as working capital.²⁷ Just 6.5 percent of short-term working-capital loans currently goes to SMEs. A World Bank survey of 2,700 private firms in China indicates that only 25 percent of them had bank credit and that 90 percent drew on other financing sources. As a result, business owners often turn to non-bank lenders, which can charge as much as 35 percent interest for a six-month loan. Innovative Chinese companies are beginning to fill the gap in SME funding. Most famously, Alibaba launched a microfinancing arm to help finance small vendors operating on its e-commerce platform. An Alibaba spinoff, Ant Financial, conducts credit risk assessment based on multiple types of data (volume of merchandise shipped, customer feedback, invoice consistency, for example) and makes small working capital loans to Alibaba merchants averaging 20,000 RMB to 40,000 RMB (\$3,300 to \$6,500). Ant's loan portfolio grew from 2 billion RMB (\$330 million) in 2010 to 400 billion RMB (\$65 billion) in mid-2015, serving more than 1.6 million entrepreneurs and SMEs.²⁸ Another innovation for small borrowers is peer-to-peer lending, which reached \$17 billion in China in 2014—the highest volume in any country.²⁹ Shanghai-based Dianrong.com, for example, provides loans to chauffeur services, sometimes using the car as collateral. The system allows the borrower to pay back at any time, and Dianrong can monitor in real time how much money the driver collects.

97%
of registered
industrial
companies
are SMEs

²⁶ Yuhua Wu and Junwu Dang, *China report of the development on aging cause*, Social Sciences Academic Press, 2013.

²⁷ See Kellee S. Tsai, *Financing small and medium enterprises in China: Recent trends and prospects beyond shadow banking*, HKUST Institute for Emerging Market Studies, Hong Kong University of Science and Technology.

²⁸ Jon Russell, "Alibaba affiliate Ant Financial confirms Series A funding at \$45–\$50B valuation," TechCrunch, July 3, 2015.

²⁹ *Debt and (not much) deleveraging*, McKinsey Global Institute, February 2015.

- Expanding access to education for poor and rural students.** While more Chinese students are completing college, access to higher education is more difficult for poor and rural students—82 percent of students in mid-tier vocational schools are from rural areas, for example. This is largely the result of school funding. In urban primary schools, per-pupil spending is 700 RMB (\$110) per year more than in rural schools. In secondary school, the gap is 900 RMB.³⁰ In urban areas, children of parents who are not registered under the hukou system have limited access to education. One way to improve access to high-quality education across the country is through remote online learning platforms. Yingwuluo, a Beijing-based education startup, offers online instruction via “Cloud Classrooms” in smaller cities. Teachers at the company’s education center in Beijing present online lessons to students in remote classrooms. Genshuixue, another online education platform, offers 69,000 classes, from piano to SAT prep.
- Expanding access to health care.** There are stark disparities in access to health care across China. Patients in rural areas may not have any health-care services nearby or may have concerns about the quality of care in local hospitals. This drives many rural Chinese to travel to major city hospitals for care that may not require a hospital visit. Every day, about 700,000 patients from other parts of China make their way to Beijing’s large hospitals; 70 percent could have received proper care in community health centers.³¹ Patients in rural areas or small cities also crowd small hospitals in larger cities, pushing occupancy rates to close to 100 percent, compared with 60 percent in township health clinics and community health centers, according to the National Health and Family Planning Commission.

Technology can help improve access to care in two ways—through telemedicine and through referral and scheduling platforms. Remote monitoring in village clinics using connected devices such as heart and blood glucose monitors can enable physicians in major cities to read patients’ vital signs and provide diagnoses and preventive treatment. Remote medicine shows particular promise for treating the estimated 250 million Chinese patients with chronic diseases. Another innovation can address big pain points for patients—not finding the right doctor and hours of waiting time. Companies such as Baidu, Spring Rain Doctor, and Weiyisheng (Guahao.com) let patients interact with doctors, find local referrals based on their symptoms, and schedule appointments with physicians via online platform. Baidu, the leading Chinese search engine service, launched the Doctor Baidu app, which recommends the best available physicians in the local area, based on the consumer’s description of symptoms. Within six months of its launch, Doctor Baidu expanded to six provinces, covering a total population of 340 million. With additional artificial intelligence programming, Baidu aims to turn Doctor Baidu into a “virtual family doctor,” filling additional unmet needs.

Improving quality of services with more choices and better customer experience

A series of innovations involve improving the quality of service, including by customizing offerings and by expanding customer choices, which can create potential value of about \$130 billion to \$360 billion.

- A wider range of financial services.** Even as Chinese households have become more affluent, they have been limited in their choices of financial service products. More than half of household savings still are held in traditional bank deposits. However, innovations such as digital banking channels are providing more choices. For example, Alibaba’s Yu’eobao (leftover treasure) has become the fourth-largest money market fund in the world. From its inception in June 2013 to March 2015, it pulled in \$115 billion

\$450B
Value of goods sold online in China in 2014

³⁰ Qiang Wang, “Rural students are being left behind in China,” *Nature*, volume 510, issue 7506, June 25, 2014.
³¹ Caizhou Yue, “RHIN: Hardship covered by rosy pictures,” *China Consumer News*, May 2014.

from 200 million savers.³² It offers innovative features such as online payments, a low minimum (1 RMB vs. 50,000 RMB) and instant redemptions. Baidu, Tencent, and Xiaomi, as well as traditional banks, now offer similar products. Another Internet-based financial services innovation is peer-to-peer (P2P) lending, which is growing rapidly in China. By the end of 2014, some 1,500 Chinese P2P lenders had made \$17 billion in loans, three times the volume in the United States.³³ Online insurance sales are also taking off, for both new players and traditional insurance companies. China's first online-only insurance company, ZhongAn, was founded by Alibaba, Tencent, and PingAn in 2013. It served 300 million customers in its first 24 months of operation, selling more than 100 online-only property and casualty products.³⁴

- **More choices and convenience in e-commerce.** Traditional stores (“offline” retail) have been challenged around the world by the rise of e-commerce, but nowhere more than in China, where online stores sold \$450 billion worth of goods in 2014, surpassing the \$300 billion sold by online stores in the United States.³⁵ The next big shift in retail will be mobile-commerce, which can dramatically change the way consumers shop (such as instant price comparison) and the way retailers can sell (such as location-based promotion offering). Both traditional stores that have had to find ways to coexist with online competitors and newly emerged e-commerce companies are also jumping into m-commerce—shopping via smartphone and other mobile devices. China is the largest smartphone market in the world, and close to 90 percent of new phones sold are smartphones. The penetration of mobile devices can expand the customer base for e-commerce services, including reaching consumers in rural markets. China has more than 230 million mobile-commerce users, and m-commerce sales grew from 12 billion RMB (\$2 billion) in 2011 to 828 billion RMB (\$135 billion) in 2014, now accounting for almost one-third of the e-commerce market.³⁶

Chinese consumers could see an enormous expansion of choices through cross-border e-commerce. Cross-border purchases (from suppliers outside of China) by online shoppers grew from less than \$2 billion in 2010 to more than \$20 billion in 2014, with US online shops the destination of choice for top-selling merchandise such as clothing, personal care products, and baby goods.³⁷ Current complexities in cross-border trading (tariffs, logistics) can triple the cost of imported items, which has created a gray market, particularly for goods such as infant formula, where imports are in high demand because of concerns over domestic supplies. Cross-border e-commerce can also provide an entrée for foreign retailers. In 2014, Costco entered China via Alibaba's Tmall global platform, instead of investing heavily in opening physical stores. The Chinese government is looking for ways to make cross-border e-commerce more efficient: in October 2013, China's Customs Department established special cross-border e-commerce zones in seven cities.

- **Homework helpers.** Chinese families are very eager for their children to succeed in school, and new services are cropping up to meet this need. 17zuoye (the name translates to “homework together”) is an online study platform for K–12 students that allows teachers, parents, and students to do homework together. Teachers upload the homework for students. Classmates using the service can discuss assignments online as well. Once students submit their work, it is corrected by the system, which can offer suggestions for additional work to improve specific skills and knowledge. Some 39,000

³² “Alibaba arm eyes more capital to build China finance empire,” Bloomberg, July 3, 2015.

³³ Dinny McMahon, “Peer-to-peer lending takes off in China,” *The Wall Street Journal*, June 3, 2015.

³⁴ May Knight, “Insurance companies must plug in to new age,” *China Daily*, March 27, 2015.

³⁵ *2014 Internet economy report*, iResearch, March 2015.

³⁶ *36th statistical report on Internet development in China*, China Internet Network Information Center, July 2015.

³⁷ Spencer Soper and Lulu Yilun Chen, “China shops Alibaba for US goods from toothbrushes to nuts,” Bloomberg, April 21, 2015.

primary schools have signed up for the system, which has been used by an estimated 12 million students since 2011. Other companies are offering a range of Internet-based education services. XSTeach provides IT courses; Jikexueyuan offers application and software development training; and Guokr.com offers science courses.

- **On demand in-home services.** A growing number of businesses offer online-to-offline (O2O) services using Internet platforms to connect consumers with offline services. Given China's massive consumer market and dense urban populations, companies can easily achieve economies of scale in businesses such as providing beauty services, cooking, house cleaning, massage, and security guards. Meidaojia.com, for example, provides a mobile app that lets consumers book a makeup artist for a home visit. The consumers can check out makeup styles they like and find a stylist who does that type of work, review the artist's previous work, and make an appointment. Helijia, which provides another platform for booking beauty specialists, claims to handle 7,000 transactions a day and was valued at more than \$300 million as of January 2015.³⁸
- **Improved experience for hotel guests.** Hotels can use data analytics to offer customized service, shape customer experience, and build loyalty. For example, technology can enable a seamless experience from check-in to checkout. Using a self-service kiosk, a guest can check in using a smartphone, which then becomes the guest's room key and controller for lights, air conditioning, and in-room entertainment. An app on the phone tracks all charges and automatically checks the guest out at the end of the stay. With data from previous visits, the system can suggest movies to view or upsell special room service offerings.

Improving service business efficiency

Chinese companies in the service sector can raise productivity through process innovations and by adopting the latest technologies, which can create potential value of about \$280 billion to \$570 billion.

- **Optimizing logistics.** China has built a modern transportation infrastructure, but its logistics industry remains inefficient. The ratio of logistics cost to GDP, one way to measure logistics efficiency, was about 18 percent in China in 2013, compared with 7 percent in the United States. The Chinese government aims to reduce the ratio to 16 percent by 2020. One issue is fragmentation: China has an estimated 700,000-plus road transport companies and the top 20 firms have only about a 2 percent market share.³⁹ Not only is the logistics industry more concentrated in the United States—providing scale advantages—but larger players have made investments in technology to optimize operations. United Parcel Service, the large US logistics operator, uses a computer algorithm to optimize schedules for 55,000 delivery routes and claims to save \$300 million to \$400 million per year through improved productivity.⁴⁰ In China, one new technology-based innovation in logistics has emerged: crowdsourcing last-mile delivery. Similar to the way in which Uber crowdsources drivers, Dada Logistics, based in Jiangsu, has enlisted 100,000 part-time delivery workers in 30 cities to complete 600,000 deliveries per day.⁴¹ Renren Kuaidi, another startup, offers courier options—by bike, by car, or on foot. Beequick promises one-hour delivery of grocery orders from convenience stores.

³⁸ "Helijia: Reasons why daily order exceeding 7,000," Sohu IT, January 16, 2015.

³⁹ *Logistics industry in China*, Fung Business Intelligence Centre, August 2013.

⁴⁰ Steven Rosenbush and Laura Stevens, "At UPS, the algorithm is the driver," *The Wall Street Journal*, February 16, 2015.

⁴¹ Frank Tong, "A service that lets freelancers make e-retail deliveries in China raises \$100 million," *Internet Retailer*, June 25, 2015.

- **Increasing utilization of hotels and restaurants.** China's hotel industry is facing occupancy challenges. Over the past three years, 56 percent of new hotels in Asia were built in China, producing a huge supply of rooms. As a result, the average hotel vacancy rate in Chinese hotels that have a government star rating was about 46 percent in 2014, up from 39 percent in 2009. This compares with 15 to 20 percent hotel vacancy rates in Germany, India, and Japan. The situation is even more challenging in smaller cities. In the relatively undeveloped west and northeast of China, vacancy rates were as high as 65 to 75 percent in 2013.⁴² Hotel operators can raise occupancy rates by trying new approaches. One way is offering unsold rooms at a discount as "last-minute deals" via smartphones, as Hotelvp and eLong are experimenting with. Chinese restaurants can raise productivity by augmenting sit-down service with O2O delivery, which requires minimal investment. According to Dianping.com, China's online restaurant review site, more than one million restaurants are registered in the top 15 cities, most of which are local and small scale and can benefit from the O2O model. O2O delivery grew by 133 percent between 2012 and 2014, while the overall restaurant business grew by 20 percent; the number of O2O users doubled from 80 million to 158 million.⁴³ Leading Internet players have invested in O2O companies (Alibaba in Meituan, Baidu in Nuomi, and Tencent in Ele.me), providing additional momentum.
- **Revitalizing shopping malls.** Around the world, the rise of online retailing has hurt the shopping mall industry. Innovative mall owners are attempting to recast their properties as destinations for entertainment and recreation and to connect online and offline shopping. Wanda Group, a commercial property developer, has teamed up with Tencent and Baidu in an \$814 million venture that will bring online-to-offline shopping to Wanda's 83 malls. The three companies also plan to collaborate on payment systems and big data projects.⁴⁴

Customer-focused innovation could also help China improve the quality and efficiency of public services. Chinese government services rate poorly in global rankings. In the World Economic Forum's 2013 competitiveness report, China ranked 120th for ease of paying taxes. In 2014, it ranked 47th for ease of settling legal disputes. Simple government services, such as transferring the title of a used car, issuing a passport, or renewing a driver's license, often require a lengthy, in-person process.

Chinese companies are uniquely positioned to capture emerging market growth because of their strengths in customer-focused innovation. Indeed, Chinese companies have already demonstrated their ability to sell everything from refrigerators to smartphones in emerging markets.

⁴² National hotel management statistics, Meadin.com, 2013.

⁴³ *China online ordering research report*, iMedia research group.

⁴⁴ Laurie Burkitt, "China's Dalian Wanda Group plans e-commerce venture with Tencent, Baidu," *The Wall Street Journal*, August 27, 2014.

CUSTOMER-FOCUSED INNOVATION CAN MAKE CHINESE COMPANIES CHAMPIONS IN EMERGING MARKETS

The global economy's center of gravity is shifting toward emerging markets, where MGI estimates 72 percent of all GDP growth and 66 percent of consumption growth will occur between 2012 and 2025. Chinese companies are uniquely positioned to capture emerging-market growth because of their strengths in customer-focused innovation. Indeed, Chinese companies have already demonstrated their ability to sell everything from refrigerators to smartphones in emerging markets, while companies from the United States and Europe continue to struggle for a foothold. Serving low-income populations and emerging middle-class consumers in China has taught Chinese companies how to interpret the needs of emerging-market consumers. Chinese companies not only know how to design and price products for these consumers, but also know how to sell to them.

Opportunities and challenges in serving emerging markets

According to MGI estimates, by 2025 emerging markets will account for \$30 trillion per year in consumption, nearly half the global total. That compares with \$12 trillion in 2010, or about 32 percent of global consumption.⁴⁵ This growth reflects continuing urbanization and economic development in economies in Asia, Latin America, and Africa, which is expected to bring 340 million more households into the global consuming class by 2025, 85 percent of the world's total growth. More than 600 million new middle-class consumers in 440 developing-economy cities could generate close to half of global GDP growth between 2010 and 2025.⁴⁶ These consumers will have rising demand for everything from apparel to appliances to consumer electronics—but only for the right price: the average price of a smartphone in a market such as India is just under \$140, compared with almost \$500 in the United States, according to IDC.

To succeed in emerging markets, companies need to address cost issues, local preferences, different shopping behavior, and poor distribution and service infrastructure. In many developing economies, consumers prefer basic products that have been designed to meet their price points over the most popular products of global suppliers. For instance, consumers in rural India prefer simple-to-use and durable refrigerators made by domestic makers to more expensive foreign models, which are sold around the world and cost two to three times as much. Marketing and sales also must be tailored. Consumers tend to rely on word-of-mouth recommendations, and distribution channels are highly fragmented, so getting products to consumers and providing service and support is far more challenging. Finally, there may be little or no access to consumer finance.

Applying the Chinese innovation advantage to emerging markets

In serving the Chinese market over the past 30 years, companies have learned how to optimize cost and features to come up with “good enough” designs and rapidly iterate new designs based on market feedback. Chinese companies also have learned how to build and manage distribution networks that work with fragmented retail industries, another key advantage. This has helped China increase its share of emerging-market exports in categories such as appliances and consumer electronics (Exhibit 18). Midea has almost 35 percent of the air conditioner market in Brazil, for example, and Huawei makes more than half of the smartphones sold in Myanmar.⁴⁷

⁴⁵ *Winning the \$30 trillion decathlon: Going for gold in emerging markets*, McKinsey Global Institute, August 2012.

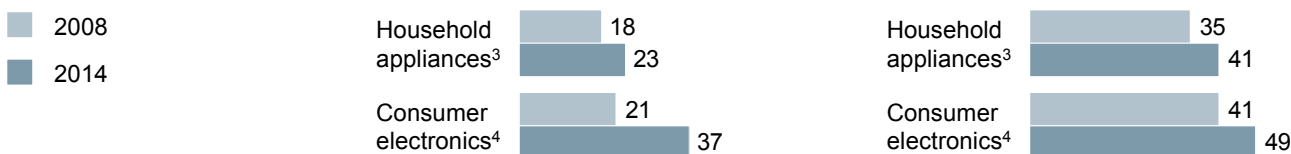
⁴⁶ *Urban world: Cities and the rise of consuming class*, McKinsey Global Institute, June 2012.

⁴⁷ Pengli Chen, “China's air-conditioners in Brazil,” *National Business Daily*, May 20, 2015; “Huawei P8 sold out in Myanmar in 1 hour, breaking the local sales record,” Tech.Huanqiu.com, June 10, 2015.

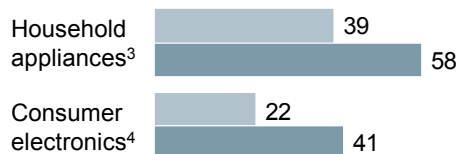
Exhibit 18

China's share of exports in emerging markets is rising

China's share of global exports in selected industries¹
%



Latin America



Middle East and Africa



1 Exports to top 5–7 countries ranked by 2014 GDP in each region. China exports data includes exports by both domestic and foreign-based companies manufacturing in China.
 2 Excluding developed Asia (such as Japan, South Korea, and Taiwan) and the Middle East.
 3 Refrigerator, air conditioner, and laundry machine subsectors were used.
 4 Smartphone, computer, television, and speakers.

SOURCE: IHS World Industry Service database; McKinsey Global Institute analysis

The record of Midea, Xiaomi, and OnePlus demonstrates the progress that Chinese companies have made in emerging markets. While these companies have room for improvement, particularly in marketing and branding, they offer lessons for other Chinese companies that also hope to succeed in emerging markets.

- **Midea**, the largest home appliances producer in China, has expanded aggressively abroad, and overseas sales accounted for 38 percent of 2014 revenue. Its biggest export markets are Argentina, Brazil, India, and Indonesia. It has built factories and research centers in India, Brazil, Russia, and Vietnam. In Brazil, Midea realized that local customers wanted air conditioners that are highly efficient and unobtrusive; more than

they wanted attractive grilles. So Midea developed all-in-one and energy-efficient air conditioners that are thinner than other air conditioners and become “invisible.”

- **Xiaomi** has made emerging markets its top priority outside of China. Xiaomi’s low-cost products and marketing strategy work very well in emerging markets. Its Mi4i, a lower-cost version of the Chinese Mi4 smartphone, was designed specifically for the Indian market. By replacing the 2.5 GHz processor with a cheaper, 1.7 GHz processor, Xiaomi was able to reduce the price by \$80, or about 40 percent to fit the needs of the local market.⁴⁸ In order to better serve the Indian market, the company has announced plans to build an R&D center, a manufacturing facility, a data center, and a technical support center in India. These centers will help to develop Xiaomi phones for Indian users for additional product release. For its online retail strategy in India, Xiaomi has adopted flash sales and limited pre-sales of new item. These are elements of the “hunger” marketing strategy that Xiaomi has used to build excitement for new models in China. Xiaomi says it plans similar strategies for Brazil and Russia.
- **OnePlus**, a two-year-old Shenzhen-based smartphone startup, has made emerging markets its primary focus. The company launched its first model in April 2014 and sold 1.5 million units. By the first quarter of 2015, more than 90 percent of sales were coming from outside China.⁴⁹ OnePlus adopted a “cheaper and better” approach and relied on the resources of Shenzhen’s manufacturing ecosystem to build phones that retail for around \$300 but are intended to match the features and design of phones from leading global brands often priced at \$400 to \$600. Creative marketing tactics such as “invitation only” product launches via social media have helped build buzz.

CHINESE COMPANIES CAN BE BRAND PLAYERS IN HOUSEHOLD PRODUCTS

Today, Chinese companies have less than their GDP-based share of global sales in consumer goods such as packaged foods and personal care products—about 6 percent in 2014, or half of what they should have, based on China’s share of global GDP. We found that foreign brands have more than a 70 percent share in eight of ten major categories: cosmetics, chocolate, chewing gum, shampoo, diapers, bath and shower goods, toothpaste, and milk formula. In these categories foreign players have built enormous brand equity through years of advertising and marketing efforts (Exhibit 19).

Chinese players came late to the competition in branded consumer products, but they are now positioned to gradually increase market share in the domestic market if they can strengthen brands and raise product quality. Close to 40 percent of Chinese consumers in a McKinsey survey said that they are willing to buy products that give them an emotional benefit. The survey also found that an increasing number of Chinese consumers are willing to try new brands in fast-moving consumer goods (food and beverages, personal care), where global brands have long dominated.

These attitudes provide an opening for Chinese players to challenge global brands, but Chinese companies will need to make substantial investments to succeed. Today, Chinese brands in household goods spend about 2 percent of sales on advertising, compared with 9 percent for major global brands. Also, most Chinese companies have not adopted the systematic marketing approaches or developed the sophisticated tools that global companies use to gather customers. At the same time, Chinese companies have a chance to leapfrog to the latest brand-building strategies—relying more on online and social media than on traditional broadcast and print media. In China, advertising sales in traditional media (TV and print) have declined from 58 percent of total advertising spending in 2012

⁴⁸ Malavika Velayanikal, “Xiaomi launches cheaper, thinner, more colorful Mi 4i in India,” TechinAsia.com, April 23, 2015.

