AUGUST 2017

The Fat Tech Dragon

Benchmarking China's Innovation Drive

AUTHOR

Scott Kennedy

CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

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Center for Strategic & International Studies
1616 Rhode Island Avenue, NW
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Contents

The China Innovation Policy Series

The purpose of the China Innovation Policy Series (CIPS) is to analyze trends in technology innovation in China and consider the implications for government policies and business strategies. The series examines general trends as well as a range of strategic sectors that have different economic dynamics, including: the Internet, new-generation vehicles (electric and autonomous vehicles), semiconductors, artificial intelligence, commercial aircraft, and pharmaceuticals. Over the life of the two-year project, reports are being issued on each sector, and CSIS is hosting events to discuss these reports and the broader issues that will shape China's innovation path and how others in government and industry should respond.

CIPS is a joint project of the Freeman Chair in China Studies and the Technology Policy Program at CSIS. The principal investigators are: Scott Kennedy, deputy director of CSIS's Freeman Chair in China Studies and director of the Project on Chinese Business and Political Economy; Denise Zheng, director of CSIS's Technology Policy Program; and James Lewis, senior vice president at CSIS. Research support is headed by Qiu Mingda of the Freeman Chair in China Studies and Will Carter of the Technology Policy Program. Administrative support is provided by Maria Sinclair of the Freeman Chair and Alvaro Genie of the Technology Policy Program. We appreciate the contributions of interns in both programs to the initiative, including (to date): Lin Xuefen, Jonathan Hall-Eastman, Mark Akpaninyie, and Frank Zhao.

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Executive Summary

The purpose of this report is to develop a benchmark analysis of innovation in China by systematically examining national trends in China while placing the country in comparative perspective. The report presents data on innovation inputs, such as finance, as well as several types of innovation outputs, such as intellectual property and commercial performance. This study relies primarily on broad quantitative measures because they facilitate measuring trends over time and engaging in cross-national comparison. The numerical data are supplemented by interviews with business executives, industry analysts, investors, and government officials in the United States and in China.

Broadly speaking, whether one looks at China in isolation or puts the country in comparative perspective, China's innovation performance has gradually improved over the last decade along a number of indicators, separating China from other major emerging economies. Yet China still has a substantial distance to travel before it approaches the level of innovation found in the world's most advanced economies. Most importantly, the level of inputs China is mobilizing is not consistently and smoothly translating into successful technology innovation outputs. This low "metabolism" of inputs into successful high-tech advancement is why we characterize China as a "fat" tech dragon.

China is dedicating an unprecedented amount of funding to research and development (R&D). Old-school banks and new-school investment vehicles are all getting in on the action. No longer are funds just being tossed at large-scale white elephants. Commercial competitiveness is now a central part of the decision calculus. Although this is a definite improvement over the earlier financing system, China may have overcorrected. By avoiding spending on basic research and foundational technologies, income is being generated less as a result of novel technologies and more as a result of new applications or business models.

China's embrace of intellectual property (IP) is highly positive when contrasted with the country's original disdain for property rights of any sort and widespread violation of IP rights. However, China's efforts to develop and obtain more IP is driven heavily by bureaucratic imperatives as opposed to market incentives. Moreover, China may now be a "large" IP country, but it is still a

"weak" one. Whether one is discussing licensing and royalties, mergers and acquisitions, or dispute settlement, Chinese patents still have little commercial value.

China's commercial success has outstripped its progress in technology innovation. Chinese companies are acquiring greater market share in high tech, particularly in the most commodified segments of sectors. The value-added contribution to manufacturing is growing in absolute terms, and domestic companies are contributing a growing share to China's high-tech exports.

Overall, China's high-tech drive may be characterized as "good-enough innovation." From a negative perspective, China is investing—and may be wasting—a great deal of human capital and funding, but is still far from a leader in high tech. From a more positive perspective, China is achieving incremental progress by benefiting from its strong capacity in manufacturing, the accumulation and diffusion of tacit knowledge, and the opportunities provided by such a large market.

Regardless of the level of support they receive from their government, Chinese companies will face growing challenges in their interactions with multinational businesses and in overseas markets. Foreign governments and multinational businesses likewise need to decide how to strategically respond to China's approach. They could take a firm stand in opposition, try to influence China's approach at the margins, or go along with the strategy as best they can. In any case, if they are not careful, they could end up under the heavy foot of a fat tech dragon.

01

Introduction: From Innovation Policy to Innovation

INTRODUCTION

The most problematic issue in the U.S.-China economic relationship is China's unprecedented drive to become a technology powerhouse. China's aspirations are not per se novel or objectionable. Overcoming technological inferiority has been a central goal of every Chinese leader since at least the conclusion of the Opium War in the middle of the nineteenth century, and it is entirely reasonable for any country, especially one as proud as China, to pursue technological advancement as part of its effort to further economic development and strengthen national security. Except for some limited breakthroughs, China's previous efforts have largely failed, particularly when measured on commercial grounds. And so it makes sense that China would intensify its efforts.

For the last decade China's technology policy has been recast in a broader framework of promoting innovation, which is defined as the development and application of novel technologies, products, and services to address societal and economic challenges. China's leadership has identified creating an innovative society as key to achieving sustainable growth over the coming decades and avoiding falling into the middle-income trap. "Innovation" (*chuangxin* 创新) has become one of the most ubiquitous buzzwords in the entire country, uttered often by central and local officials, companies, and schoolchildren.[1]

What is concerning is not China's ambition to become an innovator, but its particular strategy. The People's Republic of China (PRC) is pursuing a techno-nationalist approach that supports domestic industry at the expense of its foreign competitors. The 2006 Medium to Long-Term Plan for the Development of Science and Technology (2006–2020) embraced the concept of "indigenous innovation" (*zizhu chuangxin* 自主创新), which guides policy to this day. Soon after, China began

1. The Communist Party has even released a booklet of President Xi's statements on the topic. See Chinese Communist Party Central Document Research Office, ed., *Excerpted Comments of Xi Jinping on Science & Technology Innovation* (Beijing: Central Document Press, 2016).

funding various "megaprojects" to develop important technologies, and in 2010 the central government identified seven major "strategic emerging industries" (SEI) that were to receive special support.[2] The 13th Five-Year Plan, adopted in March 2016, turbocharges these efforts by identifying an even wider range of technologies to receive the full backing of the Chinese state.[3] The current centerpiece of China's innovation drive is its "Made in China 2025" (MC2025) plan, which sets as its goal the localization of entire supply chains in a wide range of industries. MC2025 and the other initiatives utilize a full array of policies: government and state-directed financing, strategic mergers and acquisitions (M&As), deft use of competition policy to promote domestic national champions and constrain foreign competitors, distinctive technical standards, aggressive protection of Chinese-owned intellectual property, buy-domestic government procurement directives, and broad assertion of national security needs to justify reliance on home-grown technologies and burdensome constraints on the behavior of foreign companies.[4] China is also increasingly integrating efforts to develop technologies in the civilian and military spheres.

Although the Chinese government asserts that its intervention does not discriminate against foreign industry, the evidence compiled by many observers points to the contrary. Surveys of American and European companies indicate a worsening business climate in China, particularly for high-tech firms.[5] Individual foreign companies rarely criticize Chinese policy in public, but confidential interviews with dozens of industry representatives and analysts yielded an array of specific complaints of unfair treatment even more critical than the comments reflected in the general surveys.

From a global perspective, China's approach to high tech carries potential major risks because of the country's unique size and unparalleled ability to mobilize resources. Chinese companies that receive extensive state support are eating into the market share of international competitors, both

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2. Chen Ling and Barry Naughton, "The Emergence of Chinese Techno-Industrial Policy: From Megaprojects to Strategic Emerging Industries, 2003–2011," Instituto Nacional de Ciéncia e Tecnologia em Politicas Públicas, Estratégias e Desenbolvimento (INCT/PPED), January 2013, http://inctpped.ie.ufrj.br/spiderweb/pdf/Chen_Ling_and_Barry_Naughton.pdf; Yu Zhou and Xielin Liu, "Evolution of Chinese State Policies on Innovation," in *China as an Innovation Nation,* ed. Yu Zhou, William Lazonick, and Yifei Sun (Oxford: Oxford University Press, 2016), 33–67; and Scott Kennedy, "Indigenous Innovation: Techno-Nationalist Retreat?," GKDragonomics, China Policy Watch Series, March 2, 2012.

3. Scott Kennedy and Christopher K. Johnson, *Perfecting China, Inc.: The 13th Five-Year Plan* (Washington, DC: CSIS, May 2016), https://csis-prod.s3.amazonaws.com/s3fs-public/publication/160521_Kennedy_PerfectingChinaInc_Web.pdf. The central government has updated its strategic emerging industries list on at least two occasions, and provinces maintain their own lists of strategic emerging industries.

4. Jost Wubbeke et al., *Made in China 2025: The Making of a High-Tech Superpower and Consequences for Industrial Countries* (Berlin: Mercator Institute for China Studies, December 2016); *China Manufacturing 2025: Putting Industrial Policy Ahead of Market Forces* (Beijing: European Union Chamber of Commerce in China, March 2017); *Made in China 2025: Global Ambitions Built on Local Protections* (Washington, DC: U.S. Chamber of Commerce, 2017); and Robert D. Atkinson, Nigel Cory, and Stephen Ezell, "Stopping China's Mercantilism: A Doctrine of Constructive, Alliance-Backed Confrontation," Information Technology & Innovation Foundation, March 2017.

5. *2017 American Business in China White Paper* (Beijing: American Chamber of Commerce in China, 2017); and *European Business in China: Business Confidence Survey 2017* (Beijing: European Union Chamber of Commerce in China, May 2017).

in China and elsewhere. More importantly, if left unchecked, it is possible that this frenzy of cheap financing and other industrial policies could imperil not only individual companies, but long-standing supply chains and business models that would make it more difficult for companies with budget constraints to continue investing in the research and development (R&D) that is a key source of continued progress in sector after sector. To put it plainly, China could do to semiconductors, artificial intelligence, and pharmaceuticals what it has done to steel and aluminum. This could, in turn, result in a downturn in overall productivity, the most important source of growth for countries and the global economy.

ANOTHER METRIC: INNOVATION PERFORMANCE

A conversation about China's innovation drive should not only be rooted in issues of legal compliance, reciprocity, or ideological arguments about the benefits of free markets. Allegations and even proof of unjust tactics by China show how the country's approach is potentially dangerous for others, but not necessarily for China itself. Moreover, not all government intervention is illegal or economically misguided. Governments in Europe and East Asia have intervened in a variety of industries over the years.[6] The United States has supported infant high-tech industries, and recently there has been a vigorous domestic debate about whether the U.S. government should itself have a robust industrial policy. The Obama administration developed a national innovation strategy that identified key sectors that should receive priority support.[7] Legal arguments are often met by Chinese interlocutors with denials, but just as often with the retort, "You and others have done this, too."

Hence, a central part of the discussion should be about the economic efficiency and effectiveness of what China is doing. Is China's techno-nationalist strategy working? More specifically, is China generating sufficient successes that yield improved commercial performance, raising the country's productivity and providing benefits to consumers and the broader society? If so, no amount of legal wrangling and lecturing will be persuasive. But if not, there is a greater chance China and its trading partners can have a more productive conversation about the best way to move forward.

HOT AND COLD VIEWS

In the last few years, along with reports critiquing Chinese government policies, there has simultaneously emerged an equally massive wave of breathless popular commentary highlighting the accomplishments of Chinese researchers and companies. China now boasts the world's fastest

6. Alice H. Amsden, *The Rise of "The Rest": Challenges to the West from Late-Industrializing Economies* (Oxford: Oxford University Press, 2008); Ha-Joon Chang, *Bad Samaritans: The Myth of Free Trade and the Secret History of Capitalism* (New York: Bloomsbury Press, 2008).

7. National Economic Council and Office of Science and Technology Policy, "A Strategy for American Innovation," October 2015.

supercomputer and the world's largest telescope.[8] Alibaba and its founder, Jack Ma, are the most identifiable icons of China's emerging innovation prowess, but far from the only ones. The emergence of well-recognized Chinese companies such as Tencent, Xiaomi, BYD, and Huawei provides support for the argument that China's approach is bearing fruit.[9]

Yet a few notable companies and entrepreneurs are insufficient proof that China has genuinely turned the corner and is on the right path. The scholarly research shows an improving, though still highly mixed, picture. The notion that innovation in China is impossible has long since passed, and the debate now is about how various factors help or hinder innovation and what the pattern of success and failure is.[10] Achieving innovation requires human talent, financing, protection of intellectual property rights (IPR), and some sort of diffusion channel, usually a commercial market but in some cases a government procurement system, so that novel creations can reach end users in society. There are weaknesses in each of these areas in China that act as a drag on innovation, including an education system that encourages deference to authority and does not prepare students to be creative and take risks, a financial system that disproportionately funnels funds to undeserving state-owned enterprises (SOEs), weak protection of IPR, and a market structure where profits can be made through a low-margin, high-volume strategy or through political connections.[11]

At the same time, experts point to progress in each of these areas. China annually graduates the world's largest pool of scientists and engineers, and though not encouraged to be creative in school, Chinese workers can learn on the job, either through training by their employers or in their own start-ups. An increasing percentage of bank loans has started to flow to private companies, and new sources of financing, such as venture capital, have emerged. The legal environment and funding to protect IPR has expanded. Moreover, China's large market size offers the economies of scale to reward successful innovation as well as provide a large user base against which to test and refine products and services.[12]

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8. Zhang Min and Ma Si, "Tianhe-3 to Offer Faster, Sharper Data Processing," *China Daily*, May 17, 2017, http://www.chinadaily.com.cn/business/tech/2017-05/17/content_29376120.htm; Chris Buckley and Adam Wu, "China Hunts for Scientific Glory, and Aliens, With New Telescope," *New York Times*, September 25, 2016.

9. Duncan Clark, *Alibaba: The House That Jack Ma Built* (New York: HarperCollins, 2016); Edward Tse, *China's Disruptors: How Alibaba, Xiaomi, Tencent, and Other Companies are Changing the Rules of Business* (New York: Portfolio, 2015); and Shaun Rein, *The End of Copycat China: The Rise of Creativity, Innovation, and Individualism in Asia* (Hoboken, NJ: Wiley, 2014).

10. Useful summaries are Andrew B. Kennedy, "Powerhouses or Pretenders? Debating China's and India's Emergence as Technological Powers," *Pacific Review* 28, no. 2 (2015): 281–302; and William Lazonick, Yu Zhou, and Yifei Sun, "Introduction: China's Transformation to an Innovation Nation," in Yu Zhou, William Lazonick, and Yifei Sun, eds., *China as an Innovation Nation*, 1–32.

11. Linda Jakobson, "China Aims High in Science and Technology: An Overview of the Challenges Ahead," in *Innovation with Chinese Characteristics: High-Tech Research in China*, ed. Linda Jakobson (New York: Palgrave Macmillan, 2007); and Regina M. Abrami et al., "Why China Can't Innovate," *Harvard Business Review* (March 2014), https://hbr.org/2014/03/why-china-cant-innovate.

12. Loren Brandt and Eric Thun, "The Fight for the Middle: Upgrading, Competition, and Industrial Development in China," *World Development* 38, no. 11 (2010): 1155–1174; Angang Hu, *China in 2020: A New Type of Superpower* (Washington, DC: Brookings Institution Press, 2011).

Underlying the strengths and weaknesses of each of these factors is a broader debate about two larger forces, the Chinese state and globalization. One's expectations about China's ability to innovate turns substantially on one's confidence in the Chinese party-state's leadership, their policies, and the country's political institutions. Those who believe the government can and has played a productive role are more optimistic than those who see state intervention as a major hindrance.[13] At the same time, there is an emerging view among those critical of state intervention that some of the resulting problems have to some extent been ameliorated by China's extensive engagement with the world economy. The paths to progress via globalization have been many and include: (1) sending millions of students to study abroad; (2) attracting foreign investors who share technology with local partners, create R&D centers, and train their Chinese employees; and (3) Chinese industry setting up shop in Silicon Valley and other high-tech hubs, acquiring technology through M&As, and hiring talent away from their Western competitors.[14]

Given this mix of factors, it is not surprising that the most common conclusion reached by scholars is that innovation success in China is partial and varied. Some highlight the differences across regions, recognizing that variation in local industry structures—the types of firms and networks—yields different approaches to technology development and commercialization.[15] Others emphasize the relative strength of multinationals, with particular emphasis recently being placed on transnational ethnic Chinese companies that help nurture local talent and technology development.[16] But the most common recent finding is that Chinese industry has had more success with innovations of technology applications and the integration of previously separate technologies—what some call "second-generation innovations"—than with original basic-technology breakthroughs.[17]

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13. For negative critiques, see Jakobson, *Innovation with Chinese Characteristics*; George J. Gilboy, "The Myth Behind China's Miracle," *Foreign Affairs* 83, no. 4 (July/August 2004): 33–48; Ernst Preeg, *India and China: An Advanced Technology Race and How the United States Should Respond* (Washington, DC: CSIS/Manufacturers Alliance for Productivity and Innovation, 2008); Barry Naughton, "China's Economic Policy Today: The New State Activism," *Eurasian Geography and Economics* 52, no. 3 (2011): 313–329; and Anil Gupta and Haiyan Wang, "How China's Government Helps—and Hinders—Innovation," *Harvard Business Review* (November 2016). For more positive assessments, see Can Huang and Naubahar Sharif, "Global Technology Leadership: The Case of China," *Science and Public Policy* 43, no. 1 (2015): 62–73; Sebastian Heilmann, "From Local Experiments to National Policy: The Origins of China's Distinctive Policy Process," *China Journal*, no. 59 (January 2008): 1–30.

14. Gert Bruche, "The Emergence of China and India as New Competitors in MNCs' Innovation Networks," *Competition & Change* 13, no. 3 (2009): 267–288; Denis Fred Simon and Cong Cao, *China's Emerging Technological Edge: Assessing the Role of High-End Talent* (Cambridge: Cambridge University Press, 2009); McKinsey & Company, "Three Snapshots of Chinese Innovation," *McKinsey Quarterly* (February 2012); and Douglas B. Fuller, *Paper Tigers, Hidden Dragon: Firms and the Political Economy of China's Technology Development* (Oxford: Oxford University Press, 2016).

15. Adam Segal, *Digital Dragon: High-Technology Enterprises in China* (Ithaca, NY: Cornell University Press, 2003); and Eric Thun, *Changing Lanes in China: Foreign Direct Investment, Local Governments, and Auto Sector Development* (Cambridge: Cambridge University Press, 2006).

16. Fuller, *Paper Tigers, Hidden Dragons*.

17. Dan Breznitz and Michael Murphree, *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China* (New Haven, CT: Yale University Press, 2011); *The China Effect on Global Innovation*, McKinsey Global Institute, October 2015; and Yu Zhou, *China as an Innovation Nation*.

OUR PROJECT AND THIS REPORT

The wave of flashy corporate portraits and more staid research has uncovered emerging areas of progress as well as identified strengths and weaknesses that are likely to shape China's path going forward. Nevertheless, our picture of China's innovation drive still needs to be more fully sketched out. Much of the work has involved case studies, and so we still do not have a clear sense of China's overall progress. We need to have a better sense of whether the success stories are representative of broader trends and part of a larger productive ecosystem or whether they are the exceptions to the rule. Relatedly, there is insufficient understanding of how extensive government intervention has helped and hindered corporate performance and broader trends in innovation. Equally important, we also need a better sense of where China stands relative to other countries, a question only rarely touched upon by previous analyses.

The purpose of CSIS's China Innovation Policy Series (CIPS) is to build on existing research by providing answers to these questions in ways that are helpful to scholars, policymakers, and business leaders. The current report, the first in the series, begins the process by developing a benchmark analysis of innovation in China by systematically examining national trends in China as well as placing the country in comparative perspective. The current report presents data on both innovation inputs as well as several types of innovation outputs, including intellectual property and commercial performance. This study relies primarily on broad quantitative measures because they facilitate measuring trends over time and engaging in cross-national comparison. The numerical data are supplemented by several dozen interviews with business executives, industry analysts, investors, and government officials carried out in the United States in China in late 2016 and the first half of 2017.[18] The quantitative data and interviews serve as complementary sources of information. Often the two kinds of information align with each other, but when they do not, these are welcomed as opportunities to challenge assumptions and conventional wisdom.

This report begins with an analysis of China-specific and cross-national innovation indices, which are used to establish the initial baseline of Chinese performance. Broadly speaking, whether one looks at China in isolation or puts the country in comparative perspective, China's innovation performance has gradually improved over the last decade along a number of indicators, moving China ahead of other countries with a similar level of per capita income. The discussion then turns to analyzing data on the most important input, funding, and two kinds of outputs, intellectual property and commercial performance. The result of this more discrete analysis shows that inputs such as spending have improved more quickly than outputs, which suggests a highly inefficient process that has yielded a disproportionate degree of false starts, failures, and waste. Although there are more positive ways to interpret the data, our conclusion is that the commercial success of China's high-tech sector is not always the result of technology innovations, but of other factors. In addition, progress appears to be quite uneven across sectors and types of companies.

18. In order to encourage open and frank dialogue about these important issues, interview subjects were promised anonymity and are only occasionally described in general terms in this report's text. The author is grateful to the many experts in government, business, the media, and other spheres who took time out of their busy schedules to share their views.