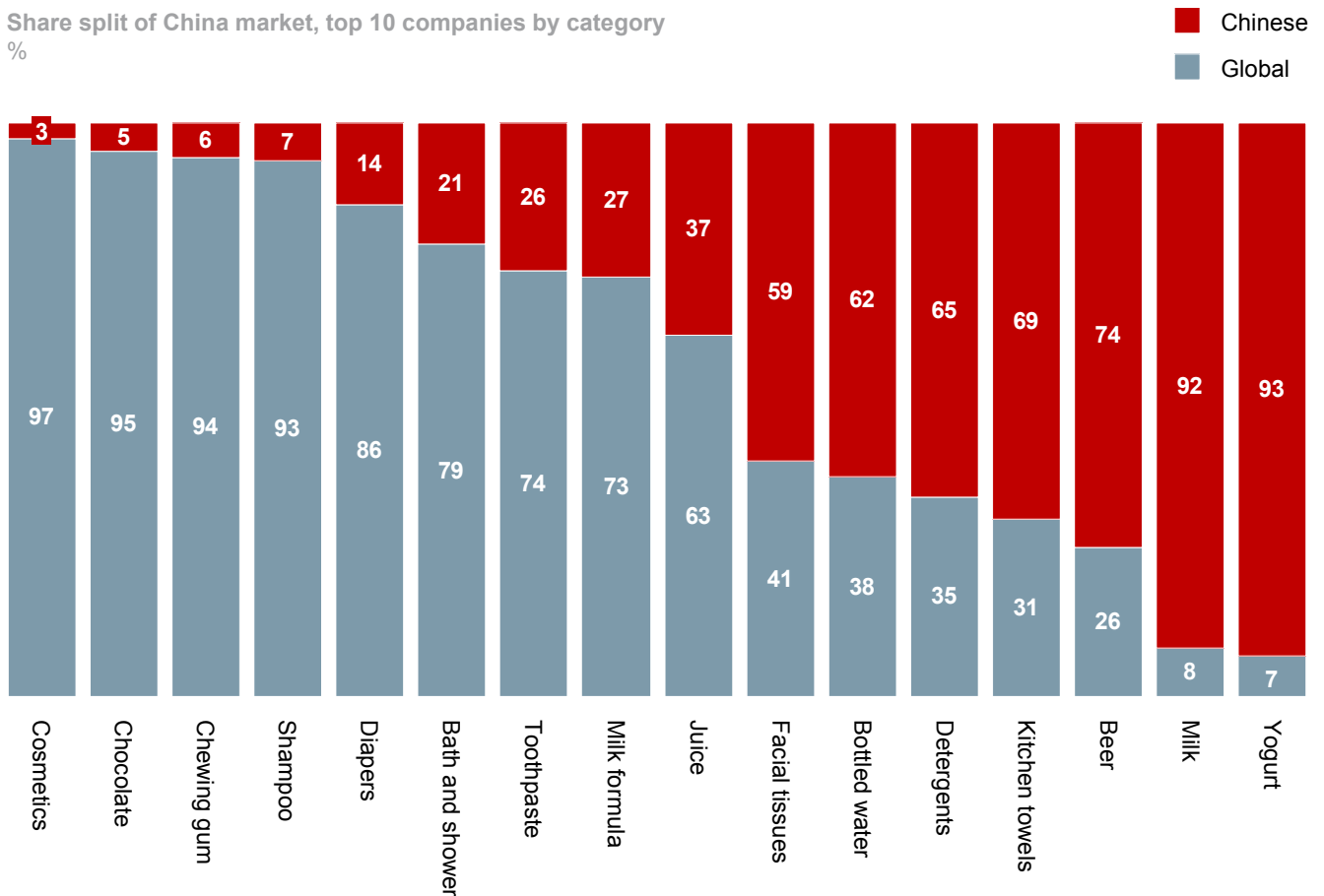
⁴⁹ “After making it big globally, OnePlus turns its gaze to China,” Forbes.com, June 24, 2015.

to 49 percent in 2014, while new media buys over the same period are up from 31 percent of spending to 41 percent. According to a 2015 McKinsey survey, close to 80 percent of Internet users spend more than two hours online a day and 70 percent use social media, where they share product tips. According to WeChat, a social messaging platform, 15 percent of its users recommend brands and vendors to others.⁵⁰

Exhibit 19

Today, multinational brands dominate many consumer goods categories in China

Share split of China market, top 10 companies by category
%



SOURCE: Euromonitor; McKinsey Global Institute analysis

A range of Chinese consumer products companies have already started to build stronger brands. They are innovating in product design and marketing and are gaining share, particularly in high-end categories. Here we consider two examples.

70%
Share of Internet users in China who use social media

- Yunnan Baiyao** is an established over-the-counter drug company whose line of bandages and other injury treatment products is well known throughout China. The company's strategy is to leverage its existing brand equity in new categories, such as toothpaste. Building on its know-how in Chinese medicine, Yunnan Baiyao introduced a toothpaste with herbal features and priced it at 18 RMB to 28 RMB (around \$3) per tube compared with 3 RMB to 8 RMB for other local products. In 2005, the first year the toothpaste was on the market nationally, sales were 80 million RMB (\$13 million); they reached 2.2 billion RMB (\$360 million) in 2013. Shampoos with the same herbal feature followed, with sales rising from 4.3 million RMB (\$700,000) in 2011 to 158 million RMB (\$25 million) in 2014.

⁵⁰ *China's iConsumer 2015: A growing appetite for change*, McKinsey China, February 2015.

- **Jahwa**, which is based in Shanghai, has been selling personal care products since 1991. In 1998, it launched the high-end Herborist brand, a line of cosmetics. The company has also developed a streamlined product-development process, cutting time to market for its Ji Huo Xin Yan line of skin care products from more than a year to eight months. The faster development time lets Jahwa experiment with more new lines and variations. Herborist products now contribute 30 percent of total company revenue. The company has also adopted new marketing tactics, such as offline experience centers for consumer education and a direct online sales channel, which contributed 15 percent of sales in 2014. Most recently, Jahwa has expanded overseas, opening a flagship store in Paris.



Chinese companies have developed strong skills in customer-focused innovation, and this is reflected in their success in industries such as home appliances and Internet services. They have taken advantage of the enormous Chinese market to turn their ideas into products and services, and they have developed rapid-fire business processes to keep up with fast-changing consumer tastes. Companies in industries that rely on customer-focused innovation have exceptional opportunities to lead in emerging markets and, at home, to raise the productivity of the service sector.





4. EFFICIENCY-DRIVEN INNOVATION

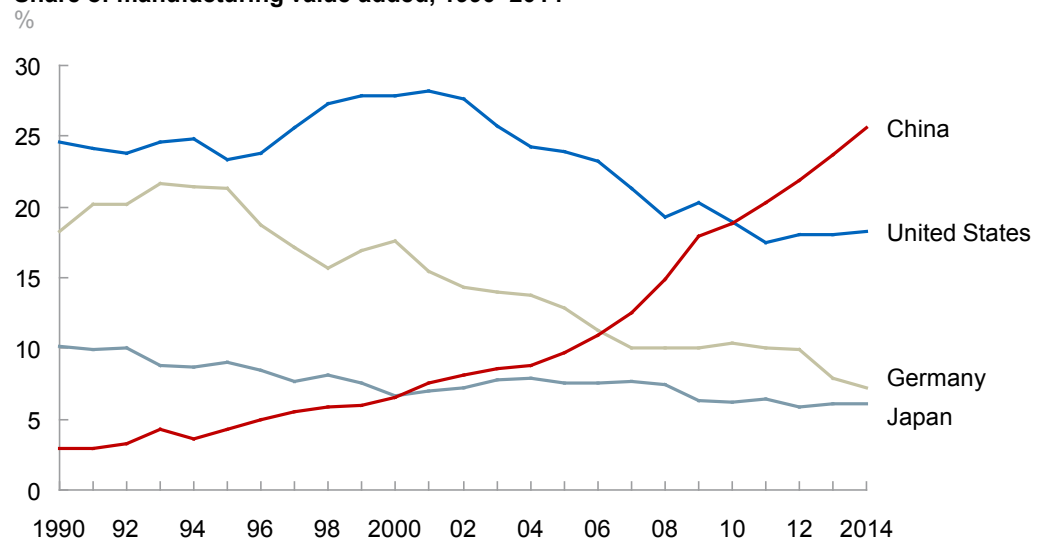
Efficiency-driven innovation involves new ideas that save time and cost in the development, production, and delivery of goods and services. In China's rise to become the premier global manufacturing location, it has become a world leader in efficiency-driven innovation, in large part because of the vast ecosystem of suppliers, workers, service companies, and logistics providers that has arisen around China's manufacturing industry. This ecosystem has transformed China into a global manufacturing hub, making it possible for both Chinese and foreign companies to put virtually any kind of product into production rapidly and affordably. In many efficiency-based industries, Chinese companies already have achieved more than their share of global sales (based on China's 12 percent share of GDP). Chinese companies have 51 percent of global revenue in solar panels, 20 percent in textiles, 15 percent in commodity chemicals, 19 percent in construction machinery, and 16 percent in electrical equipment.

Once mostly an exporter of low value-added-goods and a contract assembler for global manufacturers, China has become increasingly adept at producing more knowledge-intensive goods. Innovation in manufacturing processes and the expanding capabilities available in the Chinese manufacturing ecosystem have helped Chinese players move at an accelerating rate into higher value-added products and activities, such as product design. In the past 15 years, China's share of global manufacturing value added has risen from 6 percent to nearly 26 percent (Exhibit 20). In this chapter, we focus on efficiency-driven innovation in manufacturing, but efficiency-driven innovations are also possible in services and are critical for China's growth aspirations, as we discussed in detail in Chapter 3.

Exhibit 20

China's share of global value added in manufacturing rose from less than 7 percent in 2000 to nearly 26 percent in 2014

Share of manufacturing value added, 1990–2014¹



¹ Includes both domestic and foreign companies manufacturing in China.

SOURCE: IHS Economics; McKinsey Global Institute analysis

Today, China has fresh opportunities in manufacturing—as well as significant challenges. China is already emerging as a potential leader in open manufacturing, with “maker” communities incubators, and hardware prototyping firms enabling “mass entrepreneurship.” However, it also faces new competition for some types of manufacturing (textiles and apparel, for example) because of rising factor costs. At the same time, global manufacturing is undergoing a shift to a digitized Industry 4.0 model, in which all elements and processes of manufacturing and supply chains are digitally linked. China’s extensive ecosystem can remain an advantage in this next era of manufacturing—if Chinese companies can remain on the leading edge of efficiency-driven innovation. Doing so will be critical to raising productivity and sustaining GDP growth. We estimate that if China can prevail in the Industry 4.0 era, manufacturing could generate \$450 billion to \$780 billion to GDP in 2025, equivalent to up to 22 percent of manufacturing-sector GDP growth to 2025.

CHINA’S EFFICIENCY-FOCUSED MANUFACTURING ECOSYSTEM

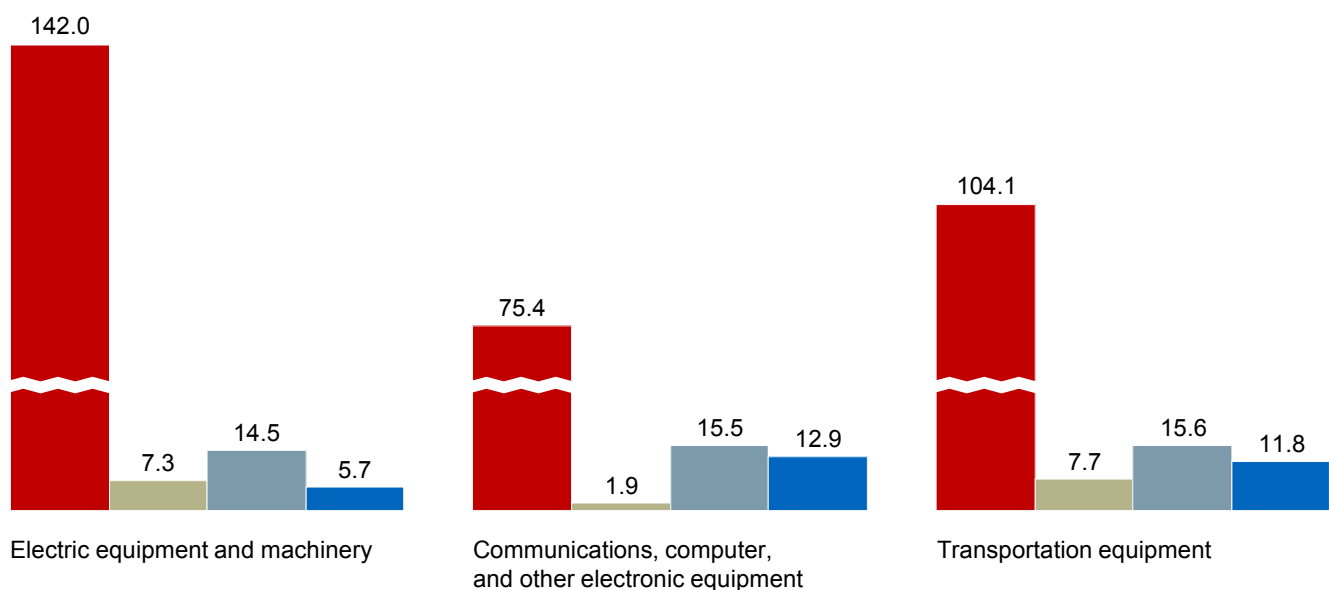
Much of China’s manufacturing success can be attributed to its extensive manufacturing ecosystem—a deep network of suppliers, a large skilled labor force, and a well-developed logistics infrastructure. This ecosystem has helped Chinese manufacturers produce goods faster and at lower cost than most other economies can, and it allows manufacturers to put products into high-volume production rapidly. China’s extensive supplier base is a critical part of the ecosystem. It allows companies to move into production quickly and helps them respond to changing customer needs, by finding new or lower-cost components, for example. China has more than 140,000 machinery suppliers, 75,000 manufacturers and suppliers in communications, computer, and other electronic equipment industries, and 104,000 companies in the transportation equipment sector (Exhibit 21). Depending on the sector, China’s supplier base is more than five times the size of the supplier base in Japan.

Exhibit 21

China’s manufacturing ecosystem has a far larger supplier base than other economies

A concentrated network of manufacturers and suppliers raises productivity and accelerates innovation
Thousands of component manufacturers, 2013

■ China ■ India ■ Japan ■ United States



1 Registered units only, 2011 data.

SOURCE: China Basic Statistical Units Yearbook 2013; Japan Financial Statements Statistics of Corporations by Industry, Annual Survey of Industries 2011–12; US Census County Business Patterns 2013; McKinsey Global Institute analysis

150M

Size of China's manufacturing labor force

China's large and flexible manufacturing workforce gives manufacturers many operations options. It not only enables companies to scale up production rapidly, but it also allows more choices of labor/capital combinations, which can be adjusted for the needs of particular products, allowing both lower production costs and faster time to market. Many Chinese firms, for example, use semiautomation approaches that mix machines and labor in ways to optimize cost and flexibility. When there is a sudden surge in demand or a need to make a quick changeover to a new product, it is much easier to hire more labor than to bring in new machinery and reprogram equipment. The flexibility of Chinese labor is largely a function of size. China has 150 million manufacturing workers, compared with 14 million in the United States, nine million in Japan, and four million in South Korea. Its manufacturing workforce is three times the entire working-age population of Vietnam, a rising force in low-cost manufacturing. To meet a surge in demand from its largest customer, Foxconn once hired 3,000 workers overnight at its factory in Shenzhen.⁵¹

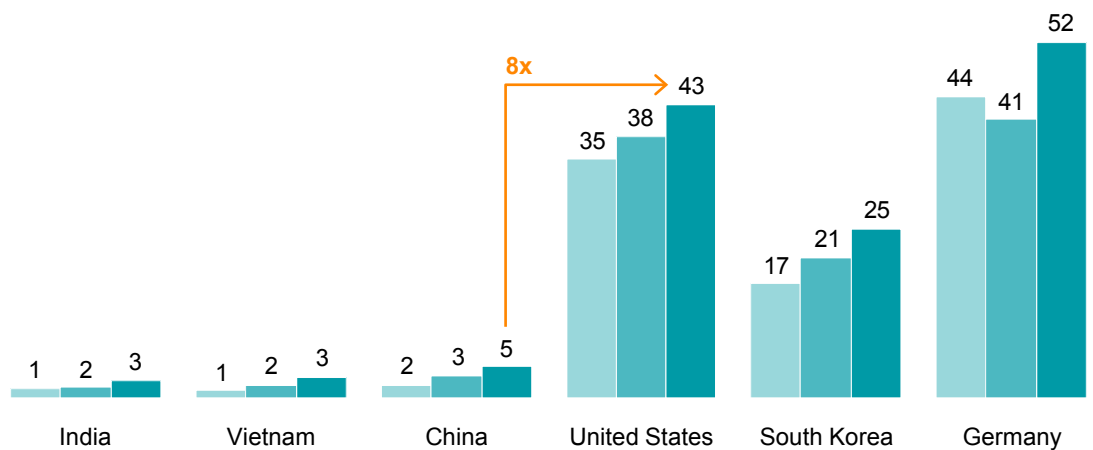
While Chinese labor costs have risen in comparison with costs in developing economies, the cost of manufacturing in China remains far below levels of advanced economies (Exhibit 22). Labor costs have been rising by 15 percent per year since 2000, and wages have reached a point where some highly labor-intensive production might migrate from China to Vietnam, Cambodia, or other low-cost countries. However, China's labor costs remain attractive for most types of manufacturing. It is estimated that Chinese labor rates could reach about 12 percent of the US level by 2019, up from 8 percent today.⁵² This suggests that China can retain labor cost advantages as it moves into higher value-added manufacturing.

Exhibit 22

Chinese labor costs have risen rapidly but remain significantly lower than in advanced economies

Cost per hour of manufacturing labor
\$

2010 2015 2019



Manufacturing labor productivity, 2014

Productivity per employee, \$ thousand, purchasing power parity, indexed to 2009

7 6 17 108 70 82

SOURCE: Economist Intelligence Unit; McKinsey Global Institute analysis

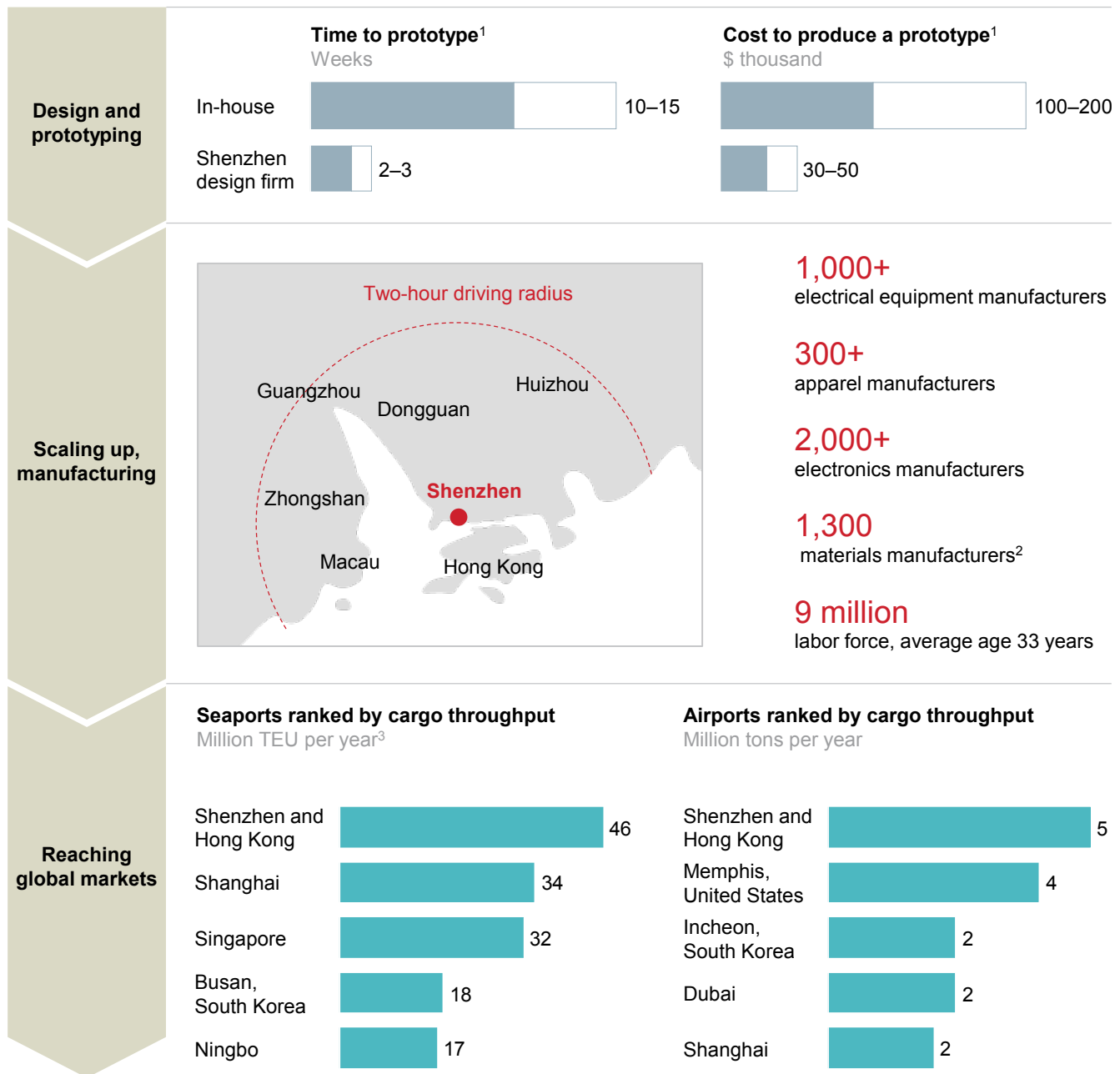
⁵¹ Charles Duhigg and Keith Bradsher, "How the US lost out on iPhone work," *The New York Times*, January 21, 2012.

⁵² The Economist Intelligence Unit.

China's manufacturing ecosystem also includes modern transportation infrastructure—highways, railroads, and airports—that link Chinese factories efficiently to global markets. For example, newly built railroads now allow manufacturers in the central Chinese city of Zhengzhou to reach consumers in Europe in 16 days, compared with 38 days via the previously used sea route. Within China, freight moves across roads 30 to 60 percent faster than freight moves within India on average. Exhibit 23 shows the benefits of the manufacturing ecosystem in Shenzhen, where companies can save time and costs in developing prototypes, tap into a large supplier base, and move products into global markets quickly.

Exhibit 23

Shenzhen has a strong ecosystem advantage in manufacturing



1 Low-tech electronics example.

2 Chemicals, rubber, minerals, metals, textiles.

3 Twenty-foot equivalent unit, a measure of cargo ship capacity.

SOURCE: Shenzhen Statistical Yearbook 2014; Drewry Container Market; Airport Council International; McKinsey Global Institute analysis

HOW INNOVATORS IN CHINA ARE RAISING EFFICIENCY

Chinese manufacturers have pursued a range of innovations to improve efficiency and bring affordable products to market at accelerated speeds. Such approaches include lean design and modularization, scaled learning, agile manufacturing, and semiautomation (a pragmatic approach that mixes advanced production machinery and labor for greater flexibility). These process innovations also reduced cost structure and improved productivity, which helped counter the impact of rapid labor cost increases.

- **Lean design and modularization.** Lean design refers to the redesign of a product's components to reduce cost, improve performance, and facilitate manufacturing. In certain instances, costs are lowered by eliminating "over-specification" and substituting lower-cost components that can perform as well as more expensive ones. Preliminary lean designs are moved quickly into production, where production engineers eliminate defects, then scale up production of final designs. While a large global manufacturer might take months or years to ensure quality of designs from the start, Chinese competitors are more likely to move designs into production within days or weeks, then improve quality through trial and error. The result is often a simplified, lower-cost version of a product, but one that is fit for emerging-market customers in China and elsewhere.

Lean design has made it possible to bring all sorts of products—from electrical machinery to construction equipment—to developing economies. But lean designs can also flow from the developing world to advanced economies in a process sometimes referred to as "reverse innovation."⁵³ For example, General Electric was able to serve China's medical device market by simplifying its \$100,000 full-featured ultrasound machines. The new \$15,000 version was designed for use in rural clinics in China and other developing economies. Later, GE found a market for the same design in advanced economies, selling the compact model in places where portability and small size are required, such as emergency rooms and operating rooms. GE has since opened Innovation Centers in Chengdu, Xi'an, and Harbin to focus on reverse innovations in medical devices, power generation, and oil and gas equipment. Similarly, the US-based Harman International Industries, which had developed infotainment systems for luxury cars in Germany and had a 70 percent market share, reengineered its design for emerging markets using a design team in China and India. The result was a unit that could be built for one-third the cost of the luxury-car system and would sell for half the price.⁵⁴

Modularization—breaking products down into modular subassemblies—is another technique for reducing manufacturing costs. This approach is being used to help industrialize construction, turning it into more of a manufacturing process. Broad Construction Building, a subsidiary of the Changsha-based Broad Group, is pioneering modular methods, building prefabricated wall and floor panels that are complete with drywall, plumbing, electrical, ventilation, and flooring systems. Only 10 percent of the work is done on site. To demonstrate the efficiency of its approach, Broad Construction completed the 57-story Mini Sky City hotel in Changsha in 19 days. The company says its method also reduces waste to 1 percent of material, compared with 30 percent in conventional construction.

- **Scaled learning.** The large size of the Chinese market, which forces manufacturers to scale up manufacturing quickly, also helps companies move on the learning curve at an accelerated rate. The solar panel industry is a good example. The cost of solar panels has fallen by half in the past three years. While much of this price reduction was driven by

⁵³ Jeffrey R. Immelt, Vijay Govindarajan, and Chris Trimble, "How GE is disrupting itself," *Harvard Business Review*, October 2009.