The report's final section considers the implications of these findings for governments and industry. These results could be varyingly interpreted, with some concluding that China's efforts are expensive yet sufficiently successful, and others finding that there is so little bang for the buck that China should rethink its entire approach. As such, the significance of China being a "fat" high-tech dragon could mean different things to different stakeholders.

02

General Trends in Innovation

INTRODUCTION

China has never been a place Americans could imagine being a hotbed of innovation. Although the reasons have changed over the years—a Confucian deference to authority, a state socialist regime supported by loyalists, and an education system that discourages creativity—the expected outcome has been the same: China can copy but not create.

That's why I was somewhat taken aback by a recent encounter with a taxi driver. Every China expert secretly depends on taxi drivers to understand China. They are as talkative as anyone we meet and willing to share their views on almost anything. I've spoken to several Chinese taxi drivers about innovation, but I was shocked to discover that my most important taxi source was the driver who brought me home from Dulles Airport in Virginia. When I told him I had just visited China, he responded without any sense of sarcasm, "Oh, the high-tech superpower!" It turns out he was born in Ukraine, but his belief was far from alone among Americans I spoke with over the last year. This impression is quite different from the long-dominant conventional wisdom, in which China has been synonymous with counterfeits and poor quality.

Other conversations I have had in the past several months with seasoned experts about China's innovation abilities touched off spirited arguments, with just as many boosters as critics. In interviews with experts in both China and global technology dynamics, observers offered widely varying impressions of how much China has progressed. Some stressed how different China had become from just a decade ago as a result of more innovative domestic companies, while others were more skeptical, pointing to poorly prepared engineers and scientists who do not know how to operate in a corporate environment and are not focused on exacting standards of quality. One veteran investor stressed a weak ethical environment in which shortcuts, shirking responsibility, and deception are all too common; his investment strategy focuses heavily on breaking this pattern.

As these encounters suggest, measuring innovation performance is not simple.[1] These conflicting impressions are highly suggestive of a continuing lack of consensus as well as a complex and evolving environment. A firmer conclusion about China's trajectory would benefit from more systematic sources of data. In this section, we present and analyze quantitative data that are used to construct broad indices of innovation performance. Some sources utilize large-scale surveys, but most depend on physical measures related to various elements of innovation, from education and financing to IP and product sales. Having cross-national data is particularly helpful in obtaining a clearer sense of China's progress and continuing challenges. No one index or approach is perfect, but a comparison of the various indices yields significant findings, which will be explored further in subsequent sections.

FINDING THE RIGHT INDEX

There are approximately a dozen cross-national comprehensive indices that speak to countries' abilities to innovate, but this report focuses on five well-known sources that are particularly suggestive. Indices are typically reported in two ways: basic scores measured in absolute numbers and rankings based on countries' relative performance against the others in the sample.[2] As one can see from Figures 1 and 2, different indices yield differing pictures of China's innovation performance over the last several years.

The brightest assessment, not surprisingly, is presented by an index developed by China's own Ministry of Science and Technology (MOST), called the National Innovation Index (NII).[3] This measure is biased upward because the score depends heavily on gross figures in which China has excelled: R&D spending, student enrollments in science and engineering programs, the number of published scientific papers, the number of patents, high-tech exports, and government procurement of technology. These gaudy numbers look impressive, but they may not translate into novel technologies that shape markets or society. Moreover, the NII only ranks 40 countries, and so China clearly sits in a higher position compared to other indices with larger samples.

Another index where China scores amazingly high is the recently created Bloomberg Innovation Index (BII).[4] In this case, there are only seven components of the index, and China scores well in several of these areas, including R&D spending, manufacturing value added, and, in particular, patent activity. In the most recent survey, China ranks 21st (out of 69 countries), ahead of every other developing country in the world, with the only three Asian countries ahead of it being South

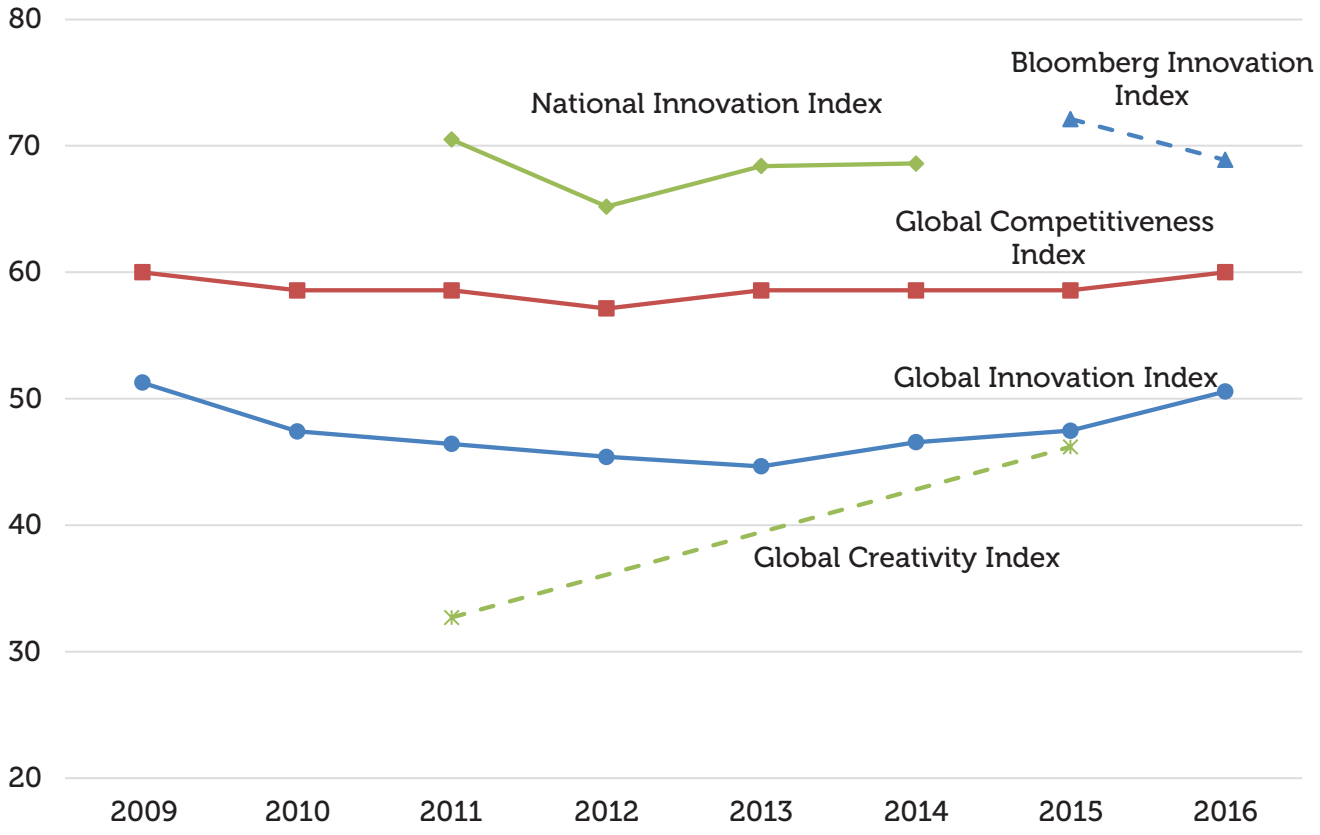
1. Christopher Mackie, rapporteur, *Advancing Concepts and Models for Measuring Innovation: Proceedings of a Workshop* (Washington DC: National Academies Press, 2017).

2. Some indices present scores using a scale of 1–100, and others use a scale of 1–7. To permit comparability, we normalized all scores into a 1–100 scale.

3. "2015 National Innovation Index Report," Chinese Academy of Science and Technology for Development, China Ministry of Science and Technology, http://www.most.gov.cn/cxdc/cxdcpjbg/201607/P020160706603195938182.pdf.

4. Michelle Jamrisko and Wei Lu, "These Are the World's Most Innovative Economies," Bloomberg, January 19, 2016, https://www.bloomberg.com/news/articles/2016-01-19/these-are-the-world-s-most-innovative-economies.

Figure 1. Innovation Indices: China's Score



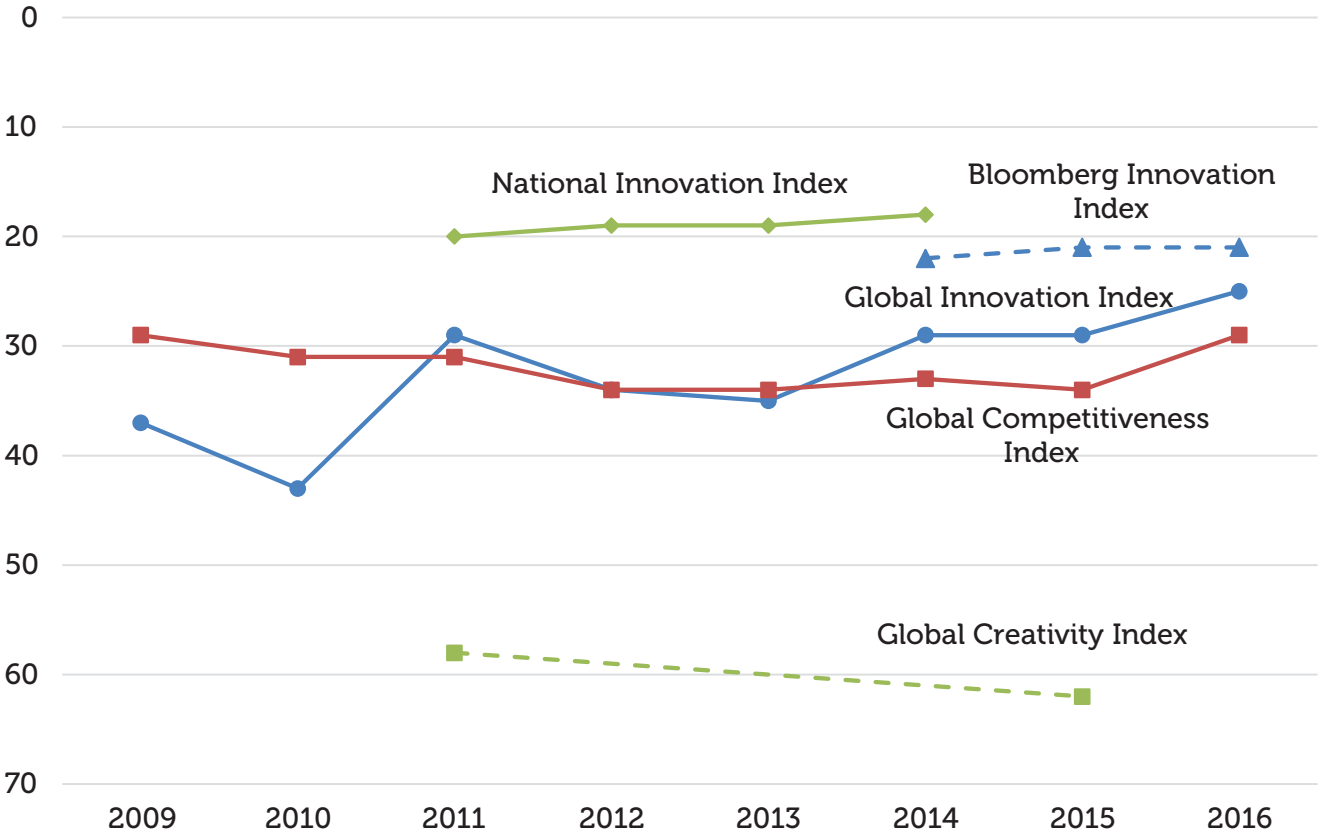
Source: See citations for each index for their respective sources.

Korea (ranked 1st), Singapore (6th), and Japan (7th). Besides the small number of variables, another reason to be concerned about the index is how young it is, with only three years of data.

At the other end of the spectrum is the Global Creativity Index (GCI). Developed by the Martin Prosperity Institute at the University of Toronto's Rotman School of Management, China ranked only 62nd out of 139 countries in the index's most recent version.[5] China did raise its overall absolute score in between the two times the index was measured (2011 and 2015), primarily due to greater R&D spending and a growing number of researchers. However, China's high ranking on technology (14th) was counterbalanced by very poor performance in the other two components of the index, talent (87th) and tolerance (96th). Talent is measured as the proportion of the workforce in the "creative class" and the share of adults with higher education. Even though China has many scientists, artists, and others who count as part of the creative class, as well as millions of college graduates annually, these people still account for such a small percentage of the overall population that this component drags down China's score. The tolerance score is based on answers to a global survey conducted by Gallup that asks whether people believe their own communities to be hospitable to minorities and gay people, and Chinese respondents gave low marks on these questions. This index is rooted in a vision of innovation that emerges from a progressive climate, for which contemporary China is a poor fit. The

5. "The Global Creativity Index 2015," Martin Prosperity Institute, http://martinprosperity.org/content/the-global-creativity-index-2015/.

Figure 2. Innovation Indices: China's Rank



Source: See citations for each index for their respective sources.

question is whether technology innovation can be produced in more closed social environments. If so, this index understates China's potential for successful innovation.

Sandwiched in between the extreme poles are two indices that may be more balanced. The first is the Global Competitiveness Index (GCI). Developed by the World Economic Forum, the GCI is based on an annual survey of almost 14,000 respondents in 135 countries from a wide range of small- to large-sized companies who answer questions about economic and business issues in their own countries.[6] In its latest iteration, 355 valid surveys were collected from Chinese respondents. The World Economic Forum draws on two parts of the survey, those addressing scientific innovation and business sophistication, to calculate a score that serves as a good proxy for what we are examining in this study. The survey questions on innovation ask respondents to judge China's capacity for innovation, the quality of its research institutions, company spending on R&D, university-industry collaboration, government procurement, the availability of scientists and engineers, and the quality of IPR protection in the country.[7] These measures are then combined with others measuring business sophistication, which ask about supplier quality, development clusters, marketing, and other factors.

6. *The Global Competitiveness Report 2016–17* (Geneva, Switzerland: World Economic Forum, 2017), http://www3.weforum.org/docs/GCR2016-2017/05FullReport/TheGlobalCompetitivenessReport2016-2017_FINAL.pdf.

7. The innovation component also includes one physical measure, that of filed patents per million people in the population.

Table 1. Global Innovation Index: China across Main Components, 2016

	Number of Indicators	China's Score	China's Rank
Total	**103**	**50.6**	**25**
Institutions	11	55.2	79
Human Capital and Research	15	48.1	29
Infrastructure	13	52.0	36
Market Sophistication	13	56.6	21
Business Sophistication	18	53.8	7
Knowledge & Technology Outputs	17	53.3	6
Creative Outputs	16	42.7	30

Source: Global Innovation Index.

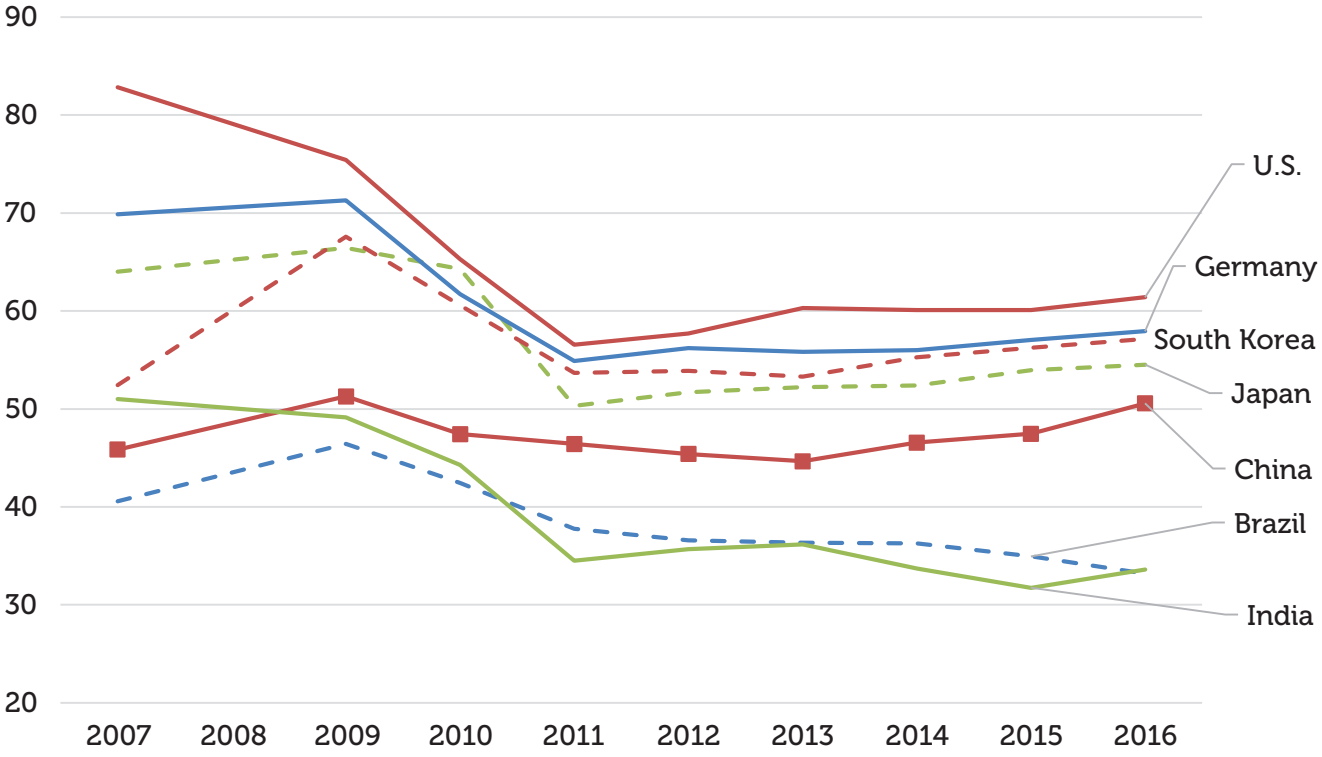
The result yields a relatively positive picture, with China performing somewhat better on basic innovation issues than on core aspects of business sophistication. Whether measured by the raw score or relative rank, China's position has generally remained relatively steady since 2009. To its credit, the index benefits from the perspectives of a large number of business respondents, who not only may be immune to hype or alarmism but also have a good sense of what innovation means in commercial terms and not just as a political slogan. To the index's detriment, respondents only answer questions about their own country, and so cross-national comparison is not based on actual common physical measures between different countries, leaving the possibility that the index does not account for any potential gaps between subjective impressions and actual performance.

THE GOLD STANDARD

The true gold standard of indices is the Global Innovation Index (GII), jointly published since 2007 by the World Intellectual Property Organization (WIPO), Cornell University's SC Johnson College of Business, and the European business school INSEAD.[8] As shown in Table 1, with 103

8. For details about the Global Innovation Index's history, methodology, and data, see its website, https://www.globalinnovationindex.org. Tellingly, as of mid-2017 the most recent report listed at the top of the website displays

Figure 3. GII: Scores of Selected Countries



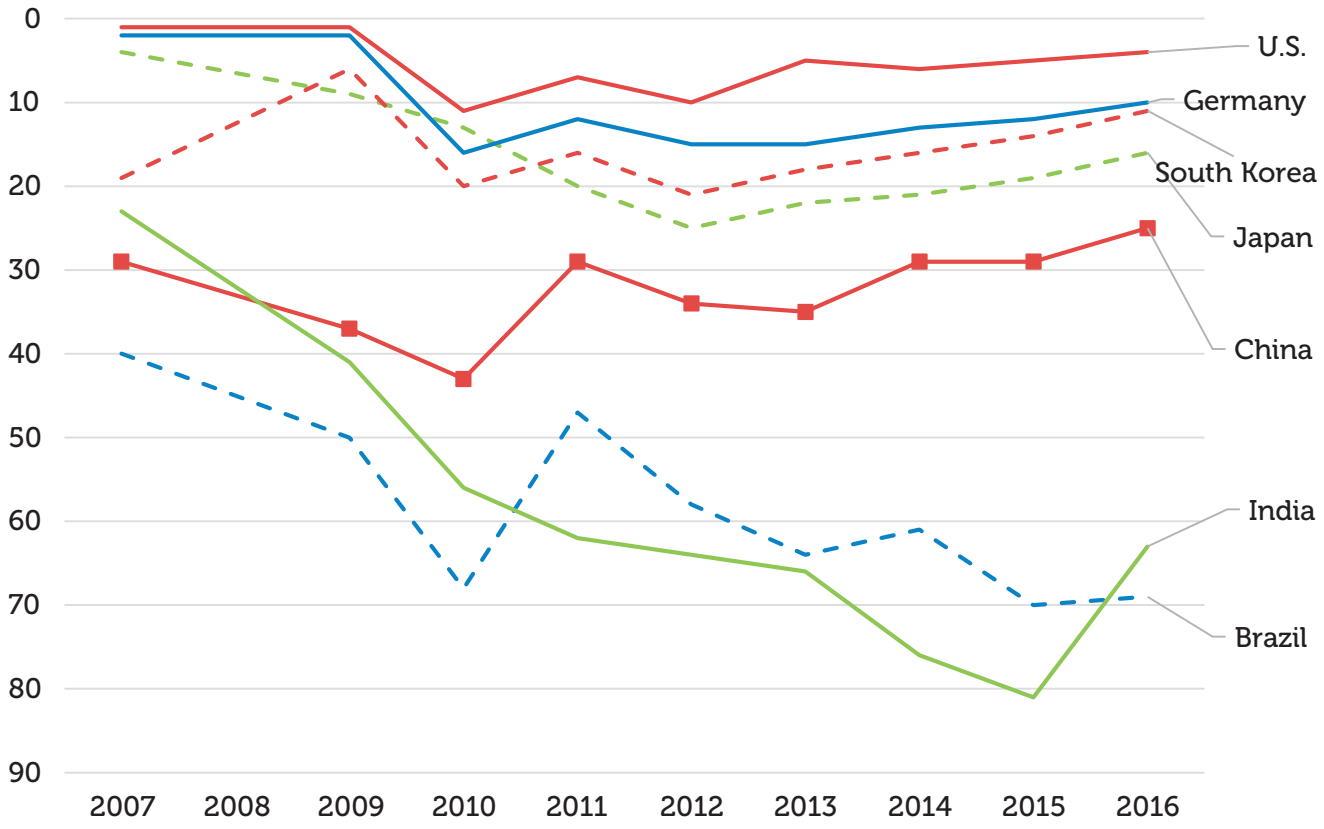
Source: Global Innovation Index.
Note: There was a two-year gap (2007–2009) between the first and second reports.