⁵⁴ Vijay Govindarajan, "A reverse-innovation playbook," *Harvard Business Review*, April 2012.

structural overcapacity in the market, Chinese firms were also able to wring efficiencies out of their manufacturing processes by applying scale economies and lessons about production processes—reducing the amount of silicon needed in wafers and the amount of silver needed for connections, for example. Companies have also introduced new production efficiencies in advanced glass, coatings, and films. The scale of Chinese solar factories—as much as four times the size of US plants—helps to drive process improvements. Together, scale and supply-chain advantages give Chinese solar players a cost advantage of 22 cents per watt, or about a 15 to 20 percent edge in cost per watt, according to an MIT study.⁵⁵

15-20%

Cost advantage from scale and supply-chain for Chinese solar-panel makers

- **Agile manufacturing.** Speed and agility are becoming increasingly important in global manufacturing. “Agile manufacturing” is a term that describes a range of approaches and activities that allow manufacturers to respond more quickly to changing customer requirements and to provide a level of flexibility that conventional manufacturing approaches do not permit. For Chinese manufacturers, agile manufacturing provides an opportunity to move into higher value activities, such as design and product development, and also get closer to consumers. Agile manufacturing is fast, iterative, responsive, and customer-focused—providing a key competitive advantage in fast-moving markets.

Everstar and Red Collar are traditional apparel manufacturers that are adopting agile techniques to transform themselves into custom clothing suppliers that work directly with consumers. Everstar’s e-commerce portal offers do-it-yourself design tools that are accessible anywhere by computer or smartphone. Customers create their designs, place their orders, and within days have their goods. Investments in 3D scanning and laser cutting enable swift production of customized designs (as quickly as 30 minutes after an order is received). The company also built a fast logistics platform that promises 72-hour turnaround on custom orders. Based in Guangdong, its factory is within easy reach of more than 2,000 textile, apparel, and accessories manufacturers. In 2014, Everstar produced 1.8 million pieces of apparel and had \$20 million in sales. Its investments in new automated tools have enabled the company to boost production capacity by 30 percent while cutting labor requirements by 50 percent.

- **Semiautomation.** China is already the largest buyer of robots in the world, but automation has limitations, including high cost and lack of flexibility. Chinese manufacturers are addressing these limitations in a very pragmatic way that combines the flexibility of labor with the efficiency of machines. Chint, an electrical equipment producer based in Zhejiang, installed four fully automated production lines in addition to manual lines with thousands of workstations. The company discovered that it cost four times as much to maintain the automated machinery as it cost to pay the workers that the machinery had replaced. Chint also found that humans were much more efficient for small batches and customized orders. The company analyzed every automated procedure and reassigned to manual lines those that could be done better by humans. It saved \$600,000 in equipment investment for every production line and gained flexibility. The move also reduced waste, because unlike in the automated process where an imperfect part would be discarded, on the manual lines, workers often could adjust a part and put it back into production.⁵⁶

Flextronics, a Singapore-based contract manufacturer, also uses semi-automated approaches. In 2006, the company began retooling its factories in Suzhou, investing in automation to take on more complex manufacturing jobs, such as components for

⁵⁵ Alan C. Goodrich et al., “Assessing the drivers of regional trends in solar PV manufacturing,” *Energy & Environmental Science*, issue 10, October 2013.

⁵⁶ Eden Yin and Peter J. Williamson, “Rethinking innovation for a recovery,” *Ivey Business Journal*, May/June 2011.

aerospace, robotics, and automotive customers. However, it learned that robots and other automation tools were not always more efficient than workers, especially in less standardized steps. One of the main trade-offs between machines and labor involves speed and frequency of changeovers to switch from production of one item to another. Changeovers cost a good deal of time to reprogram machines, but in many cases workers can be quickly trained in new processes at minimal cost.⁵⁷

WHAT'S NEXT FOR EFFICIENCY-DRIVEN INNOVATION

China has the need—and the opportunity—to maintain its strong position in manufacturing and efficiency-led innovation in the next 30 years. Maintaining China's strength in manufacturing and efficiency-driven innovation is essential for generating the productivity gains that will be needed in the coming decades. This will require overcoming immediate challenges and successfully making the transition to the next-generation manufacturing model to embrace digitization of manufacturing while also shifting to more high value-added output. Immediate challenges include rising factor cost. In addition to higher labor costs, Chinese manufacturers are paying more for electricity and land. Prices for industrial land in the top 35 cities have more than doubled since 2005, and electric rates are up nearly 40 percent over the same period.

At the same time, rising consumer expectations, demand volatility, and growing supply-chain complexities increase pressure on manufacturers to be faster and more flexible. Consumers demand more complex and varied products. One Chinese auto manufacturer increased the number of its models from 12 in 2004 to 75 in 2014. Demand is becoming much more volatile, too. Paper industry production, for example, grew by as much as 26 percent a year and by as little as 3 percent between 2010 and 2013, while electric equipment sales fluctuated between 8 and 29 percent. And, as consumption growth shifts to smaller cities, manufacturers must deal with more complicated and costly supply chains.

We believe that China has a good chance to remain a leader in the next era of manufacturing—if it can build on its many advantages, particularly its manufacturing ecosystem, as the new highly digitized operating model takes hold. The new digitized model not only promises new opportunities for raising efficiency across manufacturing operations, but it also enables manufacturers to be far more flexible and responsive to market needs. Recognizing the importance of next-generation manufacturing, the government has announced a massive, 30-year program for advancing manufacturing technology. Other nations have also announced programs to support their manufacturing industries in this transition. The global competition for leadership in the next era of manufacturing has begun and will likely be intense.

Implementing next-generation manufacturing (Chinese-style)

The critical challenge for efficiency-driven innovation in China in the next ten years will be the shift to next-generation manufacturing. If successful, it could create an additional \$450 billion to \$780 billion of value per year from manufacturing in China in 2025, equivalent to 12 to 22 percent of manufacturing-sector growth.⁵⁸

The transition to the Industry 4.0 model will not be simple. It starts with ubiquitous connectivity—using Internet of Things sensors and tags on virtually all machinery and products to enable computer supervision and control. It also involves data analytics and smart systems that can coordinate and optimize all steps of production and distribution; advanced robotics and intuitive man/machine interfaces; and new digitally driven production processes, such as 3D printing. It is estimated that fully digital control of materials,

⁵⁷ Christina Larson, "The new Chinese factory," *MIT Technology Review*, September 2014; Willy C. Shih, "What it takes to reshore manufacturing successfully," *MIT Sloan Management Review*, fall 2014.

⁵⁸ Value would include both increased profit to producers and consumer surplus, such as lower cost and higher quality.

processes, and supply-chain activity can raise productivity (by 26 percent, according to one McKinsey survey).⁵⁹ The shift also will disrupt existing value chains and enable new business models. Among them are “as a service” approaches that allow customers (perhaps including retail customers) to tap manufacturing capacity as needed, without investing in plant, equipment, and labor. Industry 4.0 levers can also enable mass customization to meet fast-changing demand efficiently.

The race for leadership in the Industry 4.0 era

Around the world, manufacturing leaders and governments have recognized the profound challenge that Industry 4.0 presents. Industry groups such as the Industrial Internet Consortium have been established to help advance the technologies needed, and governments have created long-range initiatives to support their manufacturing sectors in the transition to Industry 4.0 (see Box 5, “Battle of the manufacturing policy plans”).

In China, the government has released a comprehensive blueprint to maintain the nation’s lead in manufacturing. The massive effort envisions three ten-year plans that are expected to culminate in 2049, the centennial of the People’s Republic of China. The effort is aimed at driving further efficiency in manufacturing while raising the value added of Chinese manufacturing output by moving into such goods as robotics and aerospace equipment. It calls for establishment of a national manufacturing innovation center and state-sponsored research in intelligent manufacturing, green manufacturing, and other disciplines. It also identifies needed reforms, to improve access to finance and talent, for example, and prioritizes industries, including robotics and advanced materials.

⁵⁹ See *Industry 4.0: How to navigate digitization of the manufacturing sector*, McKinsey & Company, April 2015. Also see *The Internet of Things: Mapping the value beyond the hype*, McKinsey Global Institute, June 2015.

Box 5. Battle of the manufacturing policy plans

Recognizing the threat and opportunities in the shift to an all-digital global manufacturing industry, policy makers around the world have established programs to help their nations compete.

Germany: “High-Tech Strategy 2020,” announced in 2010, involves ten initiatives including an Industry 4.0 program to promote digitalization of manufacturing. The goal is not only to maintain German leadership in manufacturing, but also to ensure it is a major supplier of advanced manufacturing technologies. The government has invested €200 million (\$255 million) in government and academic research and has launched discussions among government, business, and trade unions to create overall strategies in manufacturing.¹

United States: The Smart Manufacturing Leadership Coalition, a nonprofit organization of manufacturers, suppliers, technology companies, manufacturing consortia, universities, and government agencies, was formed in 2012 to create an open platform for manufacturing technology. Its aim is to promote collaborative R&D, implementation, and the development

of standards and shared infrastructure for fully digitized manufacturing. The Revitalize American Manufacturing and Innovation Act, passed in 2014, provided funding for 15 public/private centers for manufacturing innovation, each focused on a different aspect of manufacturing.²

South Korea: South Korea unveiled its “Manufacturing Innovation 3.0” strategy in 2013 to digitize production facilities and create innovative products, including devices for the Internet of Things. The plan calls for spending \$1 billion to build 10,000 smart factories by 2020.³

India: Manufacturing accounts for only 15 percent of GDP in India (compared with 31 percent in China), and the government has a goal to raise that to 25 percent by 2022 and create 100 million jobs under the “Make in India” program. The program targets 25 manufacturing sectors and aims to transform India into a global manufacturing hub by improving business processes, offering incentives to companies for establishing plants to build high-value goods, and building up infrastructure and a skilled labor pool.⁴

² Karen Mills, “How Washington can renew US manufacturing,” *Fortune*, November 24, 2014.

³ “‘Smart factory’ touted as an industrial model,” *Korea JoongAng Daily*, January 26, 2015.

⁴ “Make In India campaign: 6 top hurdles,” *The Financial Express*, June 5, 2015.

¹ *Project of the future: Industry 4.0*, Germany Federal Ministry of Research and Education.

The initial phase, “Made in China 2025,” calls for raising manufacturing-sector R&D spending from 0.88 percent of revenue (in 2013) to 1.68 percent by 2025 (compared with 5.3 percent in the United States), raising labor productivity by 7.5 percent per year by 2020 and by 6.5 percent per year from 2020 to 2025 (compared with 9.5 percent per year between 2010 to 2014), and increasing the growth rate of value added of Chinese manufacturing by 2 percent by 2020 and by 4 percent from 2020 to 2025. The plan also envisions demonstration projects to prove the viability of new technologies and approaches that are expected to cut production costs and lead times by half and improve yields by 50 percent. Another goal is to raise the domestic content of core components and materials (which are estimated to be 10 to 25 percent today depending on categories) to 40 percent by 2020 and to 70 percent by 2025. This is in addition to a government commitment to set up 15 manufacturing innovation centers by 2020 and to raise the total to 40 by 2025.

Three ways “next-generation” manufacturing can strengthen China’s competitiveness

China enters the contest for leadership in the next era of manufacturing with strong advantages, including its extensive manufacturing ecosystem, large labor force, and modern infrastructure. We identify three areas where Chinese manufacturers can adopt advanced technology and build on China’s advantages: digitally linking all participants in the manufacturing ecosystem, refining hybrid automation models, and adopting open design and manufacturing platforms. These moves can position China to excel in providing the flexibility, variety, and mass customization that markets will increasingly demand.

A fully digitally linked ecosystem: new levels of efficiency and customization

The benefits of Industry 4.0 depend on ubiquitous connectivity, not only of machinery and systems within the four walls of the factory, but also across the entire manufacturing value chain. Within the plant, connected machinery and devices to monitor the movement of parts and the activities of labor can raise efficiency, including through real-time supply-chain optimization, real-time yield management, and predictive maintenance, which relies on a continuous flow of data about equipment performance to avoid breakdowns and schedule maintenance only when needed. Some of the greatest benefits could arise from allowing retailers and even consumers to connect directly to manufacturers and from matching excess manufacturing capacity to demand. Here we look at two examples of how China could have distinctive advantages in the Industry 4.0 era: using its popular e-commerce sites to aggregate demand for manufacturers, and optimizing utilization of manufacturing capacity through “networked” manufacturing.

- **Demand aggregation for mass customization.** China is well positioned to take advantage of a digitally linked manufacturing ecosystem to enable cost-effective mass customization. China can combine the world’s largest e-commerce market with agile manufacturing and logistics to deliver custom variations on standard products and even fully customized products in a timely way and at a reasonable cost to millions of consumers. Mass customization can be possible in a range of products, from shoes to smartphones, that consumers will be able to order online or purchase in stores. Chinese Internet players can play a central role in aggregating demand for customized products. Alibaba, which has more than 600 million patrons for its online shops, has announced an investment in Suning, a 1,600-store electronics retailer, providing a platform for aggregating demand for consumer electronics manufacturers.⁶⁰ For example, demand aggregators can collect orders for customized smartphones, and once volume for similar configurations reaches a certain minimum, an order would be released to the manufacturer. Demand aggregators could also help manufacturers with demand projections, based on big data analysis of consumer trends, which would allow manufacturers to prepare raw materials and component supplies. Tencent is getting

⁶⁰ Gery Shih, “Alibaba to invest \$4.6 billion in China electronics retailer Suning,” Reuters, August 11, 2015.

into demand aggregation by building a platform to connect manufacturers of Internet of Things devices to 800 million QQ users, and to use QQ to manage Internet of Things devices, such as QQ-connected smart appliances and fitness and health monitors.⁶¹ Another approach enabled by Industry 4.0 connectivity is “build to order” service for items such as refrigerators, which would allow customers to choose the design, color, and features that a flexible assembly line could turn around quickly and at little extra cost.

- **Networked manufacturing.** Ubiquitous connectivity throughout China’s manufacturing ecosystem can enable manufacturing to be offered as a service, even in very small increments. In an emerging “networked manufacturing” model, companies in a network can sell excess capacity to other members, raising utilization rates for the seller and giving the buyer a low-cost flex capacity. Similarly, multiple manufacturers can work as a “mega manufacturer” to obtain greater economies of scale in driving research and development, building logistics network, and serving demand that single manufacturer could not easily accommodate. There are early examples of these trends. In Huadu County in Guangdong Province, 7,200 companies are producing leather products, which they are exporting to more than 100 countries. The manufacturers launched a joint platform to collaborate on manufacturing, logistics, and trading among companies in the region.⁶² In Dalang County in Dongguan, 8,000 apparel companies are producing 1.2 billion articles of clothing per year. They formed a joint R&D platform to explore adoption of new technologies and better serve their customers.⁶³

Hybrid automation, a new capital/labor equilibrium model for China

Striking the correct balance between automation and labor will be a key way in which Chinese manufacturers can keep their edge. Even as China has become the largest market for robots, penetration remains relatively modest—30 robots per 10,000 workers, compared with 323 in Japan and 437 in South Korea. Penetration will certainly rise over the next decade, and the government has a goal to raise penetration to 100 robots per 10,000 workers by 2020.⁶⁴

Chinese manufacturers have an opportunity to deploy robots and automation in ways that will play to their advantages and let them remain nimble, responsive, and globally competitive.

However, fully automated production is costly and can limit flexibility. Chinese manufacturers have an opportunity to deploy robots and automation in ways that will play to their advantages and let them remain nimble, responsive, and globally competitive as the nature of manufacturing demand changes. Increasingly, success in manufacturing is less and less about producing millions of units of the same design and more about being agile enough to respond to volatile demand and changing market requirements. Each manufacturing line needs to be flexible enough to switch tasks depending on market needs, and fully automated lines are far less adaptable than lines of workers or hybrid lines that combine

⁶¹ “Tencent introducing open IoT platform, all smart hardware will have QQ identification,” *TechWeb*, April 29, 2015.

⁶² *China’s leather capital*, Shi Ling People’s Government, www.cnshiling.gov.cn.

⁶³ *Overview of export industry upgrade models, Dongguan Dalang clothes manufacturing base*, Guangdong Provincial Foreign Trade and Economic Cooperation Department of Foreign Trade Administration, February 27, 2012.

⁶⁴ James Kynge, “China seeks productivity salvation in robots,” *Financial Times*, June 25, 2015.

automation and labor. Also, many manufacturing tasks are still beyond the capabilities of traditional robots.

The emerging model in Chinese manufacturing is to use robots only in the applications where they can clearly outperform human labor or where tasks are too dull or dangerous for today's Chinese workers. The focus for manufacturers in the next decade can be on blending the strengths of robots (principally productivity and consistent quality) and the strengths of skilled Chinese workers (flexibility and intelligence). China can maximize the benefits of labor and robots to become a global, and agile, manufacturing hub, while limiting the need for capital investments.

Before manufacturers can get the expected benefits from hybrid automation, they need to address the inefficient processes across their operations. Despite efforts to raise efficiency, there is still a significant gap between Chinese manufacturers and global peers. For example, many companies have adopted lean initiatives or Six Sigma quality programs, but execution varies widely. At one company that was attempting a continuous improvement program, team leaders spent as little as 5 percent of their time coaching and problem solving with workers, when best practice is 30 percent.⁶⁵

“Open” manufacturing platforms: innovation for the masses

China's manufacturing system is changing. The vibrant and evolving manufacturing ecosystem in Shenzhen and the emergence of product design studios, incubators, and other resources are becoming an open platform for rapid, low-cost commercialization of new products. The emerging model of an open design and manufacturing platform can enable “mass innovation.” An entrepreneur no longer needs to hire an engineer to create a prototype or buy a factory or a warehouse—everything that is needed to turn an idea into a product and get it onto a store shelf is available as a service. Open manufacturing and the “maker” movement enable people and organizations that have ideas, but lack capital and design, engineering, or production expertise to get products made.

\$1,000

Cost to have a smartphone designed in Shenzhen

Although the maker movement and open manufacturing are taking hold globally, this revolution in manufacturing can happen on a much larger scale in China, thanks to the massive manufacturing base and the *Shanzhai* (copycat) tradition. Indeed, open manufacturing is very similar to how things work under the Shanzhai system, which has existed for decades in China and is still thriving. Under the Shanzhai system, small enterprises tap into a network of manufacturers, component suppliers, designers, and logistics players to get their product designs onto the market quickly. When Samsung officially launched the Galaxy 6 smartphone in 2015, a look-alike version showed up within two days. An iPhone 5 look-alike appeared even before Apple's launch.

The Shanzhai model is evolving. There is more actual innovation, Shanzhai companies are becoming brands, and the network of component suppliers, design houses, and manufacturing facilities of the Shanzhai industry is coming to resemble an open innovation and manufacturing platform.⁶⁶ For example, small Chinese players that sold knockoffs of popular mobile phones identified an opportunity to sell “dual SIM” phones, which allow consumers to switch services without buying a new phone. This was an innovation that had no appeal for major phone manufacturers, but small producers found a ready market in China and are now filling demand in Africa as well. Tianyu, one of an estimated 2,000 Shanzhai mobile phone manufacturers, is among the Shanzhai players that is transforming itself into a recognized brand and now operates under proper regulatory supervision. And rather than simply helping customers produce knock-offs of global products, the

⁶⁵ Karel Eloit, Martin Lehnich, and Alan Huang, “A new era for manufacturing in China,” *McKinsey Quarterly*, June 2013.

⁶⁶ Wade Shepard, “China's copycat manufacturers are now pushing the boundaries of innovation,” *South China Morning Post*, May 20, 2015.

Shanzhai network is serving as an open platform for entrepreneurs to move their ideas into production. It takes only \$1,000 to develop and produce a smartphone, using suppliers clustered in Shenzhen.⁶⁷

Based on Shanzhai networks and the wider manufacturing ecosystem, China can become a global center for open source manufacturing, providing would-be manufacturers everywhere with a faster and cheaper route to commercializing an idea (see Box 6, “How China’s manufacturing ecosystem is becoming an open platform”). A creative entrepreneur in Africa could turn ideas into prototypes and go into large-scale production using only Chinese suppliers and without ever setting foot in China. Large multinational companies could take advantage of China’s open manufacturing model to reduce the time and cost of putting localized products into new markets.

⁶⁷ Tim Culpan, “Start your own smartphone company for \$1,000,” Bloomberg, July 13, 2015.

Box 6. How China’s manufacturing ecosystem is becoming an open platform

Around the world, manufacturing is evolving rapidly, with all sorts of new technologies, such as inexpensive robots and the Internet of Things. Equally important, manufacturing is morphing from a capital-intensive industry that favors giant corporations with massive scale into a service that any ambitious entrepreneur can use. This “democratization” of manufacturing is embodied by the “maker” movement. Individuals and startups with good ideas are using online design tools to craft new products and flocking to maker spaces and 3D print shops to create prototypes. They are working with a virtual network of engineers and designers and ramping up production in factories they have never seen.

China’s manufacturing ecosystem provides an ideal environment for this explosion of innovation. Shenzhen already has one of the world’s most vibrant maker communities, a tightly knit network of hardware suppliers, developers, designers, and entrepreneurs. This community also includes a thriving (and growing) roster of more than 20 maker spaces as well as what may be the world’s greatest concentration of electronic design services. Within just 1.45 square meters, 21 electronics suppliers are helping companies from all over the world create designs for smartphones, drones, wearable devices such as fitness bands, and more.

Shenzhen’s burgeoning hardware innovation ecosystem has attracted makers, innovators, and entrepreneurs from around the world. In the Nanshan district alone, more than 89 tech companies have had initial public offerings. More than a half-dozen incubators are fostering hardware startups, including Seeed Studio, TechSpace, and Chaihuo. Major manufacturers such as Haier, Shanghai

Electric, and TCL have opened business incubators. Seeed Studio helps early-stage startups build prototypes and provides manufacturing services for early runs of up to thousands of pieces. In 2014, Seeed had about 200 employees and revenue of \$10 million, 90 percent of which comes from overseas.¹

Hax Accelerator, based in Shenzhen and San Francisco, is a hardware incubator that selects startups from around the world for early-stage investment and assistance in product design and development. Entrepreneurs spend three months in Shenzhen, where they get office space, support staff, and assistance on strategy, prototyping, sourcing, and supply-chain management. At the end of the three months, they travel to San Francisco and pitch their companies to investors.

Among the startups to emerge from the Shenzhen hardware innovation ecosystem is BeTwine, a maker of wristband activity monitors. BeTwine’s approach is to combine the activity monitor with a social game that allows friends and family to track each other. They can poke a player who has been inactive and compete for the highest number of steps walked and other challenges. The company was created at the Seeed incubator in 2013 and crowdfunded the seed capital to prototype its design and produce its first 1,000 products. After refining its designs based on user feedback, it went into large-scale production with InnoConn, a Foxconn subsidiary that supports promising startups. Foreign startup companies, including Oculus Rift, a maker of virtual-reality goggles, and smartwatch maker Pebble Watch, are also flocking to Shenzhen.

¹ Company interviews.

SUCCESS IN NEXT-GENERATION MANUFACTURING COULD BE WORTH \$450 BILLION TO \$780 BILLION PER YEAR IN 2025

If China can build on its manufacturing ecosystem advantage as it moves to next-generation manufacturing, we estimate that the manufacturing sector could add \$450 billion to \$780 billion per year to the Chinese economy in 2025, the equivalent of 12 to 22 percent of manufacturing GDP growth (see Box 7, “Quantifying the potential impact of next-generation manufacturing approaches”).

If China embraces new technologies, adopts structural measures to aid manufacturing, and addresses cost challenges, we believe that Chinese factories can remain highly competitive in global manufacturing. While Industry 4.0, other innovations, and changes in factor costs have the potential to alter the competitive landscape, we also think that some of these trends can favor China. For example, China can be a big beneficiary from “next-shoring”—putting manufacturing close to final demand. In our research, we find that growing demand in the United States, rather than strategies to “reshore” manufacturing, is what has driven expansion of US manufacturing in recent years. With China’s GDP currently projected to reach \$18 trillion to \$20 trillion in the next ten years (up from \$10 trillion in 2014) and with a market of more than 200 million consuming-class households, China should be a destination for next-shoring. China also remains the logical hub for regional manufacturing operations of companies (including Chinese manufacturers) that are targeting the growing markets of Asia. And an increasingly connected, digitized, and efficient manufacturing ecosystem can help hold the global players that have outsourced manufacturing to China. Open manufacturing platforms can attract a new wave of manufacturers.

Box 7. Quantifying the potential impact of next-generation manufacturing approaches

We estimate the potential economic impact of next-generation manufacturing by looking at eight areas in which next-generation approaches can improve performance.¹ We estimate the potential value of these approaches in each of the major manufacturing sectors of China’s economy to develop a view of the potential impact of next-generation manufacturing on Chinese manufacturing.

Process/resource. Typically, process and resource optimization using real-time data yields an improvement in throughput of up to 5 percent.

Asset utilization. Techniques such as predictive maintenance can cut machine downtime by 30 to 50 percent and increase machine life by 20 to 40 percent.

Labor. Through automation of knowledge work, manufacturers can reduce the cost of labor for technical professionals by 45 to 55 percent.

Inventory. Through real-time, supply-chain optimization and other data-driven techniques, manufacturers can reduce inventory costs by 20 to 50 percent.

Quality. Real-time data analytics and advanced processes enable real-time error corrections to minimize rework and scrap, reducing costs of suboptimal quality by 10 to 20 percent.

Supply/demand match. Real-time data optimizing matching of supply to actual demand increases forecasting accuracy by 85 percent.

Time to market. New processes such as 3D printing can speed up product development and prototyping, shortening time to market by 30 to 50 percent.

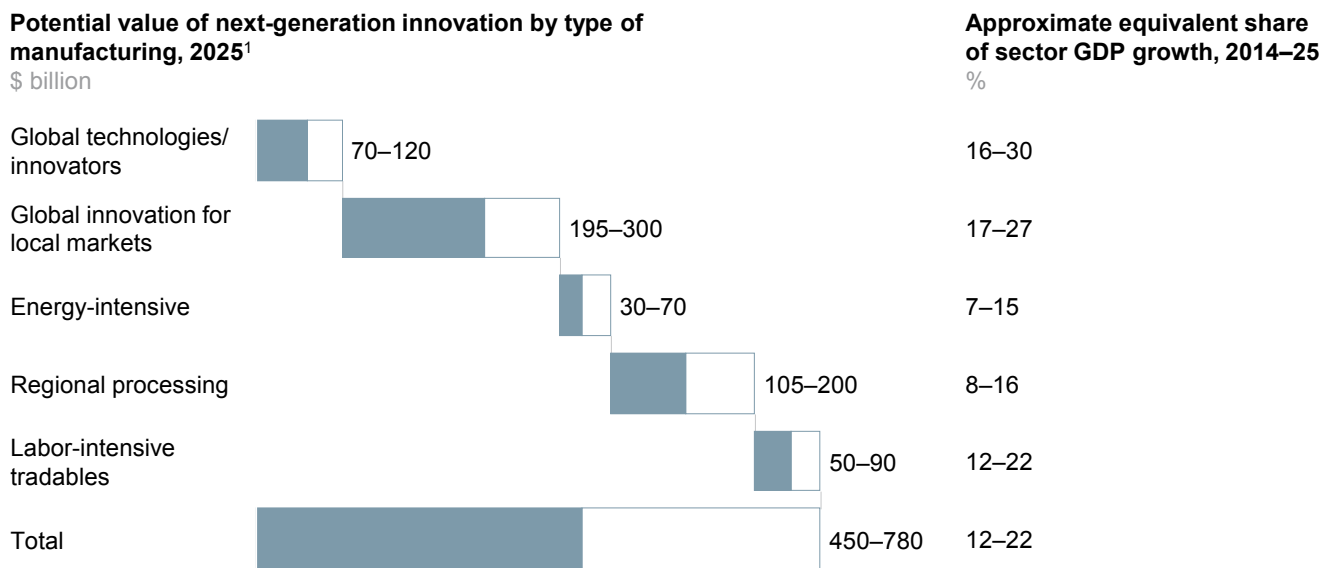
After-sale services. Remote monitoring and predictive maintenance routines can cut the cost of after-sale service by 10 to 40 percent.

¹ See *Industry 4.0: How to navigate digitization of the manufacturing sector*, McKinsey & Company, April 2015.

A successful transition to next-generation manufacturing capabilities will be critically important to keep China on the right side of these trends. Here we examine the potential impact of Industry 4.0 approaches across the five segments of manufacturing: global technologies (semiconductors and personal computers, for example), global innovation for local markets (automobiles, machinery), energy- and resource-intensive commodities (steel), regional processing (packaged foods), and labor-intensive tradables (apparel, furniture). The combined impact of next-generation manufacturing approaches could account for 12 to 22 percent of manufacturing-sector growth in China through 2025 (Exhibit 24).

Exhibit 24

Next-generation systems and methods could contribute the equivalent of 12 to 22 percent of manufacturing-sector growth through 2025



¹ High case assumes revenue gains from additional asset utilization is captured by all actors in the economy.
 Note: Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

- Global technologies and innovation products.** Products in this category include computers and semiconductors, which are usually produced in central locations for global distribution. These are fast-moving markets and suppliers that must respond rapidly to shifting consumer preferences, while also controlling costs. We expect these industries to quickly embrace digitization, which could generate \$70 billion to \$120 billion per year in value by 2025, equivalent to 16 to 30 percent of the sector growth over the next ten years. Industry 4.0 approaches in global innovation products accelerate time to market, through online collaboration with customers, and improve quality from use of real-time analytics and advanced process controls. These are industries that also will allow China to climb the value chain, if Chinese companies continue to develop capabilities in product design and software. If China takes full advantage of digitization, it can continue to be a global manufacturing hub for products in this category.

- **Global innovation for local markets.** Many products in this category—machinery, cars, equipment—tend to be bulky and often require localization to meet customer preferences and regulation. Therefore, they tend to be built in or near final markets. Companies in these industries face substantial pressure on both speed (responsiveness to customers) and cost. Raw material and parts costs are 40 to 60 percent of sales and labor is 5 to 10 percent. Therefore techniques to minimize waste (using advanced analytics for ordering, for example) will be important. We expect companies in these industries will embrace digitization rather quickly and by 2025, the value could be \$195 billion to \$300 billion per year, or about 17 to 27 percent of sector GDP growth. The scale of China’s massive domestic market—the car market hit 23 million units in 2014, or 60 percent of Asian demand, for example—should help China remain in the forefront of global innovation for local markets manufacturing.
- **Energy- and resource-intensive commodities.** These industries include paper and pulp, steel, and petroleum refining—products that are generally less differentiated—and companies compete on efficient use of energy and other inputs. In these businesses, raw materials can account for 50 to 70 percent of sales, and energy can be 7 to 15 percent of sales. Next-generation manufacturing technologies have relatively limited impact on these commodity raw material costs and, therefore, we expect modest impact—\$30 billion to \$70 billion per year by 2025, equivalent to 7 to 15 percent of sector sales growth. These businesses may adopt digitization more slowly than others due to their long capital-investment cycles as well as industry structure dominated by state-owned enterprises. The products in this category tend to be produced and traded regionally. With improved efficiency, China can serve regional demand.
- **Regional processing.** Industries in this category include packaged foods, rubber and plastic goods, and fabricated metal products. The major costs in these businesses are raw materials, parts, and energy, which typically add up to 60 to 70 percent of revenue. Because goods have a low value density (cheap yet bulky) and, in the case of food, can be lost to spoilage or damage in transit, they are made near end consumers. In the next era of manufacturing, advanced analytics may create value in regional processing by improving factory utilization, and enable process and quality improvements. Adoption of next-generation manufacturing approaches in these industries will likely proceed at a moderate pace and the potential impact could be around \$105 billion to \$200 billion per year by 2025, equivalent to 8 to 16 percent of sector growth. China can also expand in these sectors by acting as a regional hub.
- **Labor-intensive tradables.** Labor-intensive tradables are goods such as textiles, apparel, furniture, and toys, which are made in locations with low labor costs for global consumption. Raw material and labor cost tend to be a higher share of expenses than in many other industries. In textiles, for example, raw materials are about 65 percent of sales and labor is 8 to 10 percent. China became the world leader in sectors such as apparel, toys, and furniture over the past three decades because of its large supply of low-wage labor. With rising wage rates in China, some of this business—particularly the manufacture of low-value, commodity items—is vulnerable to competition from today’s lower-wage countries. However, China has an opportunity to retain higher-value and time-sensitive portions of these markets, such as high-fashion and custom apparel, which require agility and rapid turnaround. We expect adoption of next-generation manufacturing in these industries to be moderately rapid due to the potential cost savings from automation. We estimate that in these industries, value of \$50 billion to \$90 billion per year could be realized in 2025, equivalent to 12 to 22 percent of total sector growth.



The new world of manufacturing can be an opportunity for China, as well as a challenge. China is at a point in its development when there are growing risks as it shifts from reliance on manufacturing and exports as a key driver of growth to a more consumption- and services-driven model. At the same time, however, there is a massive technological shift taking place in manufacturing that could help China make this a smoother transition. In a connected global manufacturing system, China's vast manufacturing ecosystem and large manufacturing labor force can continue to be critically important advantages. Innovations such as semiautomation and open platforms can help firms deploy these assets and keep Chinese manufacturing competitive.





5. ENGINEERING-BASED INNOVATION

Engineering-based innovation depends very much on accumulated knowledge and experience. In industries such as autos, communications equipment, and high-speed trains, innovations are part science and part problem solving, based on know-how that can take years of learning by doing and experimentation. Engineering-based innovation also involves integrating technologies from multiple sources to form a single product. Creating a new automobile, for example, requires collaborating with hundreds of suppliers and integrating more than 1,800 different components to produce a coherent design.

For developing economies, building the capacity to conduct engineering-based innovation is a journey that begins with learning core capabilities, then building skills in incremental innovation, and finally operating at the innovation frontier. In China, engineering-based industries are progressing at different rates along this path. Companies that are farthest along have successfully acquired the necessary knowledge through various means, whether through repeated experimentation and learning by doing, by using technology partnerships to leapfrog to more advanced knowledge, or gaining know-how from supply-chain partners. In industries where companies lag behind, companies have not had these opportunities or have failed to use them.

In China, government policy plays a prominent role in the accumulation of knowledge in industries requiring engineering-based innovation.

In China, government policy plays a prominent role in the accumulation of knowledge in industries requiring engineering-based innovation. Policies that encourage technology transfer and competition within industry sectors can accelerate learning, as can government purchasing activities. On the flip side, government subsidies and policies can also slow the progress of an industry if they protect uncompetitive players.

In China, government has been a successful catalyst of learning for a few engineering-based industries. In others, the record is mixed. Many of the best performers have benefited from government purchasing policies and government facilitation of joint ventures that have resulted in knowledge transfer. These companies were given the opportunity to go through a cycle of acquisition, assimilation, and improvement of foreign technology. The formula has been used most successfully in high-speed rail, where China now has 41 percent of the global market, as well as in wind power (20 percent), and communications equipment (18 percent). In industries where China is further behind, such as auto manufacturing and commercial aviation, Chinese companies have had fewer opportunities to master the learning curve. For example, in the automotive sector, where China has 8 percent of global revenue, state-owned enterprises have not yet developed frontier innovation capabilities despite foreign joint ventures with partners that have core engineering capabilities.

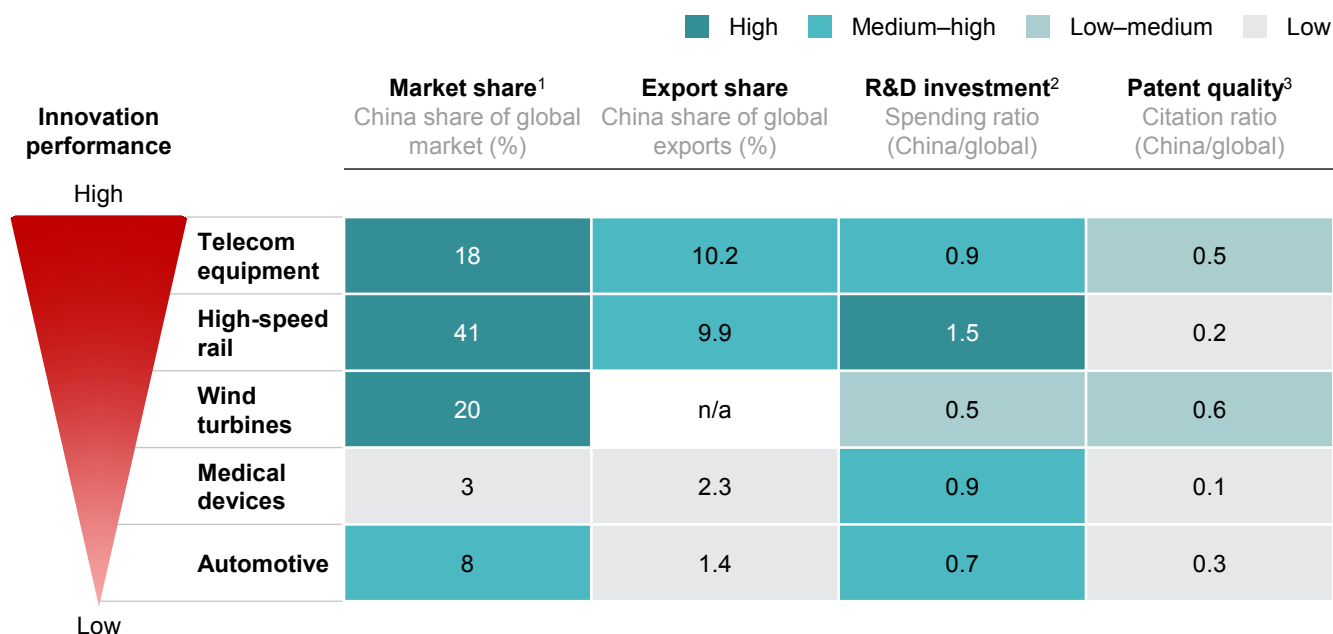
THE EVOLUTION OF ENGINEERING-BASED INNOVATION IN CHINA

Developing economies often follow a learning journey that starts with a catch-up phase, during which they accumulate know-how by reverse engineering products or by tapping into global knowledge networks through collaboration with foreign partners. In some cases, firms can leapfrog by acquiring knowledge directly from global leaders through technology transfer agreements. As they build their capabilities, developing economies gradually advance to incremental innovation—tweaking designs to meet local market requirements or yield performance or cost improvements. Eventually, they become capable of competing at the technology frontier.

In China, industries are making this journey at different speeds. Companies in the communications equipment industry, such as Huawei and ZTE, are among the fastest. Today, these companies are ranked first and third globally in terms of patents. They also compete successfully in global markets and operate extensive global R&D operations. By contrast, state-owned players in the Chinese automotive industry have lost market share to private Chinese and foreign players over the past five years and have not made meaningful inroads into global markets. Exhibit 25 shows how Chinese companies in five industries are faring in engineering-based innovation, based on global revenue share, R&D spending, exports, and patent activity.

Exhibit 25

China's engineering-driven industries are at different stages of learning and innovation success



¹ Market share derived from CPAT database.

² Ratio of average R&D spending of top Chinese players (as percentage of revenue) over global top players (excluding Chinese players).

³ Ratio of average forward citations per patent of Chinese top players to global top players (excluding Chinese global players), 2010–13.

SOURCE: Innography; McKinsey Corporate Performance Analysis Tool; McKinsey Global Institute analysis

We attribute part of the variation in progress toward frontier innovation on structural differences that affect the ability of companies to accumulate knowledge. For example, how the government shapes industry development can play a central role. As purchasers, government-owned entities such as railroads, electric utilities, and telecommunications carriers have created local demand in those industries. As a policy maker, government can set rules for joint ventures that require technology transfers and local-content requirements

to promote learning by Chinese companies. At the same time, government subsidies and policies can also slow the progress of an industry if they protect uncompetitive players.

In general, where China's engineering-oriented industries have not progressed to frontier innovation, they have had inadequate learning opportunities.

With strong local demand and technology transfers, Chinese companies in certain industries accumulated knowledge rapidly through learning by doing and went from acquiring and assimilating overseas technology to incremental innovation and, in some cases, frontier innovation. Chinese companies today account for 41 percent of global high-speed rail equipment revenue, 20 percent of wind-power equipment revenue, and 18 percent of global telecommunications equipment revenue. While soaring local demand in China has helped build these global shares, Chinese companies also compete globally; both railway and telecom equipment makers have about 10 percent of global export markets, up from 3 and 2 percent, respectively, in 2005. Today, these companies conduct research around the world and spend as much on R&D as the top five global players in their industries (3 to 12 percent of sales).

In general, where China's engineering-oriented industries have not progressed to frontier innovation, they have had inadequate learning opportunities. For example, Chinese manufacturers have less than their GDP-based share of global passenger car revenue (8 percent) and less than 1 percent of global revenue in the commercial aviation market. There are many reasons that Chinese companies have not gained the knowledge to become leading innovators in these fields. In some cases, companies have not benefited from foreign partnerships or technology transfer agreements. In others, the nature of their partner relationships limits learning. Sometimes the absence of government purchasing to create local demand slows learning. In all these cases, a common theme has emerged: government involvement can play an important role in creating a market, supporting education, and encouraging competition, but not in the actual act of innovation itself.

Here we look at examples of how three industries have progressed in engineering-based innovation.

Communications equipment

The history of innovation in the Chinese communications equipment industry illustrates some of the ways Chinese companies have learned to acquire the knowledge needed for frontier innovation. In the 1980s, China opened up its communications equipment market to foreign players and the government forged joint ventures with foreign suppliers that would operate factories in China and supply products to modernize the phone system. Shanghai Bell, for example, was a joint venture between the China Ministry of Post and Telecom and Alcatel, the French telecom equipment maker. The venture sold equipment to government customers, such as provincial phone companies, and gained substantial market share. But only 5 percent of revenue was devoted to R&D, and the partner was not required to transfer knowledge. Eventually, Shanghai Bell was eclipsed by privately held players Huawei and ZTE, which focused from the start on acquiring knowledge to innovate.

Huawei, based in Shenzhen, made the strategic decision to develop its own technology, because executives believed that foreign partners would never share cutting-edge technology. Its first in-house designs were for basic switching components, and the learning curve was steep: initial models encountered quality issues, and the company had to deploy

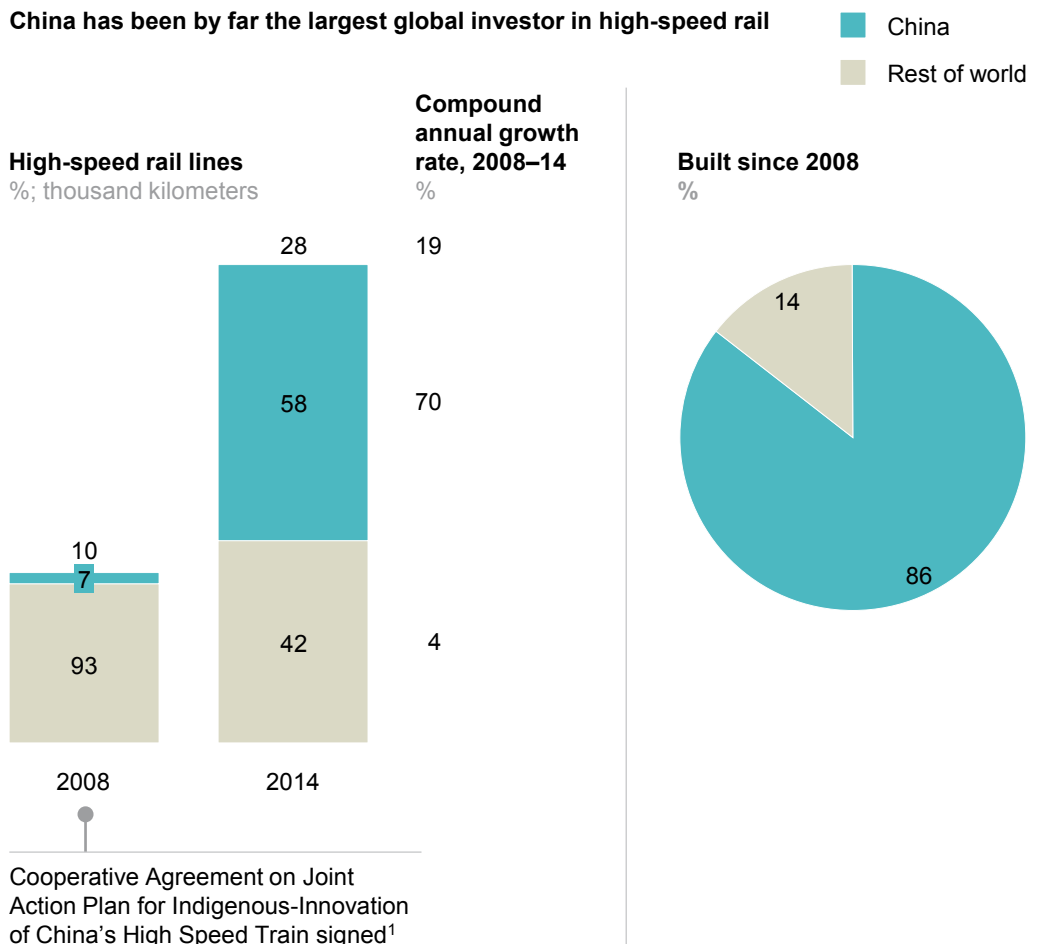
engineering teams at customer sites to manage fixes. In the process, Huawei gained critical experience and earned the trust of customers. Today, Huawei and ZTE are both global market leaders and spend nearly 19 percent and 10 percent of revenue, respectively, on R&D, and ZTE spends more than 10 percent. In both companies, employees involved in R&D account for about 40 percent of total staff. Huawei operates 19 joint innovation centers with European customers. In 2014, Huawei and ZTE submitted 3,342 and 2,179 international patent applications, respectively, making them No. 1 and No. 3 among global patent filers.⁶⁸

High-speed rail

The Chinese Ministry of Railways launched a 3 billion RMB (\$490 million) program in 2008 to develop a new generation of Chinese high-speed trains. As part of this plan, the Ministry of Railways arranged technology transfer agreements with overseas suppliers such as Alstom, Siemens, Bombardier, and Kawasaki Heavy Industries. By investing heavily in local demand, the government also created conditions for continuous learning through a cycle of development and commercialization, where customers can provide feedback to manufacturers on how to improve product performance. Since the technology transfer agreements were forged, China's high-speed rail market has grown by 70 percent per year, accounting for 86 percent of global growth (Exhibit 26).

Exhibit 26

China has been by far the largest global investor in high-speed rail



Cooperative Agreement on Joint Action Plan for Indigenous-Innovation of China's High Speed Train signed¹

¹ Agreement by Ministry of Science and Technology and Ministry of Rail for joint support of high-speed rail technology development, including via joint ventures with foreign suppliers.

SOURCE: Global Wind Energy Council; Chinese Wind Energy Association; International Union of Railways; China Statistical Yearbook; National Railway Administration; McKinsey Global Institute analysis

⁶⁸ "Telecoms firms lead WIPO international patent filings," World Intellectual Property Organization press release, March 19, 2015.

86%

China's share of global market growth in high-speed rail since 2008

The high-speed rail industry exemplifies the “digest and innovate” approach to learning. To advance learning, China South Locomotive & Rolling Stock Corporation Limited developed a 1:3 ratio approach: for every dollar spent on technology transfer, the company would invest three dollars to learn and apply the technology. Once they had the knowledge to do so, Chinese engineers pursued innovations to meet local requirements. In 2010, the company introduced the CRH380, China's first local locomotive design, which has a top speed of 380 km per hour. Other innovations include locomotives designed to operate in difficult environments, such as the Ha'erbin–Dalian route in the frozen northeast. Engineers developed a cabin designed for snowy conditions and ways to control water produced by rapid temperature changes. China has already built more than 16,000 km of high-speed rail lines, and Chinese equipment companies are in discussions with 28 countries for export deals.

Wind power

Policy also had significant effects on the evolution of knowledge in the wind-power industry, where technology transfer, local-content regulations, and investments in domestic capacity deepened Chinese engineering capabilities. The 2003 Wind Power Concession Project helped China's wind-power industry advance quickly along the learning curve. Between 2003 and 2014, China accounted for 35 percent of global growth in wind power capacity. This opportunity attracted foreign know-how and stimulated competition among domestic firms to innovate. To effect technology transfer, the government imposed localization rules under the Wind Power Concession Project—requiring 50 percent local content starting in 2003 and 70 percent starting in 2006.⁶⁹ As a result, foreign manufacturers and suppliers established plants or joint ventures in China, and in so doing, created regional clusters where domestic players could access global talent and knowledge networks. The project also required competitive bidding for wind-power equipment, which pushed innovation and led Chinese companies to establish R&D agreements with overseas design companies. UK-based Garrad Hassan collaborated with Zhejiang Windey and Baoding Tianwei; Aerodyn, a German firm, worked with Shanghai Electric. These collaborations helped Chinese suppliers learn quickly.

35%

China's share of global market growth in wind power since 2003

As seen in Exhibit 27, since the start of the Wind Power Concession Project, the gap in technology (in terms of power capacity per turbine) between foreign and domestic players has closed dramatically. In just three years, from 2004 to 2007, Chinese firms doubled their market share in China, and in 2014, domestic players were filling 98 percent of China's wind-turbine demand.