components in seven categories, the GII is far more comprehensive and balanced than any other index. The individual components are primarily physical measures, but they also include some survey responses because judgments about innovation also matter. The categories cover a range of areas, beginning with the general environment, such as political institutions and infrastructure, that can affect the potential for innovation. The index then moves on to more specific inputs such as human capital and R&D. Finally, the index incorporates data from a range of outputs, from those associated with basic knowledge and technologies to various kinds of "creative outputs," such as industrial designs, creative goods and services, national feature films, and online creativity. The 2016 index was calculated for 128 countries, giving it broad coverage over every continent.

Looking specifically at China (see Figure 3), we see that its overall raw score actually peaked in 2009. It fell in the first few years after the global financial crisis and has recovered most of its value since reaching its nadir in 2013. In China's case, the drop was likely the result of the massive expansion of spending needed to generate continued economic growth in the short term, with less focus on the quality of the investments; the result was a weakening of the input components of its score. (For most countries, though, the likely cause was recession and an absolute decline in

links for both the English and Chinese versions. Until 2010, the index was calculated on a scale of 1–7, and since 2011 on a scale of 1–100. To allow for comparison, we normalized the earlier scores to the new scale.

Figure 4. GII: Ranks of Selected Countries



Source: Global Innovation Index.
Note: There was a two-year gap (2007–2009) between the first and second reports.

economic activity.) China's total score in 2016 of 50.6 (out of 100) reflects relatively similar raw scores across each of the seven categories, with market sophistication being the strongest (56.6) and creative outputs the lowest (42.7).

China's innovation picture, however, looks somewhat more positive when viewed in comparative perspective. Figures 3 and 4 present the overall score and rank of China and several other representative countries. Regardless of which yardstick is used, China is distancing itself from other emerging economies, such as Brazil and India, and gradually approaching more advanced industrialized economies known for their innovation prowess. Even though its absolute score has only risen five points since 2013, China's global rank has jumped 10 places over the same period.

As Table 2 shows, China's rank among Asian countries has remained steady over the past few years, holding at seventh. More impressive is China's standing among countries at a similar level of development, based on World Bank classification standards (see Table 3). In 2011 China ranked first among lower-middle income countries. China was reclassified as an upper-middle income country in 2012; since 2014 it has ranked first among this group.

Table 2. GII Rankings: China & the Asia-Pacific Region

	2011	2012	2013	2014	2015	2016
1	Singapore	Singapore	Hong Kong	Singapore	Singapore	Singapore
2	Hong Kong	Hong Kong	Singapore	Hong Kong	Hong Kong	South Korea
3	New Zealand	New Zealand	New Zealand	South Korea	South Korea	Hong Kong
4	South Korea	South Korea	South Korea	Australia	New Zealand	Japan
5	Japan	Australia	Australia	New Zealand	Australia	New Zealand
. . .						
China	7	8	8	7	7	7

Source: Global Innovation Index.

REASONS FOR CONCERN

This positive trend is clear, but there are signs of concern for China as well. The most important is that when one separates the scores into their components for inputs and outputs, China's input score (Figure 5) has been rising, but its output score (Figure 6) has fluctuated within a narrow range. Relatedly, even though the absolute scores for output are closer to those of the world leaders, it is still not clear that inputs in China translate into outputs in an efficient manner or whether there is a longer time lag between inputs and outputs in China compared to other more marketized economies.

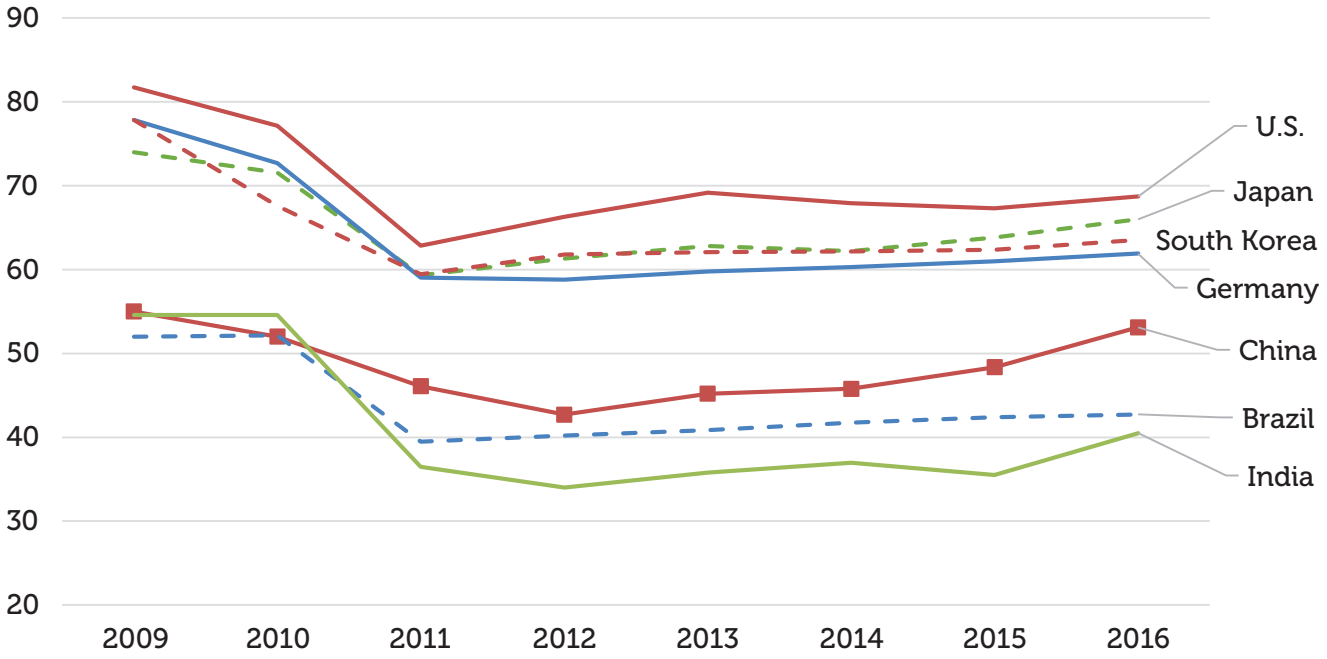
Moreover, although the GII is the best cross-national index that currently exists, it is not perfect, as it relies on data from many other sources, including the surveyed countries. It is likely that China's data on inputs and outputs is inflated. While this could be the case in all of the surveyed countries, this possibility means that we should not accept the data as sacrosanct and that we need to investigate both sides of the input-output equation more closely. This is the task of the next three sections of the report.

Table 3. GII: China's Rank Within Its Income Range

	Lower-Middle	Upper-Middle				
	2011	**2012**	**2013**	**2014**	**2015**	**2016**
1	China	Latvia	Malaysia	China	China	China
2	Moldova	Malaysia	Latvia	Malaysia	Malaysia	Malaysia
3	Jordan	China	China	Hungary	Hungary	Bulgaria
4	Thailand	Lithuania	Costa Rica	Mauritius	Bulgaria	Turkey
5	Vietnam	Chile	Lithuania	Bulgaria	Montenegro	Costa Rica

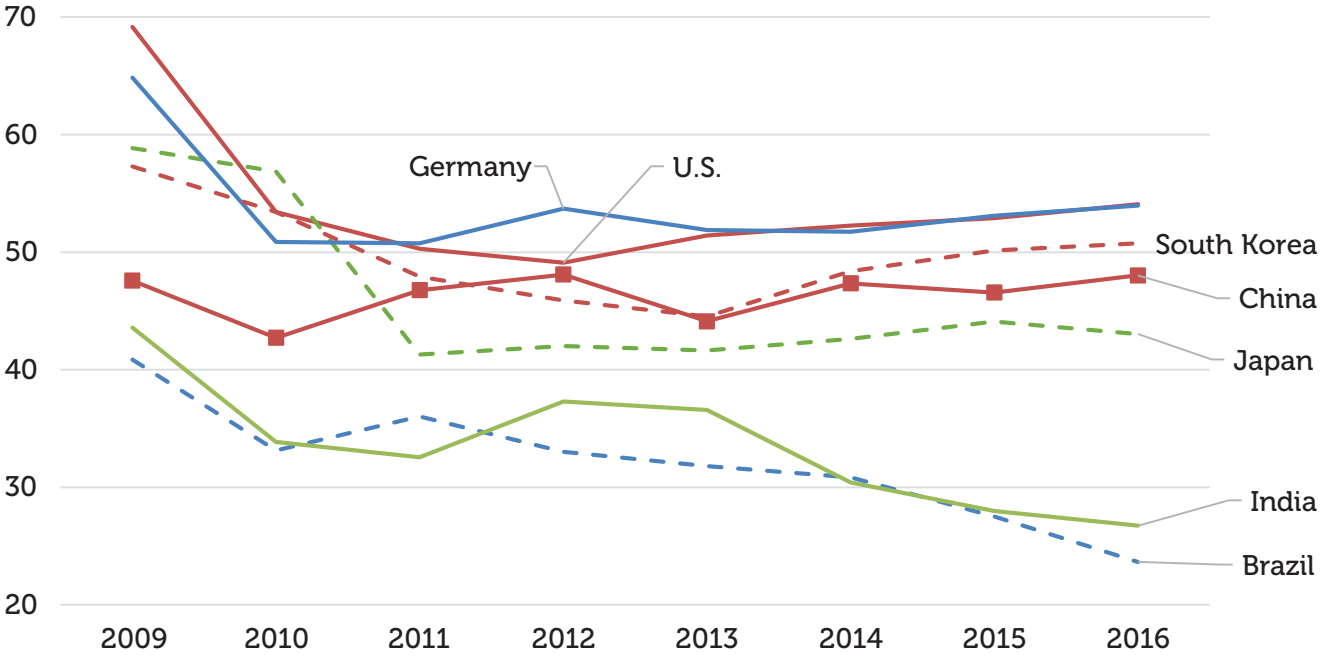
Source: Global Innovation Index.

Figure 5. Selected Countries' GII Input Scores



Source: Global Innovation Index.

Figure 6. Selected Countries' GII Output Scores



Source: Global Innovation Index.

03

Financing Innovation

INTRODUCTION

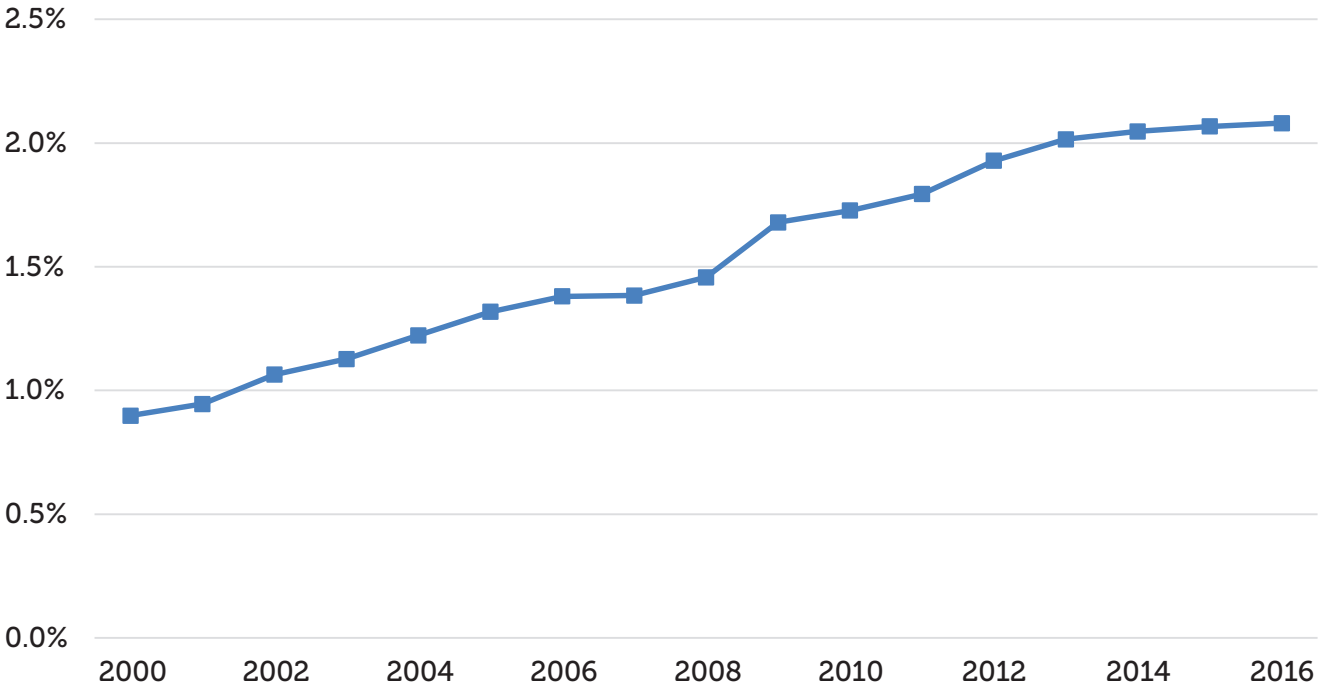
There is no perfect recipe for innovation, but we do know what some of the main ingredients are: human talent and funding. Without ideas, there can be nothing new, and without funding, these creative ideas cannot be put into practice. Developing talent and directing funds to the right targets depends on a host of other factors as well, among them vibrant educational and training systems, a mature financial system, reliable physical infrastructure, sound political institutions, and smart policies.

The human capital situation in the People's Republic of China (PRC) is fascinating, but we will not focus on it much here, as the story is already pretty well known. China graduates massive numbers of scientists and engineers who have excellent basic technical skills but are not highly creative risk-takers. China's K-12 educational system, though highly meritocratic, is geared to preparing students for the college entrance exam. Universities face a variety of social and political constraints in encouraging creativity, and students have limited opportunities for genuine exploratory research in science and technology. One interview source who oversees his company's training programs noted that his firm has internship programs around the world; in the United States, one in 20 interns are retained for permanent employment, but in China the figure is only one in 500.[1] China compensates for the weaknesses in its domestic educational system by sending a huge number of students to study abroad each year and then enticing them to return home, as well as by hiring well-trained non-Chinese to work in their companies.

The picture on finance inputs is evolving in new and surprising ways and so is given more attention here. By any measure, Chinese spending on technology development is increasing rapidly. And the sources of funding are also diversifying. China's financial system is no longer synonymous with its

1. Other interview sources challenged this example as not representative of their own experiences, particularly recently, where they have encountered a growing number of talented and creative Chinese scientists, engineers, and businesspeople. Hence, it is important to be careful about how to interpret anecdotal evidence such as this.

Figure 7. Total Expenditures on R&D in China (Percent of GDP)



Sources: For 2000 to 2014, the World Bank; for 2015 and 2016, China National Bureau of Statistics, China Ministry of Science and Technology, and China Ministry of Finance.

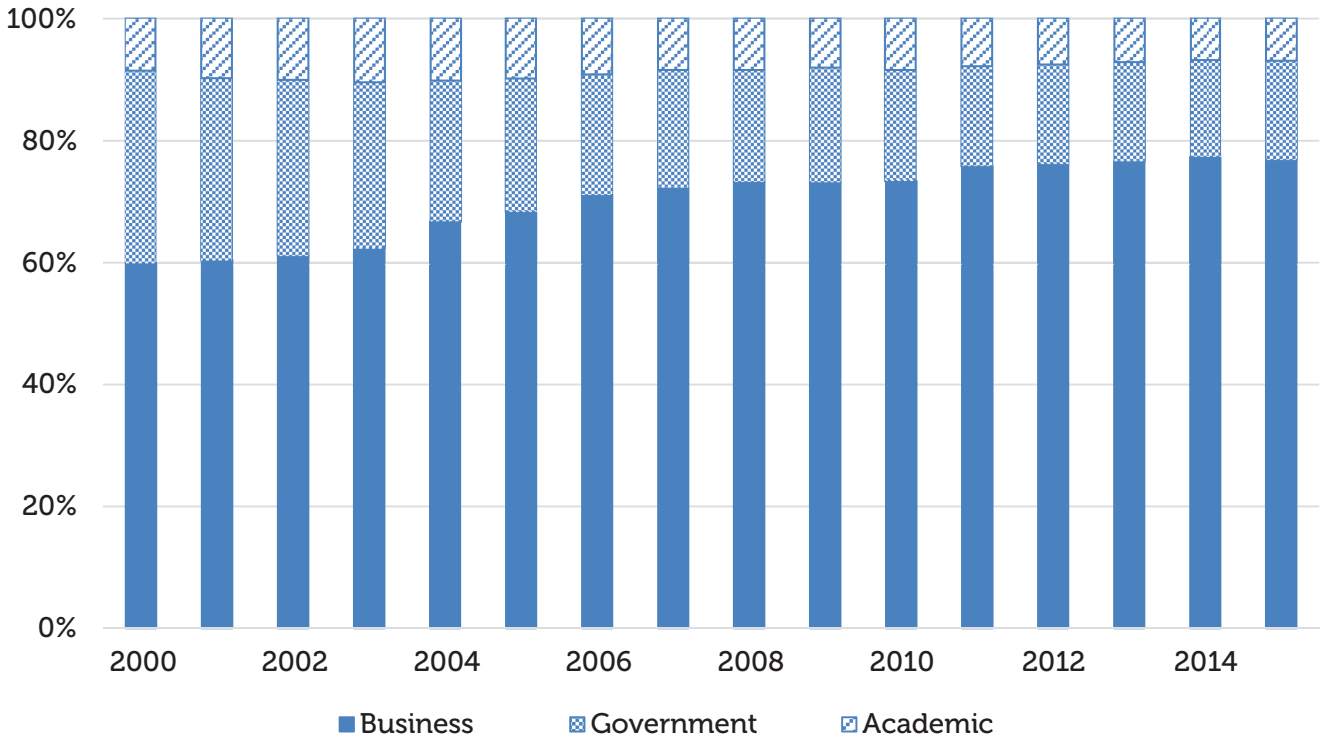
large state-owned banks; there are now regional banks, foreign banks, stock markets, purely online investment vehicles (such as Alibaba's Yu'e Bao money market service), crowdfunding, bond markets, commodity markets, venture capitalists, and private equity investors. This expanding panoply of investment channels should be welcomed, but it is worth examining toward what kinds of initiatives all of this spending flows, and whether it is translating into innovation outputs that raise productivity and serve society.

THE SHIFT TOWARD CORPORATE SPENDING

Spending on R&D has risen steadily, from 0.9 percent of gross domestic product (GDP) in 2000 to 2.1 percent in 2016, placing China in the company of other advanced industrialized economies (see Figure 7). In absolute terms, the rise is far larger, from $10.9 billion in 2000 to $232 billion in 2016.[2] The sources of funding have also diversified. As Figure 8 shows, government and academic research institutes play a much smaller role in R&D than they did prior to the Reform Era or even in 2000. Companies now account for 77 percent of all R&D activity, and the share taken on by

2. "MOST: Expects 2016 Annual Society R&D Expenditures to Be RMB 1,554 Billion," CCTV, January 11, 2017, http://news.cctv.com/2017/01/11/ARTIGl2OPlQWMEXQJvYr71H1170111.shtml.