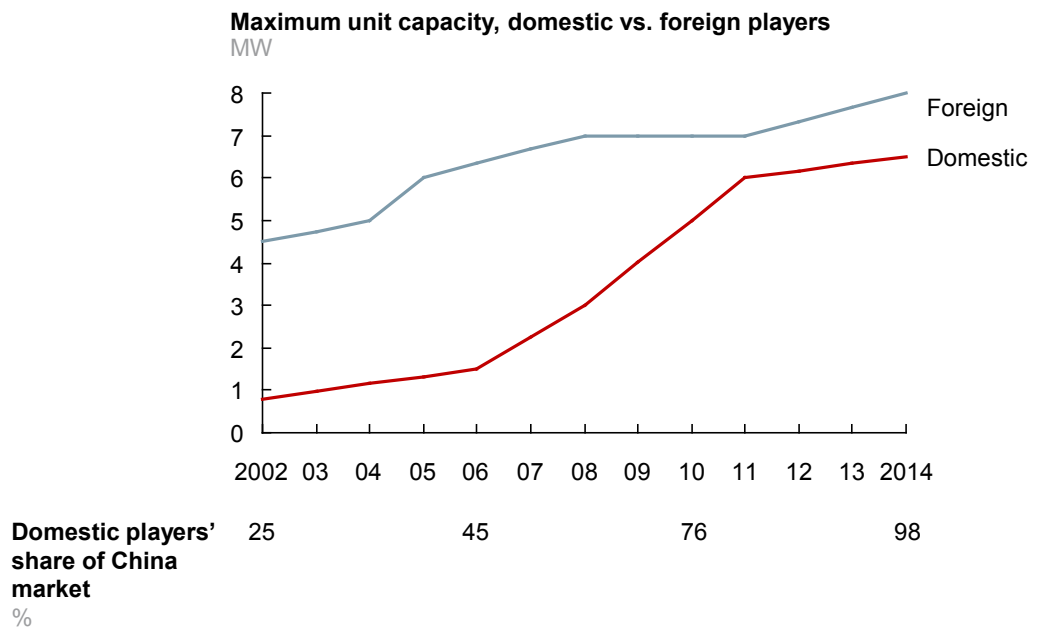
The wind-power industry is another example of Chinese companies using the “digest and innovate” approach to learning. Companies initially manufacture foreign designs through direct technology transfers and patent licenses from foreign partners. Over time, they develop sufficient capabilities to make incremental improvements and eventually produce their own designs. For example, Goldwind began manufacturing turbines under a license agreement with the US-based REpower, starting with 600- and 750-kilowatt turbines in 1999. As it gained experience, it began working with German supplier Vensys Energy to design 1.2-megawatt turbines. Eventually, Goldwind acquired a 70 percent stake in Vensys. This acquisition immediately improved Goldwind's design capabilities and provided a channel for the company to access new engineering talent in Europe. To integrate the two companies, Goldwind employees were encouraged to work in design and Vensys staff were encouraged to learn more about the manufacturing side of the business. Goldwind has focused increasingly on markets outside of China and now operates research centers in Beijing, Xinjiang, and Germany.

⁶⁹ Jean Ku et al., “Wind: The future is now,” *Renewable Energy World*, July-August 2005.

Today, some Chinese wind-turbine firms are operating near the technology frontier. For example, Envision Energy, the largest offshore wind-turbine supplier in China, has developed “smart” turbine technology that optimizes turbine operation by monitoring its own state and the surrounding environment, to make adjustments that the company says raise efficiency by 20 percent.⁷⁰ The company is also a leader in turbine technology for slow wind speeds; more than 60 percent of wind resources in China are characterized as slow. Envision is also working on ways to use superconducting materials in place of wire coils in the turbine generator to cut weight by an estimated 40 percent and boost power output.⁷¹

Exhibit 27

In wind power, Chinese players have captured the domestic market lead and are closing the gap in technology



SOURCE: Peng Ru et al., “Behind the development of technology: The transition of innovation modes in China’s wind turbine manufacturing industry,” *Energy Policy*, volume 43, April 2012; McKinsey Global Institute analysis

Auto manufacturing

In contrast to the wind-turbine and railway equipment industries, where government policies and actions helped accelerate learning and innovation, in the automobile industry, Chinese players have had limited learning opportunities and have not advanced as innovators. In autos, the government has fewer opportunities to shape local demand as a purchaser since cars are purchased by consumers. Indeed, where government has tried to shape the auto market—through high taxes on imports, for example—the effect of policy may have been to limit the development of innovation capacity. So, despite efforts to promote the domestic auto industry, policies that were designed to protect and nurture indigenous Chinese auto brands—such as joint ventures with major foreign manufacturers—have not yet led to their intended outcome. Chinese state-owned manufacturers have only 14 percent of the domestic market by volume (Exhibit 28). Even though China now has the world’s largest car market, Chinese companies have only 8 percent of global industry revenue.

⁷⁰ Envision website, www.envisioncn.com.

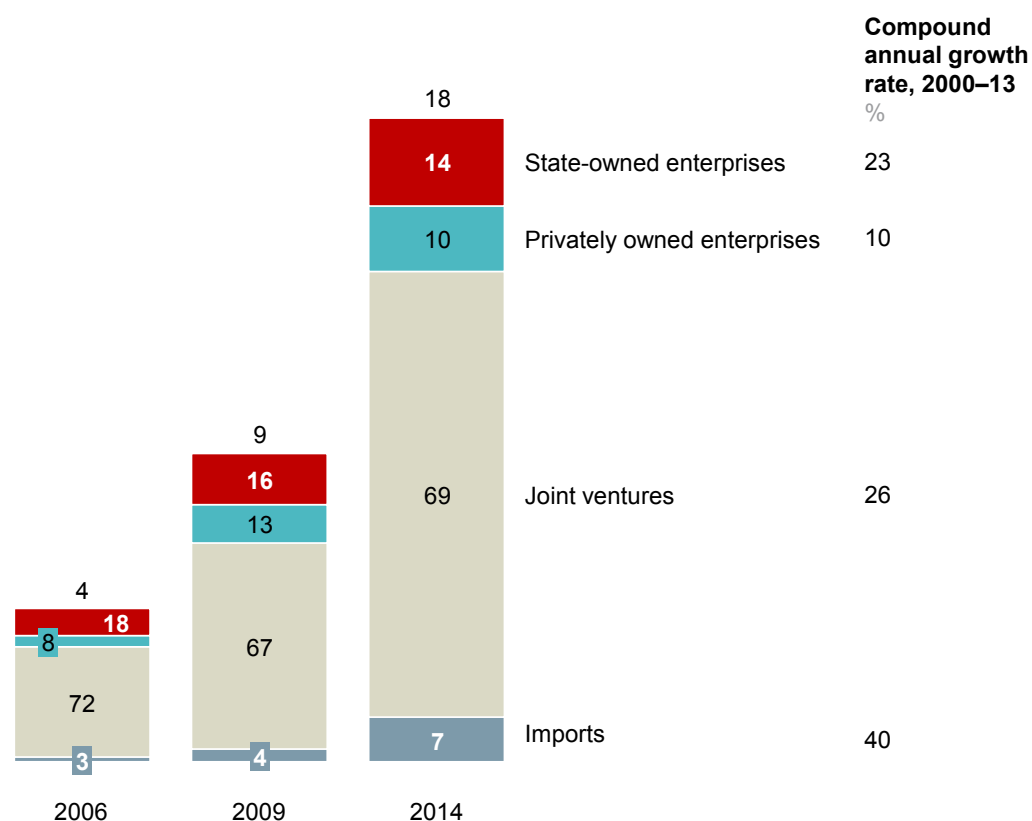
⁷¹ “Superconductive EcoSwing takes on full-size testing,” Offshorewind.biz, May 8, 2015.

Exhibit 28

State-owned car manufacturers have a 14 percent share of market volume

China passenger vehicle sales volumes by company type

%; million units



SOURCE: IHS Global Insight; McKinsey Global Institute analysis

NOTE: Numbers may not sum due to rounding.

Even in joint ventures between major overseas car manufacturers and Chinese state-owned enterprises, Chinese auto engineers have not developed strong innovation capabilities. To accelerate product development, foreign partners often import platforms from other markets, depriving their Chinese partners of the opportunity to gain knowledge from end-to-end product design. And, rather than developing their own platforms, some Chinese auto brands have outsourced engineering and design to foreign consultants. Such approaches have helped local brands shorten development time to four to five years, rather than the seven years that it takes foreign carmakers. But it has not helped build knowledge, and some Chinese designs have a reputation for poor quality.⁷²

The innovative capacity of Chinese automakers is also limited by the poor supplier ecosystem. Because the supplier ecosystem is not highly competitive, Chinese carmakers have limited opportunities to benefit from collaboration with suppliers on new products—a key source of engineering know-how. Only one company among China’s auto parts suppliers is in the top 100 global auto suppliers (Exhibit 29). Also, compared with industries such as communications equipment, in autos there are more limited opportunities to learn from parts suppliers. In communications, suppliers such as semiconductor manufacturers provide a good deal of the value in the product as well as knowledge for their customers. In autos, knowledge may flow more often from manufacturer to parts supplier, and engineering

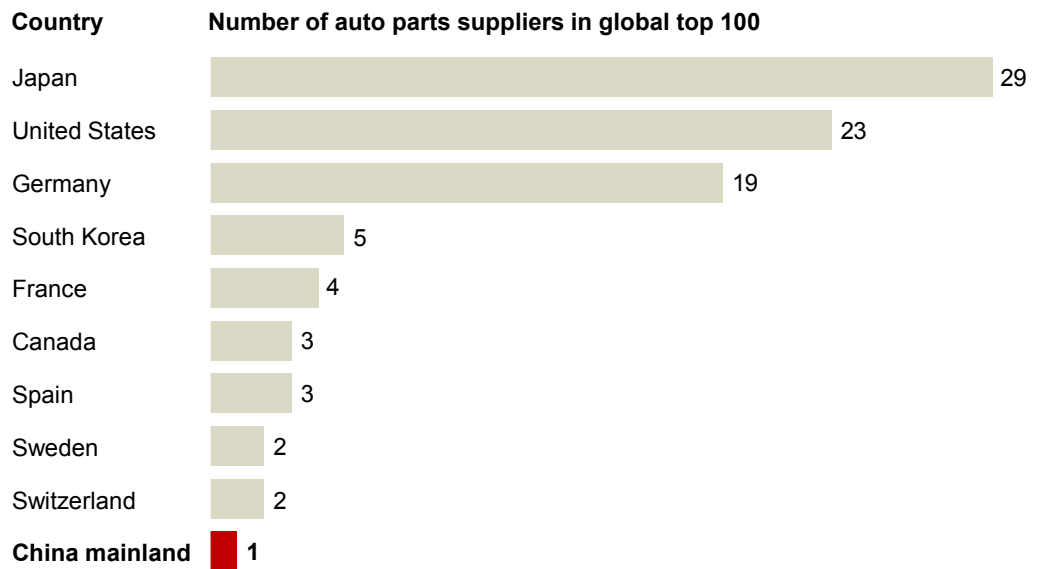
⁷² *Chinese autos, Part 1: The quest for global competitiveness—technology, competence, ambition and politics*, Sanford C. Bernstein & Co., February 2013.

innovation is largely based on the management of suppliers and expert integration of their products into finished vehicles.

Exhibit 29

Only one Chinese auto parts supplier is in the top 100

Countries with most auto parts suppliers in top 100 by size, 2013¹



¹ Suppliers are ranked by sales of original equipment parts in 2013.

SOURCE: Automotive News; McKinsey Global Institute analysis

A final issue for the Chinese auto industry is that state-owned enterprises dominate the sector, and the way state-owned enterprises are run works against the long-term investments and planning that engineering-based innovation requires. The leaders of China's state-owned companies are often rotated to other government appointments. One result of this short-term focus: Chinese players invest half what foreign partner companies spend on R&D (as a percent of sales). Between 2012 and 2014, General Motors applied for five to ten times as many patents as the top-performing Chinese automakers.

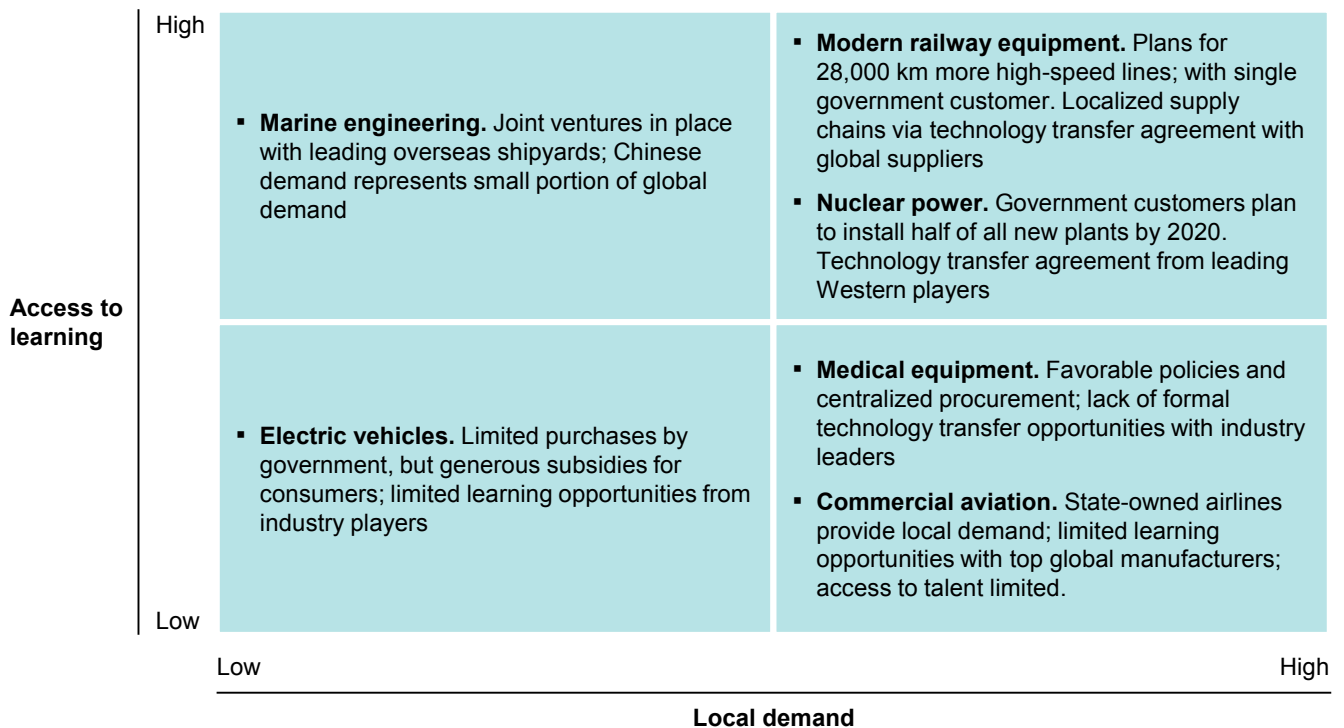
WHAT'S NEXT FOR ENGINEERING-BASED INNOVATION

Can China improve on its mixed performance in engineering-based innovation in the coming decade? The answer varies by industry. Based on the track record of engineering-based innovation, we expect that the fastest progress can be made by Chinese companies in industries that can rapidly accumulate experience by satisfying local demand and that can tap global knowledge networks. However, we also expect that two other factors will shape engineering-based innovation in the next ten years: rising competitiveness in some Chinese industries due to market reforms, and increased exposure to global competition as more of China's engineering-based companies expand overseas. Also, many fragmented industries in China have been or are in the process of being consolidated, particularly industries dominated by state-owned enterprises. This can drive overall improvements in corporate performance and create larger players that can invest in long-term R&D and innovation. In August 2015, a blueprint for broader reform of state-owned enterprises was approved by the State Council to limit government intervention in day-to-day operations of companies, allowing companies to respond better to market demand, including through innovation.

Other government initiatives will also shape innovation in engineering-based industries. In March 2015, policy makers announced “Made in China 2025”, which identifies ten priority manufacturing industries for improvement. Six of these industries fall in the engineering-based innovation archetype. Exhibit 30 shows these six priority industries and where they stand on local demand and access to learning—two factors that have driven successful engineering-based innovation by Chinese companies. Here, we look at five in depth: nuclear power, medical equipment, commercial aviation, electric vehicles, and marine engineering (the sixth, modern railway equipment, we discussed above).

Exhibit 30

Industries with access to greater learning opportunities and local markets are better positioned for innovation



SOURCE: McKinsey Global Institute analysis

50%
China's share of globally planned nuclear capacity

- **Nuclear power.** China is well positioned to become a leader in nuclear energy, with growing capabilities and a strong push from government, which wants to increase the use of nuclear power to reach its clean energy targets. Through collaboration with leading global nuclear players, Chinese suppliers have leapfrogged in technical skills and the Chinese government has increased its commitment to building nuclear plants as a way to reduce pollution and its effects on health and the economy. In 2010, the Ministry of Environmental Protection estimated that pollution cost China the equivalent of 3.5 percent of GDP, spurring the government to call for renewable energy and nuclear energy. In November 2014, President Xi Jinping announced a goal to increase the non-fossil-fuel share of all energy to around 20 percent by 2030.⁷³ To meet this goal, nuclear energy would rise from 2 percent of electricity production to 4 percent in 2020. As a result, China plans to have 58 gigawatts of nuclear capacity online in 2020, and 30 more gigawatts under construction.⁷⁴ This represents about 50 percent of all globally planned nuclear power additions, providing Chinese players with an opportunity to accelerate their learning.

⁷³ Mark Landler, “U.S. and China reach climate accord after months of talks,” *The New York Times*, November 11, 2014.

⁷⁴ *Energy development strategy action plan (2014–2020)*, China State Council, www.gov.cn.

Thanks to collaborations with Western nuclear players, China's state-owned nuclear power companies, China General Nuclear Power Group and China National Nuclear Corporation, have rapidly built capabilities for reactor design. The Hualong One reactor design was certified by the Chinese National Nuclear Safety Administration in 2014, making China the fourth country to build a Generation III reactor (joining France, Russia, and the United States). Construction of the first Hualong One reactor design started in May 2015. China has signed contracts with Pakistan and Argentina to export Hualong One technology, and is looking for other customers in Europe, South America, and Africa.

- **Medical equipment.** Chinese manufacturers have not yet captured a significant share of the global medical equipment market, but they are rapidly moving up the learning curve and entering global markets. The medical device category includes a wide range of products, from simple disposables (gloves, syringes) to therapeutic products (stents, pacemakers) to high-tech diagnostic equipment (MRI, CT, and PET scanning machines). The Chinese industry includes both private players and state-owned enterprises, and it benefits from aggressive government-funded purchasing programs. Government spending (executed by provincial and municipal hospitals) is expected to drive 12 to 14 percent annual growth in medical equipment sales through 2020, expanding the Chinese market to about \$70 billion per year. Recently, public hospitals have also been offered government subsidies if they favor domestically manufactured products in the bidding process. Locally made products can also get preferential, accelerated approval.

Aided by strong local demand, a dynamic group of Chinese players is emerging. They have sharpened their skills in incremental innovation, taking the costs out of equipment and device designs to serve the many Chinese health-care organizations that cannot afford global brands. Mindray, the largest Chinese player with \$1.2 billion in sales in 2014, specializes in selling patient monitoring, in vitro diagnosis, and medical imaging products to mid-tier hospitals for 20 to 30 percent less than what global brands charge. Mindray generates more of its sales outside of China (55 percent) than it does at home and has five R&D centers, with 1,000 employees, in China and the United States. Chinese companies are also gradually moving toward the high-end medical device market, where 70 to 90 percent of the market is held by foreign players. United Imaging, founded in 2011, has set a goal of entering the high-end medical device market. It has five R&D centers, and more than 1,000 R&D personnel, in China and the United States. United Imaging produces more than 20 high-end medical products.

In contrast to industries where Chinese firms are leapfrogging through formal technology relationships, Chinese players have had to build capabilities progressively by investing in internal R&D, extending R&D footprints globally, and partnering with foreign players. For example, MicroPort, a Shanghai-based maker of stents, purchased US-based Wright Medical in 2013, a stent manufacturer that complemented MicroPort's spine and trauma business. MicroPort now gets 60 percent of its revenue outside China and uses Memphis, Tennessee-based Wright as its global center for innovation in orthopedic products. Recognizing the global importance of the growing value segment, global companies in medical equipment are acquiring and partnering with Chinese players. Covidien, an Ireland-based maker of surgical supplies now part of Medtronic, formed a joint venture with Jiangsu-based Kangdi, a maker of medical staplers. It established a \$45 million R&D facility in Shanghai in 2012 to help enter the Chinese market. The center now employs more than 300 engineers.

- **Commercial aviation.** China's efforts to catch up with global suppliers in commercial aviation have been severely hampered by limited access to global learning networks. With their millions of parts from hundreds of suppliers, aircraft are among the most complex products to design and build. Even the most experienced global companies

have trouble managing the aircraft system integration process, and Chinese companies have found that there is no shortcut for acquiring the end-to-end knowledge of aircraft production. So, despite large investments in the Commercial Aircraft Corporation of China (COMAC), the hoped-for national champion has experienced lengthy delays on both of its first two planes: the ARJ-21 regional jet and the C919, a narrow-body plane that seeks to compete with the Boeing 737 and the Airbus 320.

Innovation in aviation in China will likely continue on a slow path due to lack of technology transfers from major manufacturers, limited learning opportunities from suppliers, and lack of access to the best talent. Unlike in high-speed rail, COMAC does not have the benefit of technology transfer through partnerships with other designers and manufacturers of long-haul planes such as Boeing and Airbus. COMAC has relationships with some of the world's top aerospace suppliers for everything from engines to avionics, but these partnerships do not provide the critical knowledge needed for successful integration of parts and subsystems, which is the central challenge in aircraft production. Finally, in the aircraft industry, access to global knowledge flows and talent is more limited since industries regarded as relevant to national security are subject to restrictions.

- **Electric vehicles.** Electric vehicles are a growing segment of the global auto market and represent a promising innovation opportunity for Chinese automakers. Today, the Chinese market for hybrids and plug-in cars is undeveloped in relation to other major car markets, accounting for just 0.3 percent of sales (compared with 1 percent in the United States). The Chinese government has singled out electric vehicles as a key sector to develop and has set a target of three million units per year by 2025.

Such growth will depend on greater advances by the Chinese industry. Electric vehicles require the integration of three evolving technologies: batteries, electric motors, and control systems. The Chinese government has made a strong commitment to electric vehicle development and has invested 37 billion RMB (\$6 billion), including R&D funding (for car manufacturers and research institutions) and investments in charging infrastructure, as well as purchase subsidies and tax breaks for buyers. The government has also driven the formation of consortia of car manufacturers, suppliers, and infrastructure players.

Despite these efforts, technology advances, vehicle sales, and infrastructure build-out are falling short of government goals. Only 134,000 electric vehicles are expected to ship in China in 2015, only 27 percent of the 500,000 goal, and only 632 charging stations—of a 2,000 target—will be in place by the end of 2015. One of the few bright spots in the industry has been the success of BYD (Build Your Dream), which had shipped more than 5,000 plug-in sport-utility vehicles in July 2015, making it No. 2 in the world to Tesla. BYD, which started out in the rechargeable battery business, also sells battery-powered buses and, in a joint venture with Daimler AG, builds Denza electric luxury cars.

Adjustments to policy approaches could accelerate electric vehicle adoption and innovation in China. Currently, China charges a 25 percent tariff on imported electric vehicles, while other nations have reduced tariffs to encourage market development. France, Norway, and Denmark, for example, have eliminated tariffs on imported electric vehicles. Also, in China, consumer subsidies to purchase electric vehicles apply only to locally produced models, reducing the impact of global competition to stimulate market demand and innovation. Finally, the standards for determining which locally-produced electric vehicles qualify for purchase subsidies are quite broad. Auto makers can convert models with internal-combustion engines to hybrids with only minor modifications to qualify, so many models are eligible for subsidies. This diffuses the impact of subsidies

and could delay the emergence of market leaders that can push the technology ahead. The government is considering ways to adjust subsidy rules.⁷⁵

- **Marine engineering.** The marine engineering industry provides vessels and platforms for offshore oil operations as well as tankers for liquid and compressed gas. Demand in this industry is expected to grow through 2025 as oil and gas exploration shifts to deeper waters and existing rigs and vessels age. China's government has included marine engineering as a target industry under the "Made in China 2025" initiative and is encouraging Chinese suppliers to move up the value chain from simple jack-up rigs to more sophisticated products such as semisubmersible platforms, drill ships, and floating storage and offloading vessels. Chinese players currently have around 25 percent of the marine engineering market, but they have not yet moved beyond more standardized products and many shipyards have a reputation for low production efficiency and quality.⁷⁶ Chinese advantages in labor and raw material costs are a big advantage over current industry leaders based in South Korea and Singapore, but Chinese technology and engineering capabilities are still developing, particularly when it comes to customized design. To compete in the more value-added and lucrative segments of the industry, Chinese companies will need to gain knowledge through close collaboration with customers. Local demand can help enable learning, though less so than in other industries. Between now and 2020, the vast majority of demand for rigs and ships will come from operators and service companies outside of China.