Figure 8. Usage of R&D Funds in China



Source: OECD's Main Science and Technology Indicators database.

government has been cut in half.[3] To put this figure in comparative context, the proportion of R&D carried out by the government in China is lower than in the United States (24 percent), the United Kingdom (28 percent), and Germany (30 percent).[4]

The shift in China toward corporate use of R&D funds has also been accompanied by a transition away from spending on basic science and toward applied research and development, with an emphasis on investments that can be easily commercialized. To put it simply, there is much more spending on "D" (development) than "R" (research) in China. According to China's National Bureau of Statistics, in 2015, out of the RMB 1.4 trillion ($209 billion) spent on R&D, just over 5 percent went toward basic research, 10.8 percent toward applied research, and a whopping 84.2 percent was directed toward development.[5]

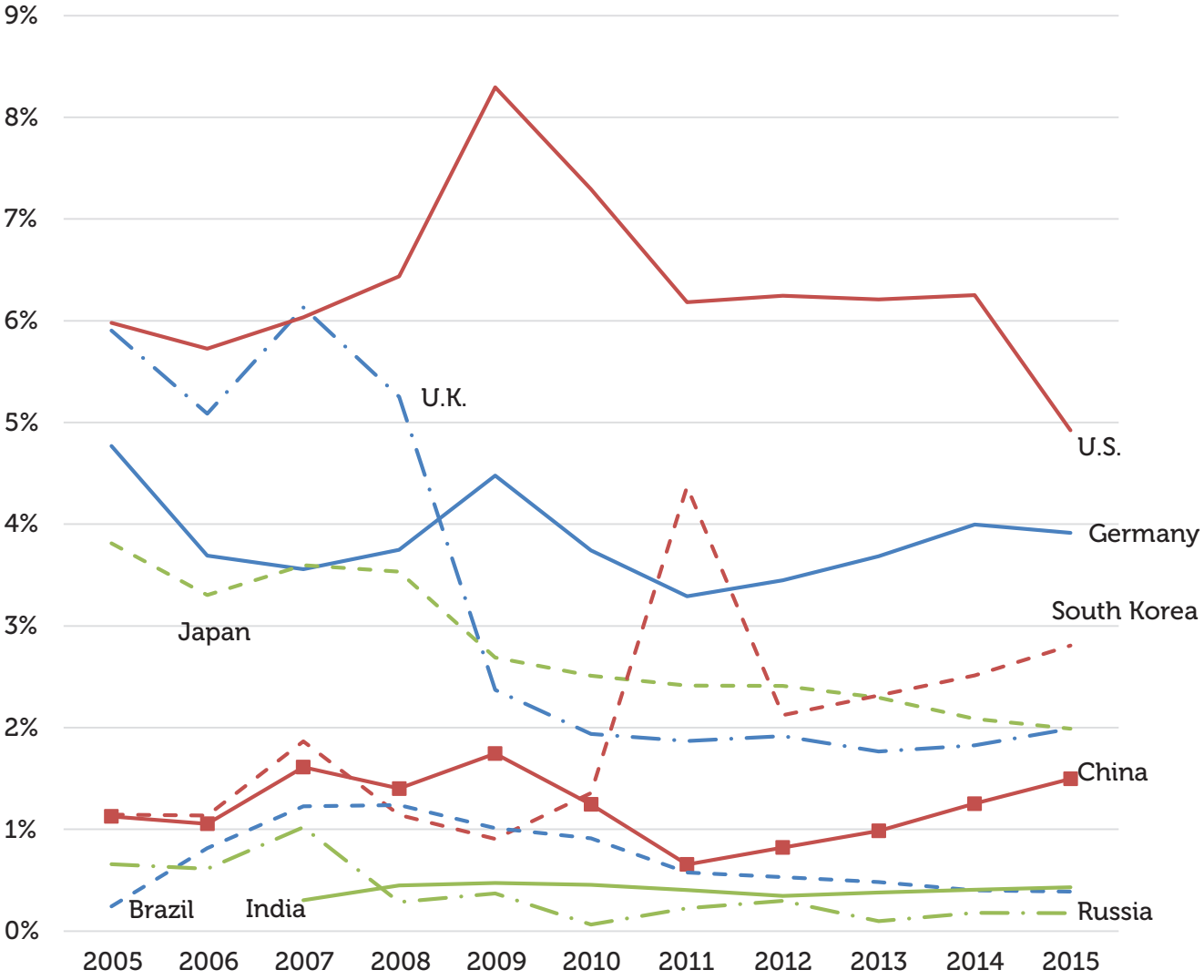
In addition to looking at macro data from the Chinese government and international institutions, another way to drill down on this question is to look at it in a bottom-up manner. We examined Bloomberg data on all listed companies over the last decade. We calculated the "R&D intensity" of

3. The figures on sources (government, companies, etc.), also from the OECD, track very closely with the data on usage, and hence, are not presented here. See *Main Science and Technology Indicators*, vol. 2016, no. 2, (Paris: OECD, 2017), http://www.oecd-ilibrary.org/science-and-technology/main-science-and-technology-indicators_2304277x.

4. Ibid. These figures are for 2015. The figure for Japan is 15 percent.

5. China National Bureau of Statistics, accessed August 1, 2017, http://data.stats.gov.cn/easyquery.htm?cn=C01.

Figure 9. Corporate R&D Intensity (R&D/Revenue)



Source: Author's calculations from Bloomberg database.

each firm based on its reported R&D expenditures and revenues to see not only how much Chinese companies are spending, but if they are doing so at rates similar to or different from listed companies in other countries.[6]

As shown in Figure 9, the data show that R&D spending among Chinese companies rose during the 2000s, then fell after the global financial crisis, and then began rising again, reaching 1.50 percent of revenues in 2015. These findings are consistent with the macro data and indices, which show China's R&D spending to be somewhat below leading innovators but ahead of other large developing countries. Since 2012 Chinese companies have begun separating themselves

6. The data include companies from several countries regardless of where the stock market is located on which they are listed. We only include data from companies that report figures on both R&D and total revenues.

from those in other emerging economies such as Brazil, Russia, and India. Nevertheless, Chinese companies still invest less in R&D than their corporate cousins in the United States, the United Kingdom, Germany, South Korea, and Japan.

An important caveat is that business spending is influenced by the Chinese government in other ways than direct budget allocations. State-owned banks typically adhere to industrial policy guidelines when issuing loans, and stock market IPOs and some kinds of corporate bonds can also be subject to approval, at least informally, based on state priorities. The same can be true for movement of funds in and out of the country for M&A deals. In addition, the central government and local authorities have created general and sector-specific investment funds in the past few years that are used to invest in priority areas. By the end of 2015, there were at least 780 such funds with RMB 2.2 trillion ($328 billion) in capital.[7] The largest component is in the semiconductor industry, with the various related funds totaling at least $120 billion.[8] Private capital accounts for a large share of these funds, but according to several interview sources, state guidance at the national and local levels has a profound effect on actual investment decisions.

NEW GENERATION OF FINANCING INNOVATION

Despite the continued long reach of the state, an undeniably important shift in China's innovation investment picture is the rise of genuine alternative sources of funding, such as venture capital (VC) and private equity (PE). The level of VC activity has exploded. In 2000 there were 249 VC firms with total capital of RMB 51.2 billion ($7.6 billion); by 2015, there were 1,775 VC firms with total capital of RMB 665 billion ($99 billion). When Chinese VC was in its infancy, the large majority of deals were in high tech. That figure gradually fell, reaching only 46 percent of investment in 2011, but recovered to 60 percent of investment (and 65 percent of projects) by 2015.

The private equity sector is likewise booming and is even larger in absolute terms. By 2016, China had 46,505 PE funds with RMB 7.89 trillion ($1.18 trillion) in capital under management.[9] Over time, PE funds have increasingly shifted their attention toward supporting advanced technology. In terms of the number of individual projects, the Internet and IT were the top two targeted sectors in 2015, whereas machinery manufacturing and chemical processing were the leading recipients in 2011. In terms of overall investment levels, the financial sector is still the largest target, but it is followed, in order, by the Internet, real estate, telecom, and biomedicine.[10]

VC and PE executives are highly enthusiastic about China, but they are also highly pragmatic. One investor who has done business across Asia reflected widespread sentiment when he said that

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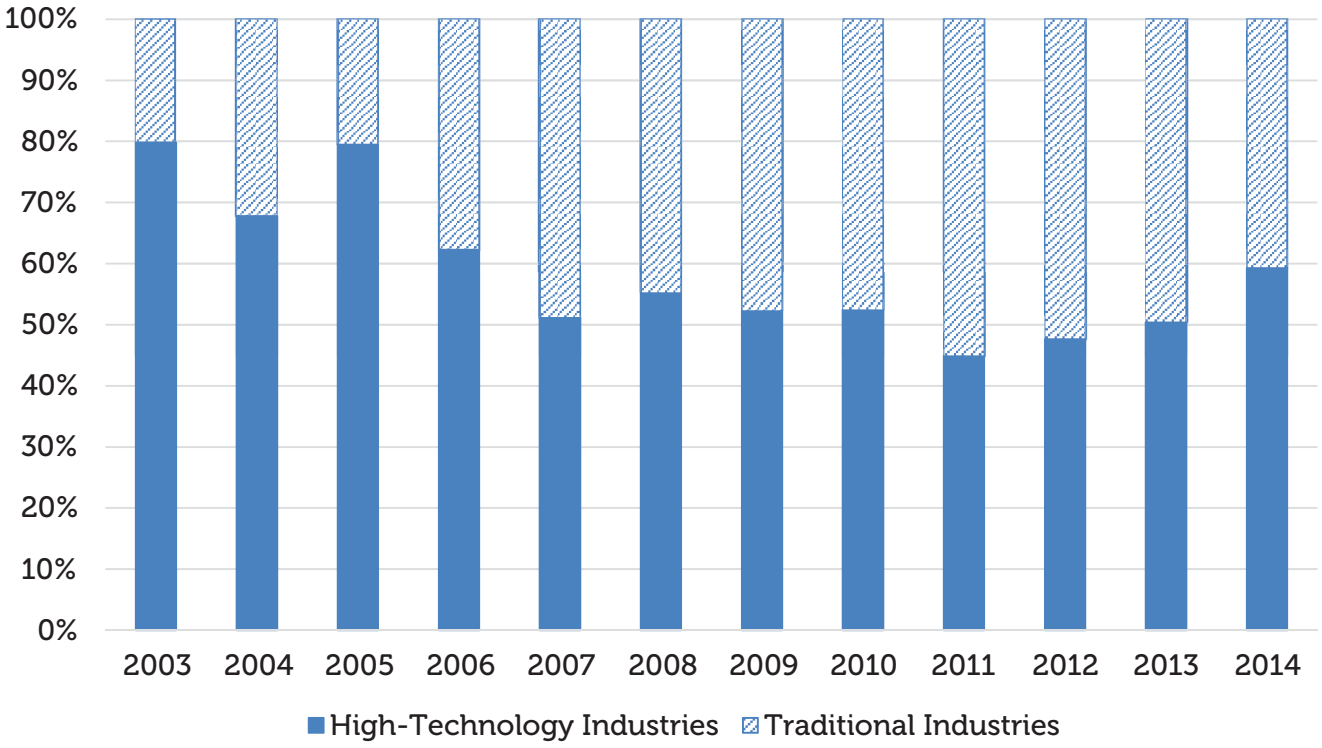
7. *Made in China 2025: Global Ambitions Built on Local Protections* (Washington, DC: U.S. Chamber of Commerce 2017), 18n37.