There are not many shortcuts to the knowledge needed for engineering-based innovation, as many Chinese companies have discovered. However, as China's success stories in engineering-based innovation demonstrate, there are proven paths to gaining critical knowledge and expertise. Chinese companies and policy makers can learn from these success stories and adopt strategies and policies to replicate them.

⁷⁵ For further details, see *Supercharging the development of electric vehicles in China*, McKinsey & Company, April 2015.

⁷⁶ "The deeper the better," *The Economist*, November 23, 2013.





6. SCIENCE-BASED INNOVATION

Science-based innovation—making scientific discoveries inventing truly new products—is what many people consider the highest form of innovation. Science-based innovation not only can lead to high levels of economic value but also can have profound social impact (lifesaving drugs, for example). China has placed science-based innovation near the top of the national agenda and has invested substantially in building the institutions and capabilities needed for discovery and invention. While progress is being made, these investments have not yet translated into innovation leadership. In the three industries we analyze that depend on science-based innovation, China is not a top global competitor: it has less than a 1 percent share of global revenue in branded pharmaceuticals, 3 percent in biotech, and 3 percent in semiconductor design. In these markets, Chinese firms still tend to focus on lower value-added products, such as generic pharmaceuticals. This record reflects both how long it takes to build science-based innovation capacity and how much catching up China still has to do, despite its large investments in R&D.

Chinese companies are forging their own paths—taking advantage of scale and speed advantages to innovate in uniquely Chinese ways.

We identify several reasons for the limited results from China's push into science-based innovation, including regulatory bottlenecks that limit market access for innovative products, lack of effective incentives for private-sector R&D (including guarantees that intellectual property rights will be protected), and inefficient allocation mechanisms for public research funding. There is also the matter of time. Science-based innovations, such as new drug or materials development, require long development cycles, as long as ten to 20 years in some areas. Therefore investments take time to bear fruit, and in most cases only large pharmaceutical companies are capable and willing to invest.

Meanwhile, in the industries that depend on science-based innovation, Chinese companies are forging their own paths—taking advantage of scale and speed advantages to innovate in uniquely Chinese ways. In life sciences, Chinese companies have been focusing on lower value-added segments, such as generic drugs. However, we see examples of companies in China that are making good progress using novel approaches to cut the time and cost of development and commercialization of patented drugs.

CHINA IS STILL LEARNING SCIENCE-BASED INNOVATION

In recent years, China has made substantial investments in science capabilities. It has invested in science education to raise the number and quality of scientists and researchers. It has also attracted Chinese scientists from overseas who have made significant contributions to research in industries such as biotechnology. As of mid-2014, China had 2,246 colleges and universities, second only to the United States.⁷⁷ Today, China graduates more university students in the STEM fields of science, technology, engineering, and mathematics than any other nation—about 2.5 million per year, or about five times the number in the United States. The difference is partly a function of population, but it also reflects a greater interest in the sciences. In China, more than 40 percent of college students choose STEM majors, compared with 32 percent in the United States.⁷⁸ At the postgraduate level, China conferred 218,700 master's degrees and PhDs in STEM areas in 2012, exceeding the 197,200 in the United States.⁷⁹

China has also used incentives such as guaranteed professorships and relocation allowances of 1 million RMB (about \$160,000) under the Thousand Talents program to encourage senior Chinese-born scientists who were affiliated with top overseas institutions to return. From its inception in 2009 to May 2014, the program had attracted more than 4,000 returnees, more scientists than had come back to China in the preceding 30 years.⁸⁰ Similar programs have been instituted at the city and provincial levels.

OBSTACLES IN BASIC RESEARCH AND COMMERCIALIZATION HOLD BACK INNOVATION

China's investments in science have led to publication of more scientific papers, more patent filings, and a growing science workforce, but have not yet translated into breakthrough innovations and commercial successes. In the four industries we analyze that rely most heavily on science-driven innovation, China has yet to approach global leadership. Chinese companies have less than 1 percent of global revenue in branded pharmaceuticals, 3 percent in biotech, 3 percent in semiconductor design, and 3 percent in specialty chemicals. And despite the quantity of patents and research papers, the quality of Chinese research still lags in terms of measures of innovation impact. For example, in the area of drug discovery, Chinese researchers have written 17 percent of all global life science journal articles and have filed 10 percent of patents, but they have produced only 2 percent of new drugs (Exhibit 31).

We identify several barriers to successful scientific innovation, affecting both academic and basic research and the commercialization of inventions by the private sector. Slow and cumbersome regulatory processes, for instance, remain a significant barrier to commercialization in pharmaceuticals. There is also underinvestment in basic research by the government. Chinese companies still spend far less on R&D, as a percentage of sales, than their larger global competitors do. There are also issues in the ways research projects are funded by the government and questions about oversight because of the persistence of fraudulent grant applications and research. Finally, better-qualified talent is needed by both academic research institutions and private R&D organizations.

⁷⁷ Ministry of Education, www.moe.edu.cn.

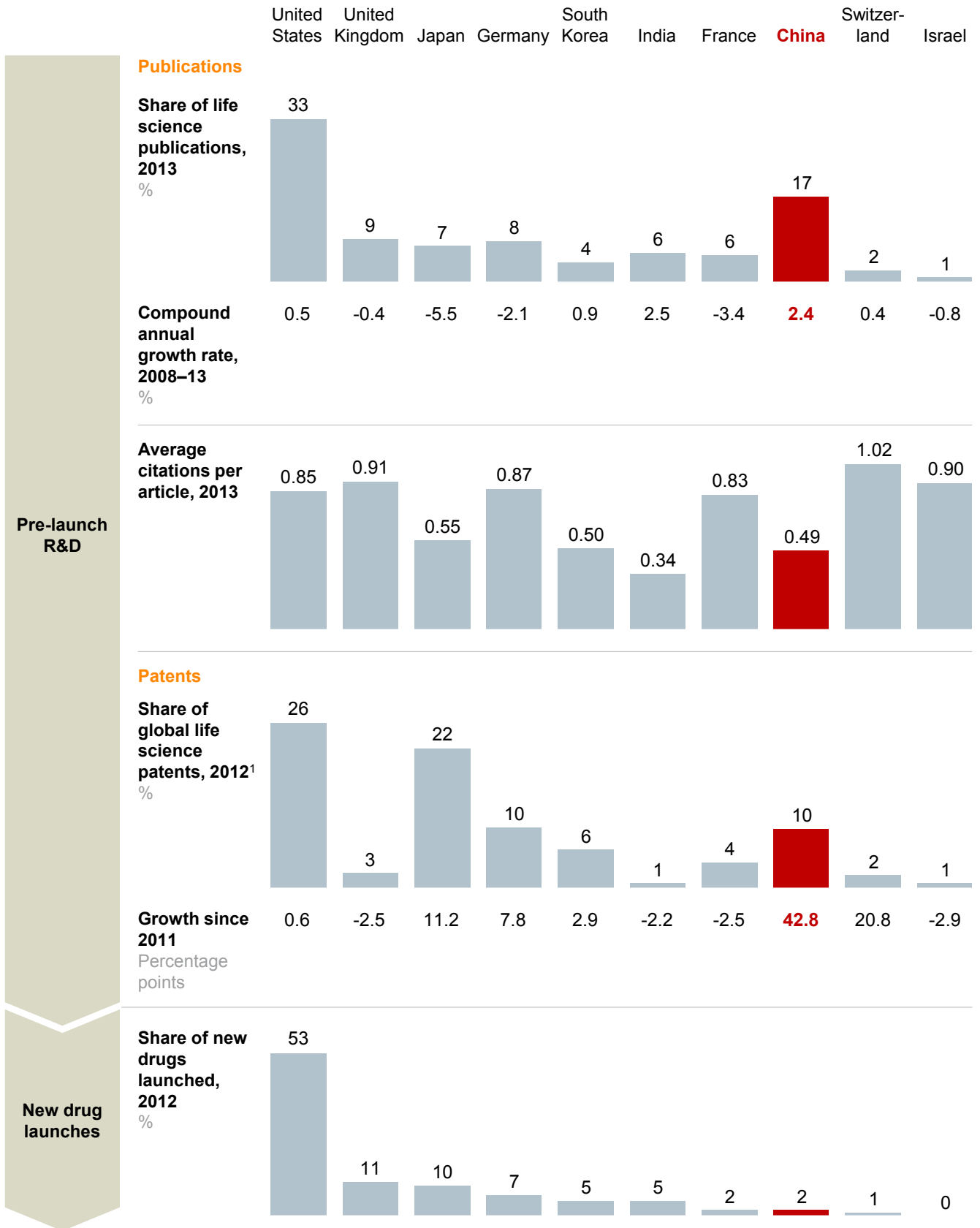
⁷⁸ As of 2013, data for China are from the National Bureau of Statistics and US data are estimated from the National Science Foundation's Center for Science and Engineering Statistics, Department of Education, and National Center for Education Statistics.

⁷⁹ China Ministry of Education Survey of earned doctorates, http://cn.chinagate.cn/infocus/2013-10/16/content_30315378.htm; National Science Foundation.

⁸⁰ The Thousand Talents Plan, www.1000plan.org.

Exhibit 31

Chinese researchers have published many papers and drug companies have filed many patents, but China has launched few new drugs



1 Patent Cooperation Treaty patents.

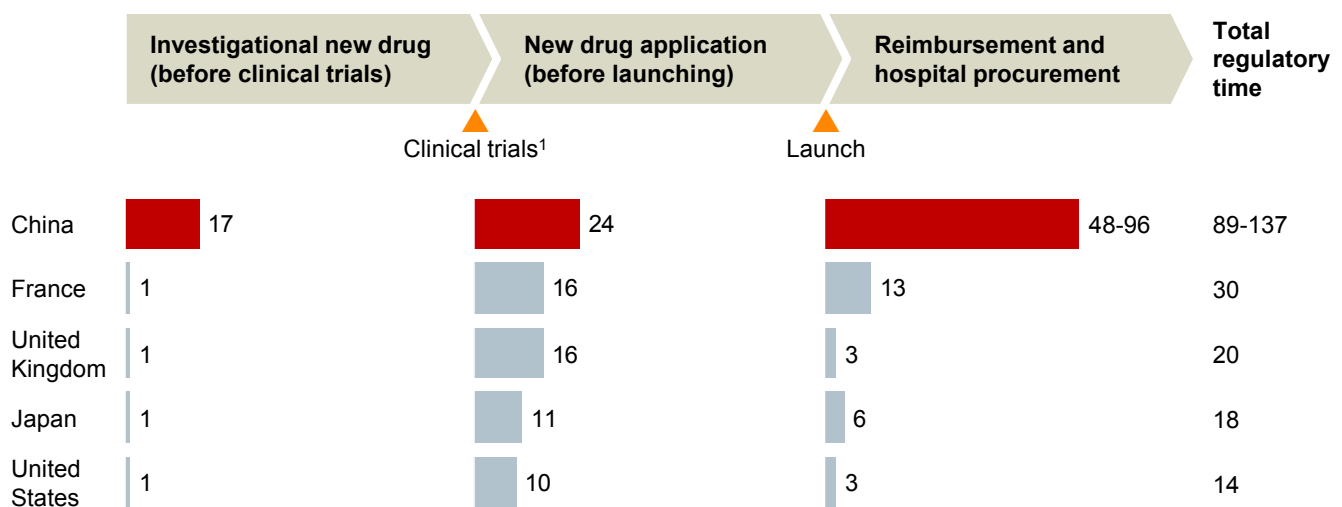
SOURCE: NSF Science and Engineering Indicators 2014; Web of Science; JLL Life Science Cluster Report 2014; SCImago Journal; McKinsey Global Institute analysis

- Regulatory issues.** Chinese drug companies face regulatory hurdles that have limited their commercial success. It can take two years longer to get a drug approved in China than in other countries, and it can take three to seven more years for a drug to be approved and become widely available (Exhibit 32). In the United States, for example, it takes a month, on average, to get approval for an “investigational new drug”—essentially permission to move from animal testing to human testing. In China it takes 13 months to approve trials for a conventional drug, and 21 months for a biological (protein-based) drug. Chinese regulators recently released a policy for reforms to move drugs to market more quickly by accelerating hospital procurement processes. One of the shortcuts would be to allow adoption of new drugs for formularies at the local level, rather than waiting for nationwide adoption. The reform is intended to accelerate commercialization of both generics and branded drugs and successful implementation could encourage Chinese drugmakers to invest more in innovation. Intellectual property protections also remain weak, which is a disincentive for attempting to commercialize inventions in China. While the government has taken steps to boost patent protection and the number of patent-related suits has jumped from 1,786 in 2008 to 24,479 in 2014, penalties are limited to fines, rather than damages, making litigation economically unattractive to many patent holders.⁸¹

Exhibit 32

In China, it can take up to five to nine years longer for a new drug to reach patients than in other countries, but a new policy would shorten that

Months



¹ Not included in calculation as it is not a regulatory process.
NOTE: Numbers may not sum due to rounding.

SOURCE: Thomson Reuters; European Medicines Agency; US Food and Drug Administration; expert interviews; McKinsey Global Institute analysis

- Underinvestment.** There are two ways in which China underinvests in science research. First, despite spending more than \$200 billion per year on research, China allocates only a small percentage—about 5 percent of the total—to basic research (Exhibit 33). Second, major Chinese research programs have not had adequate tracking or evaluation systems, and in 2014 scientists were implicated in embezzlement schemes.⁸² Evaluation for promotion of professors and doctors as well as for graduate students is usually

⁸¹ State Intellectual Property Office, www.sipo.gov.cn/tjxx/.

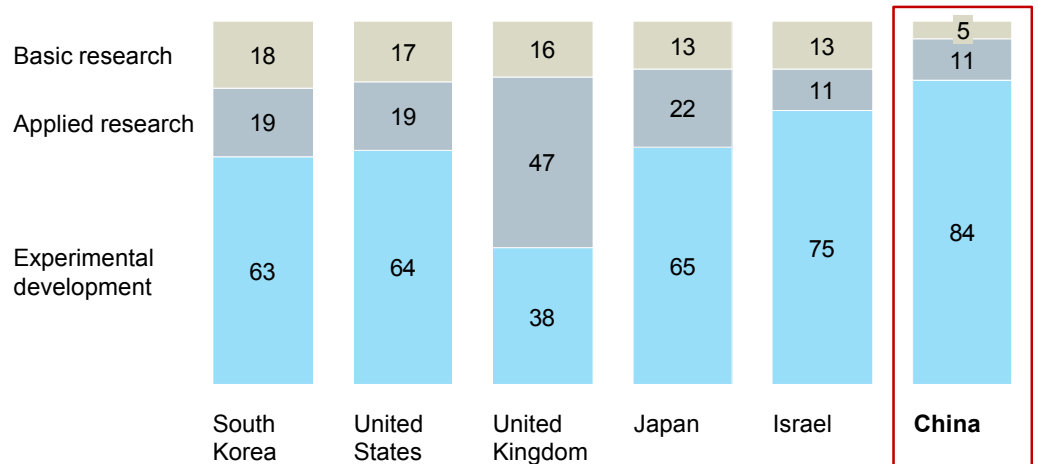
⁸² Jane Qiu, “Scientists caught in Chinese anti-corruption sweep,” *Nature*, volume 514, number 7522, October 16, 2014.

based on the number of papers included in the Science Citation Index, a database of citations in major journals.⁸³ In contrast, funders in the United States and other advanced economies have tried to de-emphasize volume of published research and rate research on criteria such as contributions to knowledge in the field of research. For example, overall impact of proposed projects is listed as one of the key aspects during funding reviews by both the National Science Foundation and the National Institutes of Health.⁸⁴

Exhibit 33

Only 5 percent of Chinese R&D is invested in basic research

Breakdown of R&D expenditure by type, 2012
%



NOTE: Numbers may not sum due to rounding.

SOURCE: OECD; McKinsey Global Institute analysis

Under pressure to get papers published, professors and graduate students in China tend to select research projects that will appeal to publishers, rather than pursuing the most innovative studies. Even worse, they sometimes have resorted to fraud. There is even a black market for papers, complete with price tags and, in one survey, a third of more than 6,000 scientific researchers at six leading institutions admitted to plagiarism, falsification, or fabrication.⁸⁵ A global study on retracted research articles published by *Proceedings of the National Academy of Sciences* in 2012 shows that China led the world in retractions of papers because of duplication, was in the top three for plagiarism, and was the fourth highest for fraud.⁸⁶ The Chinese government has announced a plan to reform research funding decisions by 2017, replacing current programs with five specialized “channels” to review different types of grants.

- **Lack of qualified talent.** Even though China leads the world in conferring PhDs and each year graduates more college students with degrees in STEM specialties than the next four countries combined, research institutions and companies still complain of a skills gap. Low pay for researchers in China also encourages science majors from top Chinese universities to choose opportunities other than research. Other graduates

⁸³ Li Jiao and Ma Qionghui, “China’s publication bazaar,” *Science*, volume 342, number 6162, November 29, 2013.

⁸⁴ National Science Foundation, www.nsf.gov.

⁸⁵ Jane Qiu, “Publish or perish in China,” *Nature*, volume 463, number 7278, January 14, 2010.

⁸⁶ Ferric C. Fang, R. Grant Steen, and Arturo Casadevall, “Misconduct accounts for the majority of retracted scientific publications,” *Proceedings of the National Academy of Sciences*, volume 109, number 42, October 16, 2012.

choose to go to advanced economies such as Germany, the United Kingdom, and the United States to pursue research work. According to a recent study, of all foreign students who go to the United States to study for doctoral degrees, a higher percentage of Chinese PhDs stay after graduation.⁸⁷ New policies have been announced to address some of these issues.

WHAT'S NEXT FOR SCIENCE-BASED INNOVATION IN CHINA

Today, Chinese companies in science-intensive industries are finding ways to build their capacity for frontier innovation, while also pursuing distinctively Chinese approaches for true innovation. These companies are using scale advantages, such as hiring thousands of PhDs, to speed up discovery. Chinese researchers are typically paid 20 to 40 percent of what researchers in advanced economies earn.⁸⁸ They are tapping the massive Chinese population to accelerate commercialization. Some are taking industrialized approaches to rapid experimentation and data collection. At the same time, a growing number of foreign drug companies are conducting R&D in China and using China for low-cost testing and manufacturing capacity as well as access to a large market.

We believe that China has the potential to become a global center for innovation in life sciences. This is possible because of the momentum of domestic and global players in science research, the growing innovative capacity of Chinese companies, and the size and speed of China's markets. China can build on its advantages and momentum in life sciences by making regulatory processes more transparent and efficient. Here we examine two examples of areas in which China is positioned to become a global innovation leader: drug discovery and genomic research.

Drug discovery

Today, more than 90 percent of the Chinese drug market is generics, rather than branded drugs. Chinese drug companies have an opportunity to move into branded drugs by focusing on diseases that are prevalent in the Chinese population. These include liver and stomach cancers: about 400,000 Chinese patients were diagnosed with stomach cancer in 2012 and 400,000 were diagnosed with liver cancer—11 to 18 times the rates in Europe and the United States (Exhibit 34). Incidence of hepatitis B is nearly 30 times the rate in the United States. Chinese drugmakers also are gaining better access to skilled biologists and chemists, thanks to the Thousand Talents program, which encourages overseas Chinese to return home.

Developing drugs in China for diseases that are prevalent in China is also an opportunity for global players. US-based Pfizer opened its China R&D center in Shanghai in 2005 and opened a second center in Wuhan in 2010 to focus on clinical research on diseases such as liver and lung cancer. Novartis opened a biomedical research center in Shanghai in 2009 also to focus on treatments for cancers that are common in China. Johnson & Johnson opened its fourth global innovation center in Shanghai in 2014 and is collaborating with top local institutes such as Peking University, Zhejiang University, and China Pharmaceutical University.

Chinese companies are using novel approaches to develop drugs and are taking advantage of scale and a low cost structure to accelerate research. BeiGene and Hutchison MediPharma are examples of innovators in drug discovery. WuXi AppTec provides research and production services for Chinese and global companies.

⁸⁷ Michael G. Finn, *Stay rates of foreign doctorate recipients from U.S. universities, 2011*, Oak Ridge Institute for Science and Education, January 2014.

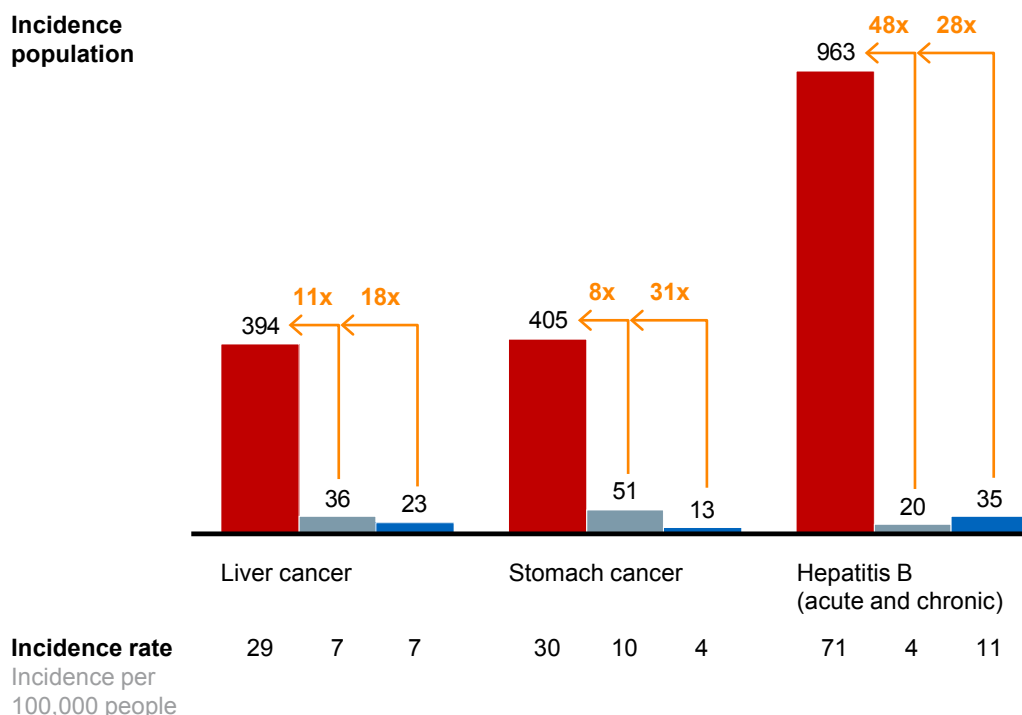
⁸⁸ Hepeng Jia, *China calls on foreign postdocs*, Royal Society of Chemistry, 2011.

Exhibit 34

China has advantages in developing treatments for diseases that occur more frequently in its population

Selected oncology and infectious diseases across geographies ■ China ■ EU¹ ■ United States

Incidence population



¹ Statistics for 28 European Union and European Economic Area member states.

SOURCE: International Agency for Research on Cancer; Population Reference Bureau; US Centers for Disease Control and Prevention; European Centre for Disease Prevention and Control; China National Health and Family Planning Commission; McKinsey Global Institute analysis

- BeiGene:** BeiGene, a biopharma company, has found a way around one of the most common problems that hold back successful drug commercialization—drugs that perform well in preclinical testing on animals, then fail in human trials. An estimated 90 percent of proposed drugs fail in the human clinical trial stage, costing companies years of effort and perhaps hundreds of millions of dollars. BeiGene is addressing this obstacle with a proprietary method for testing compounds on human cancer cells to get an early indication of whether they will succeed during the clinical trial phase. The approach enabled the company to get four cancer drug candidates into clinical trials within the past 18 months.
- Hutchison Medi Pharma:** It is not uncommon in the pharmaceutical industry for companies to abandon drug candidates under development because of setbacks, cost concerns, mergers, or shifting priorities of company leadership. Hutchison Medi Pharma empowers scientists to sustain research when other drug manufacturers have given up, and it is willing to invest the additional time and money needed to bring a drug to market. One of Hutchison Medi Pharma's advantages, it claims, is more patient capital than other biotech startups—the company's lead investor is Li Ka-shing, the billionaire owner of Hutchison Whampoa, a Hong Kong-based conglomerate. In some cases, Hutchison Medi Pharma has taken on development of potential drug molecules after they were abandoned by other companies due to technical difficulties. One example is research

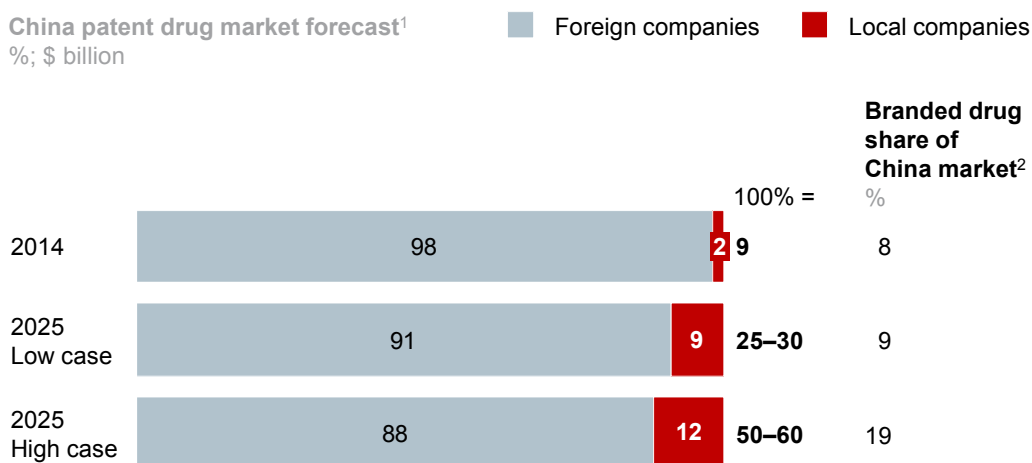
on a c-Met inhibitor, a potential cancer drug target that was abandoned due to kidney toxicity. Hutchison eventually modified the molecule to resolve the issue.

- WuXi AppTec:** Drug companies often rely on contract research organizations to conduct trials and other phases of research. WuXi AppTec, a CRO that also provides outsourced manufacturing capacity, is applying an industrial approach to contract research by using scale to reduce time and cost. It is also expanding the range of services it offers, from preclinical testing to clinical trials. It retains a massive in-house staff, including more than 4,000 chemists, and has amassed a large collection of lab equipment. These investments not only provide economies of scale and speed, but also allow WuXi to turn on capacity as needed by customers. The company has developed its own software to manage its machinery and claims to have achieved utilization rates of 100 percent (for eight hours a day, five days a week). WuXi AppTec has become the largest contract research organization in the Asia-Pacific region, with sales of \$674 million in 2014. It has expanded to 19 sites in Asia, the United States, and Europe.

Innovation—by Chinese and foreign companies—can help the Chinese pharmaceutical industry evolve. In 2014, branded products accounted for 8 percent of the \$100 billion Chinese pharmaceuticals market. Innovation can help accelerate the growth of the branded drug segment. In our low-case estimate, by 2025, branded products could be about 9 percent of the market and account for about \$25 billion to \$30 billion a year in sales (Exhibit 35). But in an upside case, where more branded products are developed and approved in China due to improved innovation processes, patented drugs could capture 19 percent of the market in 2025, with sales of nearly \$40 billion to \$60 billion per year. Depending on how well Chinese pharmaceutical companies build their capabilities, they could increase their share of the local branded drug market to 9 to 12 percent in 2025.

Exhibit 35

Local players can capture a larger share of the patent drug market by 2025



¹ Patent drugs are branded drugs before patent expiration.

² Patent drug market size divided by total pharmaceutical market size in China.

SOURCE: Global Business Intelligence; IMS Health; Justin Chakma et al., “Asia’s ascent—Global trends in biomedical R&D,” *New England Journal of Medicine*, 370.1 (2014); McKinsey Global Institute analysis

Genomics research and commercial applications

China has already become a major center for genomics research, because its population affords access to abundant and diverse genomic data and because Chinese companies have built up sequencing capacity. These capabilities give China the potential to take the lead in developing commercial applications of genomics, such as genetically modified crops and personalized medicine. Here we look at two companies that are leading in genomics innovation.

- **BGI.** This Shenzhen-based biotech company recognized that gene sequencing also is largely about computing power and data mining. The company has innovated in two ways: employing more than 2,000 PhDs and tapping China's enormous population for genomic data. At one time, BGI once owned about half of the world's genome sequencing capacity. Today it produces at least a quarter of the world's genomic data, more than any other scientific institution. As of June 2014, BGI had 230 sequencers, which could generate 16 terabytes of sequencing data per day, or capacity to map genomes for approximately 100 to 200 people.⁸⁹ BGI has also ventured into cloning, producing 500 cloned pigs a year, which makes it the world's biggest center for animal cloning.⁹⁰
- **Berry Genomics.** Many Chinese hospitals and testing labs lack the financial and technical resources to perform genetic testing for infectious diseases or for prenatal genetic screening. Berry Genomics, which was founded by former BGI employees, is trying to address the challenge by introducing low-cost and easy-to-use sequencing machines. The company says its machines can cut the cost of genetic tests by 50 percent. To design its machine, Berry collaborated with US-based Illumina. The companies co-developed the sequencer and a non-invasive prenatal testing kit, both of which have received premarket clearance from the China Food and Drug Administration.⁹¹

Innovations based on genomic research have important implications for the Chinese people that can lead to many commercialization opportunities. For example, China still needs to address food security issues, which affect millions of people. In 2014, BGI, the Chinese Academy of Agricultural Sciences, and the International Rice Research Institute published the genomes of 3,000 rice varieties, quadrupling publicly available genetic information about rice to speed development of rice strains that resist disease and grow more rapidly to increase yields.⁹² Berry Genomics has announced plans to use Alibaba's cloud computing platform to analyze more than 400,000 genomes to develop custom therapies for Chinese patients. Jun Wang, the former CEO of BGI, is developing an artificial intelligence health monitoring system to link genomic and lifestyle information to provide advice on how to prevent disease.



Advancing to leadership in life sciences and other science-based industries is the highest hurdle for innovation in China. It takes years of investment and relentless effort to produce and successfully commercialize new drugs or get a new type of crop into the ground. China continues to invest in the capabilities of science-based innovation and, increasingly, Chinese companies are showing that with ingenuity and scale, they have the potential to start showing better results. It will take further investment, with continued oversight, and continuing reforms to unleash the full potential of China's innovators in science.

⁸⁹ Michael Specter, "The gene factory," *The New Yorker*, January 6, 2014.

⁹⁰ David Shukman, "China cloning on an 'industrial scale,'" *BBC News*, January 14, 2014.

⁹¹ "Berry Genomics NextSeq CN500 instrument and non-invasive prenatal testing reagent kit receives Chinese FDA premarket clearance," Berry Genomics and Illumina press release, March 31, 2015.

⁹² Jia-Yang Li, Jun Wang, and Robert S. Zeigler, "The 3,000 rice genomes project: New opportunities and challenges for future rice research," *GigaScience*, volume 3, number 8, May 2014.



7. THE CHINA EFFECT ON GLOBAL INNOVATION

As the second-largest economy (by GDP) and the most populous nation, China exerts a strong influence on the rest of the world. Its progress and success have not only benefited hundreds of millions of its own citizens, but have also helped drive growth in other nations that trade with China and supply the raw materials China's industries need (and when China struggles, the effects are also felt globally). The China effect also applies to global innovation, and that influence, we believe, will grow and become far more apparent around the world over the next ten years. In this chapter we examine the China effect on innovation and look at the ways in which companies and China's policy makers can maintain the momentum in Chinese innovation and broaden the scope of Chinese innovation leadership.

THE CHINA EFFECT

The "China effect" on global innovation can be boiled down to three ideas: cheaper, faster, and more globally connected. Chinese innovators are showing that innovation can be done inexpensively and on a large scale; they are vastly accelerating the speed of innovation; and they are demonstrating how China can be a platform for global innovation. Understanding the China effect on global innovation will be essential for companies that wish to compete in China, take advantage of China's innovation capacity, and adopt Chinese approaches to innovation to improve their own performance. The overall effect is that more innovation will originate in China—from both Chinese and global companies—and more companies would adopt the Chinese style of innovation. The China effect has the potential to increase competition around the world, disrupt markets and industries, and fill the unmet needs of consumers in emerging economies, while allowing companies to serve the rapidly shifting preferences of consumers in advanced economies. Overall, the effect could be profound.

Understanding the China effect on global innovation will be essential for companies that wish to compete in China, take advantage of China's innovation capacity, and adopt Chinese approaches to improve their own performance.

Cheaper: China has developed a low-cost, large-scale innovation model

China's particular characteristics and challenges have helped make it a leader in low-cost innovation. In China, innovators can tap a large supply of low-cost talent—for everything from factory work to basic research. And they can use the speed and scale of the Chinese market to commercialize their inventions quickly and at minimal cost. Although wages are rising, China still offers low-cost capacity for R&D and manufacturing. Chinese manufacturing workers and researchers are both paid 10 to 20 percent of what their counterparts in advanced economies command. Even with recent wage increases, it is estimated that by 2019, Chinese manufacturing labor costs would still be just 12 percent of the US level, up from 8 percent today. Over the years, Chinese companies learned how to take costs out as they fashioned “good enough” products for their developing economy—appliances with 80 percent of the functionality and a fraction of the cost of global brands, for example. That talent is now being applied to “cheaper and better” products for increasingly demanding Chinese consumers, and to exports. At the same time, China's large domestic market helps companies accelerate along the learning curve and find operating efficiencies rapidly. The scale of the Chinese talent pool is another important factor in low-cost and rapid innovation. Chinese universities confer nearly 30,000 PhDs in science and engineering every year and graduate 2.5 million students with degrees in engineering and other STEM specialties every year.

Faster: China is accelerating the pace of innovation

China's large consumer and B2B markets enable companies to scale up quickly, which is increasingly important for successful innovation. Chinese companies have developed a unique innovation model for rapid commercialization. As they have attempted to keep up with massive demand, Chinese innovators have learned to be fast and nimble—digesting market feedback and quickly turning it into new features and designs. “China speed” is often a function of scale. China is already the largest or second-largest market in the world in categories ranging from autos to smartphones, typically accounting for 10 to 30 percent of global demand. China has 650 million Internet users, compared with 230 million in the United States. It has 750 million smartphone users vs. 177 million in the United States. China's railroads and utilities are the biggest buyers of high-speed trains and wind turbines.

Chinese companies have developed a unique innovation model. They have learned to be fast and nimble—digesting market feedback and quickly turning it into new features and designs.

The ability to innovate quickly and on a massive scale could give Chinese players a significant advantage in the competition for emerging markets in the next decade, as nearly three billion people will join the consuming class. The Chinese model is applicable to all markets, not just developing economies. The clock speed of all sorts of markets has accelerated, and customer requirements are continually shifting—and rising. Companies that innovate at a traditional pace will have difficulty keeping up. But by adopting elements of the Chinese model to generate ideas more rapidly and get them into the market sooner (and then refine them), companies can compete better in both manufacturing and service innovation. Increased competition from China, from emerging economies that follow China's lead, and from multinational companies that need to keep up should lead to more innovation and greater benefits to consumers and business customers.

More globally connected: China is becoming a globally integrated platform for innovation

China is becoming a platform for global innovation—for both Chinese companies and multinationals. China has a huge pool of research talent, low-cost and flexible R&D capacity, and a manufacturing ecosystem that can turn ideas into products rapidly and inexpensively. This can help move the center of gravity for global innovation toward China and help local and global companies accelerate innovation.

Chinese and global companies are building their own research facilities to take advantage of Chinese resources and are also tapping the many virtual resources that Chinese companies offer. In life sciences, for example, Chinese contract research organizations are using the scale of the Chinese population and large-scale resources (both researchers and equipment) to speed up drug development for customers around the world. Global companies and entrepreneurs (from China and around the world) can plug into China's emerging "open innovation" platform to get a prototype in as little as one-fifth the time that it would take in-house and can move a product into full production by tapping on-demand manufacturing capacity. Chinese innovation is also driven by China's challenges. For example, China must deal with some of the world's most daunting environmental problems. Addressing them will shape innovation in China in the coming decade and could broaden its innovation leadership by providing solutions to energy and environmental challenges that can work across the world.

CAPTURING VALUE FROM CHINESE INNOVATION

As we have seen, China is becoming an innovation leader in some industries and has built the capacity to be a global innovation hub. It has also developed unique approaches to innovation that could be a model for the rest of the world. However, to maintain this momentum, businesses and policy makers will need to address barriers to innovation and put in place "enablers." Strong clusters of companies, suppliers, research institutions, and other resources that concentrate knowledge, energy, and activity around particular types of industries are emerging and could have global impact (see Box 8, "China's innovation clusters"). Barriers include limited access to capital for small companies that could be stronger innovators and regulatory systems that slow commercialization of innovative ideas.

Here we look at the company strategies and public policies that would build on China's innovation strengths and, over the next decade, help China to be recognized as a center of global innovation. These policies and strategies will need to be flexible and dynamic to accommodate rapid shifts in markets and technologies. To pursue innovation as a national priority and as a driver of company performance, policy makers and business executives will need to learn to adapt quickly to new data and insights and to think creatively about innovation.

As we have seen, innovation can happen anywhere and thrives in open systems and in competitive markets. This requires both new approaches to innovation policy and a willingness by policy makers and business leaders to cede control so that creative entrepreneurs and employees have the freedom to explore, experiment, and build. Policy also should be built on knowledge of how the four archetypes work. Here we offer suggestions for possible policies and strategies to capitalize on and support innovation in China. Some are broadly applicable across our four innovation archetypes. Some apply to only one or two.

Box 8. China's innovation clusters

China has three major innovation cluster cities—Beijing, Shanghai, and Shenzhen—and a group of smaller but rapidly growing innovation clusters in other cities (Exhibit 36).

Beijing is the center of technology innovation and has a large R&D talent pool. It is home to 26 of 112 key national universities (designated by the Ministry of Education) and research centers of global companies such as IBM and Microsoft. Leading Chinese tech companies, including Lenovo, Xiaomi, and Baidu, are headquartered in the Zhongguancun district of northeastern Beijing. An estimated 49 companies launched every day in 2014.¹ Innovators benefit from proximity to the capital and government ministries, but the cluster could have better coordination across companies, research institutions, and universities.

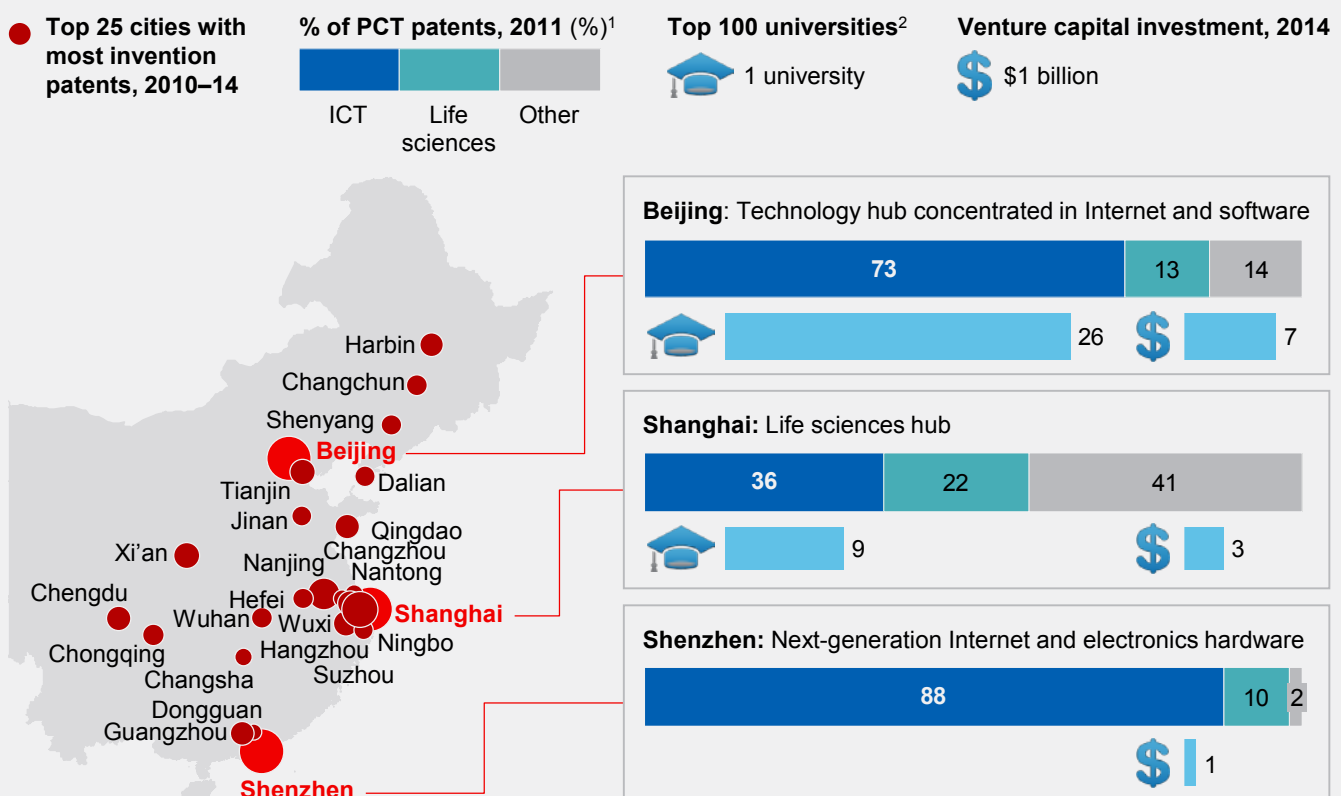
Shanghai is becoming the hub for life sciences, with the largest concentration of life science companies and the R&D operations of 11 of the 14 largest global pharmaceutical companies, many in the Zhangjiang technology park. There are also contract research organizations to serve both Chinese and global companies with trials and other outsourced services. Shanghai is dominated by large enterprises and could do more to encourage innovation by entrepreneurs and by small and medium-sized enterprises.

Shenzhen was designated a special economic zone in the 1990s and has become the center of tech and Internet startups, including Tencent and Huawei. More patents have been awarded to Shenzhen companies than to companies in Beijing and Shanghai combined. Proximity to electronics manufacturing operations in Guangdong Province has made Shenzhen a center of tech hardware innovation. Shenzhen could benefit from the richer talent pipeline that stronger universities and research institutes could provide.

¹ "China's Silicon Valley sparking 49 technology startups a day," Bloomberg, March 11, 2015.

Exhibit 36

Beijing, Shanghai, and Shenzhen are China's top innovation clusters



¹ PCT patents are international patents filed under the Patent Cooperation Treaty.

² "211" universities stands for 21st century and 100 universities (actual number is 112), a project initiated by the Ministry of Education to raise the research standards of high-level universities.

NOTE: Numbers may not sum due to rounding.

How companies can use Chinese innovation to enhance global competitiveness

Here we look at how companies can take advantage of China's distinctive innovation capabilities and help expand them (Exhibit 37). For Chinese companies and global companies operating there, China provides a unique testing ground and launchpad for innovations in everything from appliances for emerging markets to bioengineered drugs. For their own benefit and for China to meet its innovation imperative, both domestic companies and global companies operating in China can make bigger bets on innovation in China. Companies can also adopt the China speed of innovation, discover new sources of innovation outside their companies, and build innovation talent pools.

Exhibit 37

How companies can innovate in China

● Primary ● Secondary

Theme	Action	Science-based	Engineering-based	Customer-focused	Efficiency-driven
Making bigger bets on China's innovation potential	Invest in basic research	●	●		
	Move operating units to China	●	●	●	●
	Strengthen global research footprint	●	●	●	
Operating at China speed	Accelerate test-learn-refine cycle	●	●	●	●
	Engage Chinese consumers directly		●	●	●
	Tap China's open innovation ecosystem	●	●	●	●
	Flatten organization		●	●	●
Discovering new sources of insight	Use internal competition to generate ideas			●	●
	Tap outside sources for ideas	●	●	●	●
Building a Chinese talent pool	Develop talent directly	●	●	●	●
	Recruit talent in novel ways	●	●	●	●

SOURCE: McKinsey Global Institute analysis

Making bigger bets on China's innovation potential

Both Chinese companies and global companies operating in China can make larger investments in innovation in the country, to take greater advantage of China's innovation capacity and make it a base for innovation for all markets.

- Invest in basic research in China.** China is an increasingly attractive location for companies to pursue basic research in the life sciences. There are stronger capabilities in companies and institutions and an improving talent pool. Foreign companies have established more than 1,200 R&D centers in China, but most focus on commercial opportunities for the local market rather than pursuing innovations they can use globally. This is partly due to concerns over intellectual property, but it also reflects an outdated bias about the capabilities of Chinese innovation talent. Nearly a decade ago, Microsoft took a different tack. It expanded the responsibilities of the Beijing-based Microsoft Asia-Pacific Research and Development Group in 2006 to take on global research assignments. Today, more than 3,000 scientists and engineers, including some transferred from Microsoft headquarters, are assigned such frontier topics as natural user interfaces, next-generation multimedia, and data-intensive computing. They recently developed Xiaolce, a language-recognition engine that uses artificial intelligence

algorithms to understand human language and engage in conversation. The first version understands Chinese, and Microsoft is adapting it to other markets. Baidu, a leading local search engine company, is increasing investment in basic research, too, focusing on artificial intelligence. The Beijing Deep Learning Lab opened in 2013 in Silicon Valley, funded with \$300 million and charged with recruiting leading scientists.

- **Move operating units to China.** For a growing number of companies, it makes sense to base entire operations in China to commercialize innovations and penetrate the Chinese market. China then can be the base from which companies spread those innovations to other emerging markets in Asia and elsewhere. Companies not only benefit from proximity to target customers, but they also can take advantage of low-cost local talent and China's huge supplier base to accelerate innovation. With sales of small appliances declining in advanced economies and rising in emerging markets, in 2011, Philips relocated its global headquarters for home appliances (including vacuum cleaners, juicers, and rice cookers) to China. Its small appliance sales grew 56 percent between 2012 and 2014. GE is also making a big bet on China-based operations. In 2011, the company moved the headquarters of its 115-year-old X-ray business from the United States to Beijing to tap into growth opportunities in emerging markets. It has opened three innovation centers in China. GE is now producing X-ray and CT scanners that are designed and built in China for sale across the region and says it is developing products in China in as little as half the time and for 20 to 40 percent less cost than in the United States for some product lines.
- **Strengthen China's global research footprint.** For Chinese companies to sharpen their innovation skills and serve foreign markets, they need to conduct R&D in their most important global markets. Chinese companies such as Huawei in telecom equipment and WuXi AppTec in pharmaceuticals have already built global R&D footprints with research centers and joint-venture R&D activities around the world. Lenovo continues to benefit from maintaining dual headquarters in Beijing and in North Carolina in the United States, the former headquarters of IBM's ThinkPad division, which Lenovo acquired in 2005. The North Carolina headquarters has more than 2,000 employees, including an R&D department, helping the company double its share in the US market since 2011.

Operating at China speed

One of China's biggest contributions to innovation may be speed. In industries as varied as smartphones and medical equipment, Chinese companies have shown that they can move from idea to commercial product or service in far less time than companies in other economies. Traditionally, large companies have had long development cycles, made longer by the extra time it takes for multiple sign-offs at various milestones. In China, even large organizations have learned to operate at China speed to keep up with fast-moving local markets. Chinese innovators grab new ideas from the market, take bold bets on early designs, and quickly scale up production of products or implementation of new services. Global players can benefit by emulating China's rapid innovation approaches. At the same time, Chinese innovators will need to think about how they can remain nimble and continue to operate at China speed as their companies grow.

- **Accelerating the test, learn, and refine cycle.** To attain China speed, companies need to compress the time it takes to turn customer feedback and other data into new features or products. Mindray, a maker of medical devices, gathers customer insights from many sources—its sales network, maintenance reports, doctor reviews, and customer service data—and relays them directly to product development teams in its R&D center. The

company claims that it can start work on a new idea within a week of the idea's approval. The approval process itself has been streamlined, which accelerated Mindray's product launch cycle to every six months, compared with the two-year cycle of many foreign competitors.⁹³ Further time savings come from using one round of prototyping instead of the four rounds that global companies often rely on.

- **Engaging directly with the Chinese consumers.** The Internet has provided a way to get instant feedback from consumers everywhere, and Chinese consumers are particularly eager to share their opinions. In online forums and on social media sites, they talk about products they like, share advice, and voice opinions about features, pricing, or policies they dislike. Many Chinese consumer-facing companies have websites for customers to share their thoughts and social media pages where fans gather. Xiaomi, for example, regularly posts proposed features for smartphone software on an online forum for its fans. Consumers vote for their favorite ideas, and the company adds popular ones to the product development system, sometimes within a week. The result: Xiaomi has more competitive products and more loyal customers.
- **Tapping China's open innovation ecosystem.** One factor in China speed is the ability to tap into a growing ecosystem of outsourced services that can take on design, prototyping, and manufacturing. This system can reduce cost and shave months off the innovation process. For example, it takes half the time to get a prototype of a consumer electronics product designed and built by a service in Shenzhen than it would take to do the work in-house—and usually for one-fifth of the cost. Established companies in China—both domestic and foreign-based multinationals—can make better use of this “open” innovation network. DJI, a Shenzhen-based technology company, for example, became the top maker of civilian drones by tapping suppliers and designers in Shenzhen's manufacturing ecosystem. While the company focused on core technologies where it could differentiate, including an operating system that improved controllability, it gave away a software development kit, which allowed developers and programmers to introduce new applications such as 3D mapping and live video streaming on the DJI platform. DJI has quickly grown to become the global market leader, accounting for about 70 percent of small civilian drones. Over the past two years, the company went from 300 employees to 3,500, including 1,000 in R&D.⁹⁴
- **Flattening the organization.** Chinese companies tend to be hierarchical. Top executives make the plans, which managers turn into orders, which lower-level employees carry out without questions and without offering their own ideas. To flatten its organization and encourage a freer flow of ideas, Haier is experimenting with a new approach: getting rid of middle management and creating 2,000 self-managed teams from 80,000 employees. Each team is responsible for profit and loss, and team members are paid based on team performance. If ambitious employees spot an opportunity, they are encouraged to propose an idea for a new product, service, or process improvement. An idea is submitted to a vote of fellow team members (sometimes with input from suppliers and customers as well), and if it is approved, the worker who proposed it becomes the project leader.⁹⁵ This creates incentives for everyone in the organization to seek innovation opportunities. Although the results of the Haier experiment are not yet in, the principle might be applied by other traditional companies to achieve China speed and uncover more ideas for innovation.

⁹³ Peter J. Williamson and Eden Yin, “Accelerated innovation: The new challenge from China,” *MIT Sloan Management Review*, summer 2014.

⁹⁴ “Commercial drones: up,” *The Economist*, April 11, 2015; “DJI innovation—behind the overnight success,” *People's Daily*, May 6, 2015.

⁹⁵ “Haier and higher,” *The Economist*, October 10, 2013; Peter Cai, “Chinese innovation and the Haier model,” *Business Spectator*, January 30, 2015.

Discovering new sources of insights for innovation

Innovation starts from insights. Typically, companies have formal processes for generating insights—market research departments, R&D labs, product development groups. These departments do market research, survey consumers, and run experiments to gather insights. But there are many other sources of insights for innovation ideas—both inside and outside the organization—that companies often fail to use.

- **Using internal competition to generate ideas.** Employees can be excellent sources of insights that can inform innovation, since they understand the company and its products and markets. To uncover these ideas, some Chinese companies, including Alibaba, rely on the *saima* (horse race) concept. Since 2010, Alibaba employees have submitted ideas for innovations. In 2010, the company received 350 project proposals. It green-lighted ten and empowered employees to set up project teams to pursue new business ideas. Since 2013, Alibaba has turned the competition from an annual event to a permanent method to continuously identify and incubate interesting ideas from employees.

Tencent uses internal competition among product internal teams to generate innovation ideas. One of the results of this competition was the popular WeChat mobile phone messaging service, which now has 500 million users. WeChat was approved for development in a competition with two existing Tencent products: the QQ computer-based messaging service and QQ address book. WeChat stood out as the winner because the company wanted to build a new mobile-based platform.

- **Tapping outside sources for ideas.** Sources of ideas for new products and services are multiplying in China. Under the “mass innovation and entrepreneurship” policy initiative, public incubator spaces—places where entrepreneurs can gather and work on their ideas—are spreading across China. An estimated 18,000 open-space innovation cafes have opened since 2012, offering work space for a day and a chance to connect with other innovators, all for the cost of a cup of coffee.⁹⁶ At places like Cheku Cafe and 3W Coffee in Beijing’s Zhongguancun district, entrepreneurs, investors, and executives from large companies mingle—some selling ideas, some investing, some buying.

A growing number of companies are joining or operating open innovation platforms to find fresh ideas. By participating in online innovation platforms, companies can regularly interact with entrepreneurs and other innovators to discover ideas and fund interesting projects. Baidu, China Unicom, and Microsoft have gone a step further, opening their own business incubators. They offer startups office space, funding, training, and consulting services. This helps attract young companies with innovative ideas to their technology platforms, and the corporations also have the potential to profit from their early-stage investments.⁹⁷

Building a Chinese talent pool

A shortage of qualified talent is often cited as a barrier to innovation in China, particularly in science and technology. Companies can help themselves and Chinese innovation by training talent and looking for talent in novel ways.

- **Develop talent in-house.** Neusoft, a Chinese leader in health-care technology and IT services, is getting around the talent gap by creating a talent pool for itself, its business partners, and the broader health-care technology ecosystem. The company has set up three universities and schools for biomedical and information engineering, with a total current enrollment of 29,000. Since the first school opened in 2001, Neusoft and its business partners have hired hundreds of graduates every year. Graduate-level

⁹⁶ “More than 10,000 garage cafes emerged,” Xinhuanet, July 21, 2015.

⁹⁷ *China innovative incubator development report 2015*, Zero2IPO Research Center, May 2015.

researchers at the schools have also helped Neusoft’s R&D efforts, contributing to such innovations as a cloud health-care platform and visual recognition software for computer-assisted driving.

- **Find talent in novel ways.** Looking for talent in the usual places (graduate programs, for example) can often be frustrating. The top candidates are hard to land, and other candidates may not have the required skills. BGI, a biotech company, looks for recruits slightly outside the norm and plucks promising young researchers from colleges before they graduate. Some of the employees who were hired before they finished their undergraduate degrees have become top executives, including one CEO.⁹⁸ In China, where children are told from birth that they must earn a university degree, this is radical.

How policy makers can accelerate innovation in China now

The Chinese government has supported innovation for three decades, through economic and industrial policies and through investments in educational and research institutions. These broad supports have helped China create innovation leaders in certain industries such as telecom equipment and have given China the talent and institutions to pursue the most challenging forms of innovation. Continuing to build capabilities in science and engineering is an important government responsibility, and reforms to the research funding system can help. However, additional policy approaches are possible to accelerate innovation now (Exhibit 38). The highest priority in the coming decade could be to enable individuals and companies to innovate, rather than for government to try to drive innovation itself. We would recommend considering four policy approaches: empower entrepreneurs; raise the innovation bar by being a demanding customer; remove obstacles that prevent innovators from receiving financial rewards for their efforts; and foster stronger innovation clusters.

Exhibit 38

How the Chinese government can support innovation

● Primary ● Secondary

Theme	Action	Science-based	Engineering-based	Customer-focused	Efficiency-driven
Empowering innovators and letting markets work	Provide risk capital	●	●	●	●
	Cut red tape	●	●	●	●
	Help SMEs acquire innovation skills			●	●
	Encourage market-based competition	●	●	●	●
Raising the bar for innovation	Be a demanding customer	●	●	●	●
	Educate consumers on quality, safety	●	●	●	●
	Measure innovation impact (not inputs)	●	●	●	●
	Improve research grant process and supervision	●	●		
Helping innovators to get their full reward	Reform IPO process	●	●	●	●
	Enforce intellectual property protection	●	●	●	●
Supporting innovation clusters	Brand innovation clusters	●	●	●	●
	Address lifestyle factors to attract talent	●	●	●	●

SOURCE: McKinsey Global Institute analysis

⁹⁸ Henny Sender, “Chinese innovation: BGI’s code for success,” *Financial Times*, February 16, 2015.

Empowering innovators and letting markets work

One of the most important tasks for government in the next decade is to create an environment in which innovators can thrive. Entrepreneurship in China is growing, with more venture capital investing and the creation of incubators and other infrastructure to nurture innovative young companies. And more Chinese citizens are interested in building companies and innovating. Government can continue to improve the environment for innovators by offering risk capital, removing regulatory barriers, providing resources for small businesses that lack the skills to turn ideas into new products or services, and continuing to reform state-owned enterprises. The overall thrust of these efforts should be to unleash the energy and creativity of individuals and enterprises—then step back and let the free market work. Additionally, more active flow of information and people in China and across the world can further contribute in achieving full innovation potential in the market.

- **Providing risk capital.** Access to risk capital—particularly early-stage funding—is critical for entrepreneurs, and government can help fill gaps left by private funders. The Chinese government has already announced programs to support new-business accelerators and incubators and has earmarked \$6.5 billion for a government-backed startup fund. While access to early-stage financing is critical for entrepreneurs, the government should be careful as it invests these funds to avoid crowding out private financing. The government of Singapore has addressed these concerns by co-investing with independent venture investors rather than investing directly. Under its Spring Startup Enterprise Development Scheme, the government matches private investment in companies dollar for dollar, thus helping companies scale faster while lowering risk for investors. Government can also play a role to build networks among companies and facilitate joint research and development. To spur research on Industry 4.0 manufacturing technologies, Germany created an online platform for academic and corporate researchers to share ideas, part of a €200 million (\$255 million) investment in Industry 4.0 research.
- **Cutting red tape.** Slow and convoluted regulatory processes can stymie innovation. It can take two years longer to get a drug approved in China than in other countries, and it can take three to seven more years for a drug to reach patients. The long time to market for new patent drugs is a factor in the continuing focus on generics by Chinese companies. Governments can identify the bottlenecks that hold back innovators and make doing business easier. Australia, for example, launched a 90-day “Simplify” project to reduce red tape. Several government organizations hosted sessions with industry representatives and elicited more than 500 ideas to eliminate bureaucratic hurdles for businesses. A Simplify team—consisting of ten current government employees and ten recently retired senior executives—developed additional recommendations.⁹⁹
- **Helping small companies acquire innovation skills.** In China, many small and medium-sized enterprises struggle to innovate because they lack the knowledge and skills to commercialize innovative products and services. In a 2013 survey of 3,000 small business executives in China, more than 30 percent cited lack of innovation capability as a barrier to growth.¹⁰⁰ Other countries, recognizing the potential contribution of small enterprises, have created programs to help SMEs build capabilities. In 2000, the Netherlands started offering vouchers to small companies to purchase training and consulting services. Since then, the knowledge voucher has become an increasingly popular tool to help SMEs across the Europe.¹⁰¹

⁹⁹ “Simplify—the government’s red tape reduction initiative,” Government of South Australia, Office for the Public Sector, www.publicsector.sa.gov.au/.

¹⁰⁰ “Survey reveals SME activity facing significant challenges,” Guangzhou Cooperation Office, March 5, 2013.

¹⁰¹ Erik Olsson, “How innovation vouchers are boosting business,” *Innovation Management*, May 31, 2010.

- **Reforms to encourage market-based competition.** Market reforms have opened up competition and given innovators the chance to tap China's huge and dynamic consumer market, making China a world leader in customer-focused innovation. Additional reforms can unleash competition in other sectors of the economy, resulting in more innovation. Today, many state-owned enterprises do not have enough incentive to innovate. Often, they have guaranteed sales to public-sector buyers and in many state-owned enterprises, there is a lack of commitment to long-range strategy because of the short tenure of rotating leadership. Where companies have been exposed to international competition, they have been forced to improve their performance and innovate. For example, when Huawei began competing against global players and collaborating closely with global customers, it quickly evolved from innovation sponge to innovation leader.

Raising the bar for innovation

Governments have many ways of influencing the course of innovation beyond direct support for R&D or targeting particular industries for development. Governments can raise the bar for innovation as a purchaser of goods and services. They can also use safety and quality regulation to force suppliers to improve their wares and to assure consumers that products are safe to buy and use. China can also raise the bar by adopting better metrics of innovation for policy making and by continuing to reform the process for awarding and overseeing government research grants.

- **Government as a demanding customer.** Government's role as a customer can be effective when applied in the early stages of technology development, helping to spur learning and rapid scaling-up of young businesses. This was demonstrated in China's purchasing of high-speed rail and wind-power turbines. However, it can also impede innovation if government purchases become guaranteed markets for domestic champions. Policy makers can avoid this by making sure that government is a demanding customer, continuously raising technical requirements and insisting on competition. For example, the UK Department of Health and the National Health Service have used procurement competitions to redesign hospital equipment. One contest focused on ways to counteract hospital-borne infections and yielded a new method for reducing ventilator-associated pneumonia, a common problem in intensive care units.
- **Educating consumers on quality and safety standards.** Government also can support innovation through quality and safety standards that encourage higher quality and build consumer trust and confidence in new goods and services. In the United States, for example, Underwriters Laboratories, a government-approved testing company, performs safety-related certification, validation, and testing. Established in 1894, UL helped enable public acceptance of electricity by assuring consumers that wiring and electrical devices such as lamps and appliances were safe.

Another example is the EU energy efficiency labeling directive, under which most appliances, lightbulbs, and cars on sale must have an EU energy label disclosing the product's energy-efficiency rating. The goal is to cut carbon emissions, provide consumer savings, and reduce EU fossil fuel imports. Since its introduction 20 years ago, the labeling program has encouraged development of more energy-efficient products and has shaped consumer behavior. According to EU research, 85 percent of European consumers consider energy label information when purchasing. In 2012, 90 percent of appliance products qualified for the highest "A" rating (the EU has since raised the bar, adding three ratings beyond A).¹⁰²

¹⁰² *The new EU energy label explained*, UK Department for Environment, Food and Rural Affairs, April 2011.

- **Measuring the impact of innovation.** To encourage successful innovation, policy makers can look beyond traditional measures such as R&D spending. Adopting metrics of outcomes can shift the focus of innovation from meeting quotas for patent applications or published research papers to delivering results. In the United States, the National Science Foundation launched the Science of Science and Innovation Policy program to help policy makers assess the impact and efficiency of R&D investments. The program recently established a cross-agency database in which R&D investments can be linked to social outcomes such as health and environmental impacts, workforce impacts such as student mobility and employment, and economic outcomes such as new company formation.¹⁰³ The European Union surveys companies in member countries every two years to assess performance and impact in innovation. It seeks to understand sources of innovation, revenue contribution from new products, and spending on innovation and other measures.
- **Improving research grant and supervision processes.** The ways in which China awards and supervises government research funds has left opportunities for fraud and abuse in some cases, which has affected quality. While there is peer review, it is not as extensive as reviews used by advanced economies. China's evaluation system is much more centralized, and funding decisions are often made by small groups with limited independent oversight, which often leads to suboptimal use of funding and abuses. For example, 2014, Gansu Province found that 120 out of 3,443 research projects funded had already been fully funded elsewhere. These abuses can be curbed with impact- and output-based evaluation schemes and more rigorous peer reviews.

In an effort to improve the quality of university research, in 2014 the United Kingdom instituted the Research Excellence Framework, a method for scoring university research. Research is scored by expert panels in 36 subject areas. The scores include non-academic criteria such as impact on society and culture, which count toward 20 percent of the score.¹⁰⁴ Results are used to allocate ongoing research support, and institutions that score poorly risk loss of funding. In 2014, 154 UK universities participated in the scoring, and panels reviewed 190,000 research submissions from 52,000 academics.¹⁰⁵

The US National Institutes of Health also uses a rigorous system to ensure the quality of research and fair resource allocation. An initial review is conducted by scientists who are experts in the field and not affiliated with the government. A second review is conducted by panels of scientists and representatives of the general public, and submissions are scored on nine criteria including scientific significance and impact.¹⁰⁶

¹⁰³ Known as Science and Technology for America's Reinvestment (STAR) metrics.

¹⁰⁴ *REF 2014: Assessment framework and guidance on submissions*, Higher Education Funding Council for England, 2014.

¹⁰⁵ Rebecca Ratcliffe, "REF 2014: Why is it such a big deal?" *The Guardian*, December 17, 2014.

¹⁰⁶ www.grants.nih.gov/grants/peer_review_process.htm.

Helping innovators get their full reward

For innovation to thrive, not only do innovators need a favorable environment, but they also need to know that they will be rewarded fully for their efforts. This means being able to achieve whatever financial rewards public markets are willing to bestow and ensuring that the fruits of their efforts—their intellectual property—will be protected by law.

- **Reforming the IPO process.** In places such as the United States, fast-growing companies are able to raise money in public markets (and provide a “liquidity event” for founders) as long as they meet the very broad listing requirements of public exchanges. These requirements emphasize disclosure of material information for investors but do not specify performance standards, such as levels of profitability. In China, initial public offerings (IPOs) must be approved by the government through the Chinese Securities Regulatory Commission. A 25-member panel examines IPO applications and controls the flow of IPOs, enforces pricing rules such as limits on price to earnings ratios, and profitability requirements. Applicants must show accumulated net profits of at least 10 million RMB (\$1.6 million) and continuous profitability for two years; or they can qualify if they can show net profit of 5 million RMB and revenue of 50 million RMB in the previous year. These restrictions have led some fast-growing Chinese companies to list overseas. Also, because officials can close the IPO window during times of potential instability, entrepreneurs have less control over IPO timing, even if their companies meet the qualifications. Three times in the past eight years, the government has suspended IPOs: from December 2008 to June 2009 during the global financial crisis; from September 2012 to January 2014 to maintain market stability during China’s leadership transition; and in the summer of 2015, during the steep correction in the Chinese stock market. In the latest instance, 28 companies that had been approved to sell shares to raise a total of 11.4 billion RMB (\$1.9 billion) had to delay their IPOs as of July 2015.¹⁰⁷

Chinese regulators have recognized the limitations of the current system and have announced plans to introduce new IPO rules, possibly by the end of 2015. The new rules are aimed at providing a more market-driven approach to IPOs, including moving toward removing pricing rules and strict profitability requirements, and limiting the government’s role to ensuring proper disclosures in registration documents.

- **Enforcing intellectual property protection.** Questions about protections for intellectual property have been a concern for foreign companies and for Chinese innovators. There have been improvements in recent years, but more progress is needed. The number of intellectual property cases adjudicated by Chinese local courts increased from about 27,000 in 2008 to 100,000 in 2013, implying increased awareness of intellectual property rights.¹⁰⁸ In the 2015 China Business Climate Survey conducted by the American Chamber of Commerce in China, 86 percent of respondents said that China’s enforcement of intellectual property regulations had improved in the past five years. In a 2013 survey, only 47 percent expressed that view.

There is more progress to be made, particularly in how intellectual property cases are resolved. First, there are limits on compensation. Rather than using legal discovery during trials to determine the damages that a plaintiff has suffered because of patent and trademark infringement, the current law calls for maximum fines of only 1 million RMB (\$160,000). The average award is just 190,000 RMB, or about \$30,000—an amount that may not cover legal costs. Also, judges often do not publish detailed rulings, or do

¹⁰⁷ “28 firms postpone IPOs,” Xinhuanet, July 4, 2015.

¹⁰⁸ “China’s IP court to be established in 2014,” *China Daily*, August 29, 2014.

so only after long delays, so rulings may not provide any clarity for intellectual property holders and other players in the market.¹⁰⁹

Supporting China's innovation clusters

Industries tend to cluster in geographic proximity, which can help drive innovation by facilitating collaboration among entrepreneurs, research institutions, suppliers, and investors. Strong clusters are the birthplaces of successful innovation, and many governments around the world have tried to create the next Silicon Valley. However, top-down, policy-driven approaches have largely failed; the entrepreneurial culture, academic and business ecosystems, and critical mass of talent that created Silicon Valley cannot be conjured by policy action alone. China has a variety of innovation clusters—technology in Beijing, and life sciences in Shanghai, for example—and government policy can help these clusters thrive and expand. In addition to providing supportive infrastructure, government can help clusters gain international visibility, attract talent, and work together.

- **Branding clusters.** Beijing is well known for the technology hub concentrated in the Zhongguancun area, which is home to both established technology companies and many startups. Shanghai is becoming a hub for life sciences and bioengineering. Shenzhen's manufacturing ecosystem makes it a center of efficiency-driven innovation. However, for midsize and smaller cities, the identity is less obvious. Government agencies can work with local authorities, companies, and universities to clarify an area's "brand," then help promote that brand globally to attract investment. Policy makers can assess the strengths and competitive advantages of groups of cities that function as regional innovation clusters, to create a clear branding message that will help attract more investment.
- **Attracting talent to clusters by addressing lifestyle factors.** The success of an innovation cluster depends heavily on the quality of talent it can attract. China's top innovation-cluster cities have invested heavily in producing as many patents as possible but are not as strong on the quality-of-life issues that are important to potential employees (Exhibit 39). Top scientific talents have many choices of where to work, and these men and women are in a position to turn down jobs in places that do not meet their lifestyle requirements—affordable housing, good schools, recreation choices, clean air. Chinese cities are currently at a disadvantage on these "soft" metrics, such as housing costs, traffic, and pollution. Air pollution is three to ten times as bad as in peer cities around the world, which industry leaders say contributes to emigration by scientific talent. Diversity, often a driver for creative ideas, is low, too. In Silicon Valley, 36 percent of the population is foreign born, and 44 percent of technology and engineering startups founded between 2006 and 2012 had at least one immigrant founder.¹¹⁰ In most of China's innovation cluster cities, foreign-born residents account for less than 1 percent of the population. To make each of China's innovation clusters more globally competitive, policy makers can focus on the quality-of-life issues that are critical for attracting top talent.

¹⁰⁹ "Still murky," *The Economist*, April 21, 2012; Thomas I. Ross, "Enforcing intellectual property rights in China," *China Business Review*, October 1, 2012.

¹¹⁰ "2014 Silicon Valley index," Silicon Valley Community Foundation press release, February 4, 2014; Vivek Wadhwa, AnnaLee Saxenian, and F. Daniel Siciliano, *America's new immigrant entrepreneurs: Then and now*, Kauffman Foundation, October 2012.

Chinese cities need to improve quality-of-life factors that attract top talent

China's top four cities have built innovation capacity but lag behind global peers on lifestyle metrics

	Innovation capacity			Lifestyle factors			
	Patent applications, 2011 ¹	Applications compound annual growth rate, 2006–11 (%) ²	Number of IPOs, 2014 ³	Air quality (PM 2.5)	Diversity (% foreign-born)	Traffic inefficiency ⁵	Property price/income ⁶
Silicon Valley, United States⁴	6,912	1.8	35	10	36	179 ⁷	29
Boston, United States	3,553	0.4	18	6	27	89	6
Paris, France	748	4.1	6	15	13	101	31
Tokyo, Japan	12,041	9.9	55	16	2	132	34
London, England	678	0.6	34	16	31	275	47
New York, United States	3,698	-4.6	25	7	37	108	37
Seoul, South Korea	3,379	11.6	11	46	3	84	26
Beijing	2,634	31.5	38	83	1	202	52
Shanghai	1,439	22.2	13	52	1	192	40
Shenzhen	7,892	30.6	14	33	0.3	192 ⁸	39
Guangzhou	1,106	26.6	3	47	0.2	192 ⁸	31

1 PCT patents by inventor's residence.

2 Global compound annual growth rate over this time period is ~4.3%.

3 By issuer/company city.

4 California value used for Silicon Valley.

5 Index estimates of inefficiencies in traffic; with high inefficiencies it assumes driving, long commute times.

6 Average price of a 90 sq. meter property (in and out of city center) divided by the average disposable income after tax.

7 Uses San Francisco as proxy; likely an overestimate. As benchmark, Sacramento, which is not in Silicon Valley but is in Northern California, has an inefficiency index of 97.36.

8 Estimated using commute time comparison with Shanghai.

SOURCE: OECD; World Intellectual Property Organization, Dealogic; Chinese Statistical Yearbooks by city; Numbeo; China Ministry of Environment; Seoul Metropolitan Government; Tokyo Metropolitan Government; Massachusetts 2014 Air Quality Report; New York State Department of Environmental Conservation; spartanair; Air Quality in Europe Report (Air Quality in Paris Region 2014); Greater London Authority (London Average Air Quality Levels); McKinsey Global Institute analysis

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How well China can address the innovation imperative will help determine the course of its economy in the next ten years. Rising productivity, higher value-added activities and employment, and significant value gains in services and manufacturing can ensure that China's economy grows at the expected rate. China can become a true innovation leader, competing with advanced economies in all kinds of global markets and bringing better products, services, and quality of life to its citizens. A decade from now, the "China effect" on innovation could be a recognized force around the world, as more companies (Chinese and foreign-based) use China as a base for developing and commercializing innovations for the rest of the world and the Chinese model of rapid, low-cost, and nimble innovation spreads. The China effect may disrupt markets, create new opportunities for innovators, and bring consumers and B2B customers better products and services.



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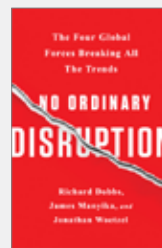
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