8. Bob Davis and Eva Dou, "China's Next Target: U.S. Microchip Hegemony," *Wall Street Journal*, July 27, 2017, https://www.wsj.com/articles/chinas-next-target-u-s-microchip-hegemony-1501168303.

9. *Private Equity Capital Comprehensive Filed Case Situation* [私募资金整体备案情况] (Beijing: China Securities Regulatory Commission, 2016), http://www.csrc.gov.cn/pub/zjhpublic/G00306226/201701/t20170109_309140.htm.

10. *2015 China Private Equity Investment Annual Research Report* [2015 年中国私募股权投资年度研究报告] (Beijing: Qingke/Simutong, February 23, 2016), cited in http://pe.pedaily.cn/201601/20160113392457.shtml.

Figure 10. Venture Capital Distribution of Investment



Source: *China Venture Capital Yearbook*, various years.

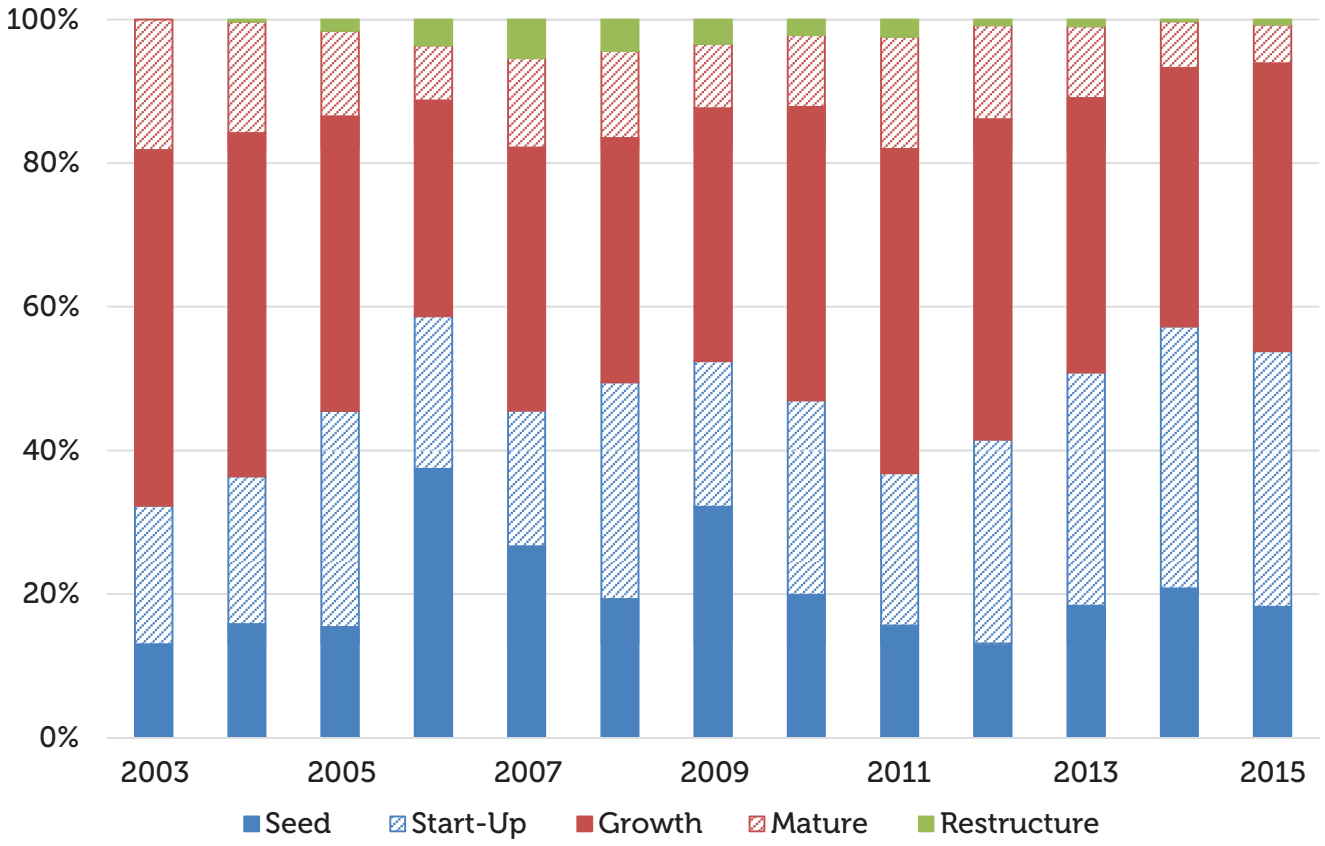
Beijing unequivocally is currently the "most exciting location for VC in the world." He and others breathlessly described a variety of projects they had launched that had generated double-digit returns. Another industry observer held that the quality of technologies investors were considering had risen substantially over the last decade and were now in some sectors on par with those in Silicon Valley and other famous technology hubs.

VC and PE investors in China are also highly realistic and, despite their reputation, less adventurous than one might expect. Hence, they typically avoid entirely untested technologies and garage-style techies with good ideas but little business experience. True angel investors are rare in China. Instead, investors prefer to support technologies that have already shown commercial promise. As one told me, "We don't invest in zero to one, we invest in one to one hundred." That is, they avoid getting an entirely new technology off the ground and instead focus on helping a business scale up. Hence, they are drawn toward commercially viable applications and customizations for the China market.

The general quantitative data reflect these sentiments. Around half of all VC projects that receive funds are beyond the start-up phase, are either growing or mature, and in some cases, are being restructured. From 2004 to 2016, the percentage of VC deals invested in at the seed/angel level in the United States grew from 9 percent to 50.6 percent of the total.[11] By contrast, in China only 18.2 percent of VC investment in 2015 was in seed-level projects.

11. Yuan Wang et al., *China Venture Capital Yearbook* (Beijing: Economy and Management Press, various years).

Figure 11. Stages of VC Projects Invested in China



Source: *China Venture Capital Yearbook*, various years.

Another clear sign of investors' reticence in going too far out on a limb is that the proportion of projects in high-tech industries that yield a profit has been almost identical to that in traditional industries. In 2014, the last year for which data are available, 47.8 percent of high-tech projects were profitable, compared to only 38.5 percent in traditional industries. If investors were embracing a lot of novel technologies, the likelihood of success would be lower than in other sectors. By contrast, in the United States, the likelihood of success for VC projects is somewhat lower; only 35 percent of VC investment made in the United States between 2004 and 2013 was profitable.[12]

CONCLUSION

The amount of funds that China has dedicated to developing advanced technologies is staggering. Old-school banks and new-school investment vehicles are all getting in on the action. No longer are funds just being tossed at large-scale white elephants. Commercial competitiveness is now a

12. Seth Levine, "Venture Outcomes Are Even More Skewed Than You Think," VC Adventure, August 12, 2014, http://www.sethlevine.com/archives/2014/08/venture-outcomes-are-even-more-skewed-than-you-think.html.

Figure 12. VC Performance: Proportion of Profitable Projects

Source: *China Venture Capital Yearbook*, various years.

central part of the decision calculus. Although this is a definite improvement over the earlier financing system, it is reasonable to consider whether China has overcorrected. By avoiding spending on basic research and foundational technologies, income is being generated less as a result of novel technologies and more as a result of new applications or business models. These are reasonable strategies, but they suggest that China differs from more established technology leaders.

One paradox is that despite an investment focus on non-core technologies, patenting activity in China has risen dramatically. The next section seeks to explain this puzzle by suggesting that perhaps there is less novel knowledge creation in China than meets the eye.

04

Creating Valuable Knowledge

INTRODUCTION

An important measure of whether China's innovation drive is paying dividends is to assess the value the country places on intellectual property (IP). Some innovations are not associated with any particular IP, but typically innovators file for patent, copyright, or trademark protection to protect their contribution and increase the likelihood that they can generate sufficient returns to recoup the original investment and generate profits. China has been the largest source of IP violations globally, a place where counterfeits and pirated goods seemed in endless supply.

China's relationship with IP has evolved substantially in the last two decades as the government and businesses have recognized that developing, utilizing, and leveraging IP is central to the country becoming a high-tech power. To some extent, this shift was borne out of admiration of the world's leading innovators in industry and academia, but it also emerged out of the jealousy created in the 1990s when China first started paying steep royalties to IP holders in the United States, Europe, and Japan. Particularly ingrained in China's memory was what was perceived as exorbitant royalties paid to Qualcomm for its CDMA technology used in second-generation cellular technology and to the DVD Forum for DVD players that Chinese companies assembled.

As a result, China has shifted its overall posture from seeing itself as a consumer of IP who stresses its diffusion, legal and illegal, to seeing itself as an IP creator who emphasizes the need to protect IP rights and reward the work of innovators. China has joined all of the world's important IP treaties, drafted and updated its various IP statutes, strengthened its IP bureaucracy, encouraged the filing of IP, and created IP courts to handle legal disputes.[1] China has also ramped up its efforts to set novel domestic technology standards and shape international standards based on proprietary

1. See Bruce Reynolds and Susan K. Sell, "China's Role in Global Governance: A Comparison of Foreign Exchange and Intellectual Property," in *Global Governance and China: The Dragon's Learning Curve*, ed. Scott Kennedy (New York: Routledge, 2017), 132–157.

Chinese technology.[2] IP theft is still a massive problem, and has moved from the street to online, but there has been progress in some significant ways. The Business Software Alliance estimates that in 2015, 70 percent of installed software in China was pirated, down from 79 percent in 2009, and 93 percent in 2003. This is still far higher than piracy rates in the United States and Europe, but the trajectory is clear.[3]

Integral to this transition has been the increase in IP filing activity, particularly patents, which is the focus of this section of the report. As with the analysis on financial inputs, the current picture for IP is decidedly mixed. Although patent filing has risen dramatically, the actual commercial value of Chinese patents is still extremely low. This outcome raises questions about the efficacy of the R&D spending and efforts documented in the preceding section.

PATENT AWAY!

The growth of patent filing in China is astounding. Chinese applied for only 170,000 patents in 2000, but in 2015 submitted almost 2.8 million applications. The number of granted patents is somewhat lower, but the trajectory is the same (see Figure 13). The vast majority of patent applications, over 93 percent, are filed by permanent residents of China, not foreigners.[4]

According to the World Intellectual Property Organization (WIPO), China has also moved up in terms of filing international patent applications. The country now files far more international patents than Germany or South Korea and almost as many as Japan and the United States (see Figure 14). In fact, in 2008 Huawei became the first Chinese company to be the world's single largest patent filer. Since then Huawei and ZTE have held the number one spot for six of nine years, with ZTE at the head of the pack in 2016.[5]

PATENT PROBLEMS

Despite the about-face in attitude towards IP, it is unclear that this activity has translated into technological innovations with equally impressive commercial value. The further one digs, the weaker China's patent credentials appear.

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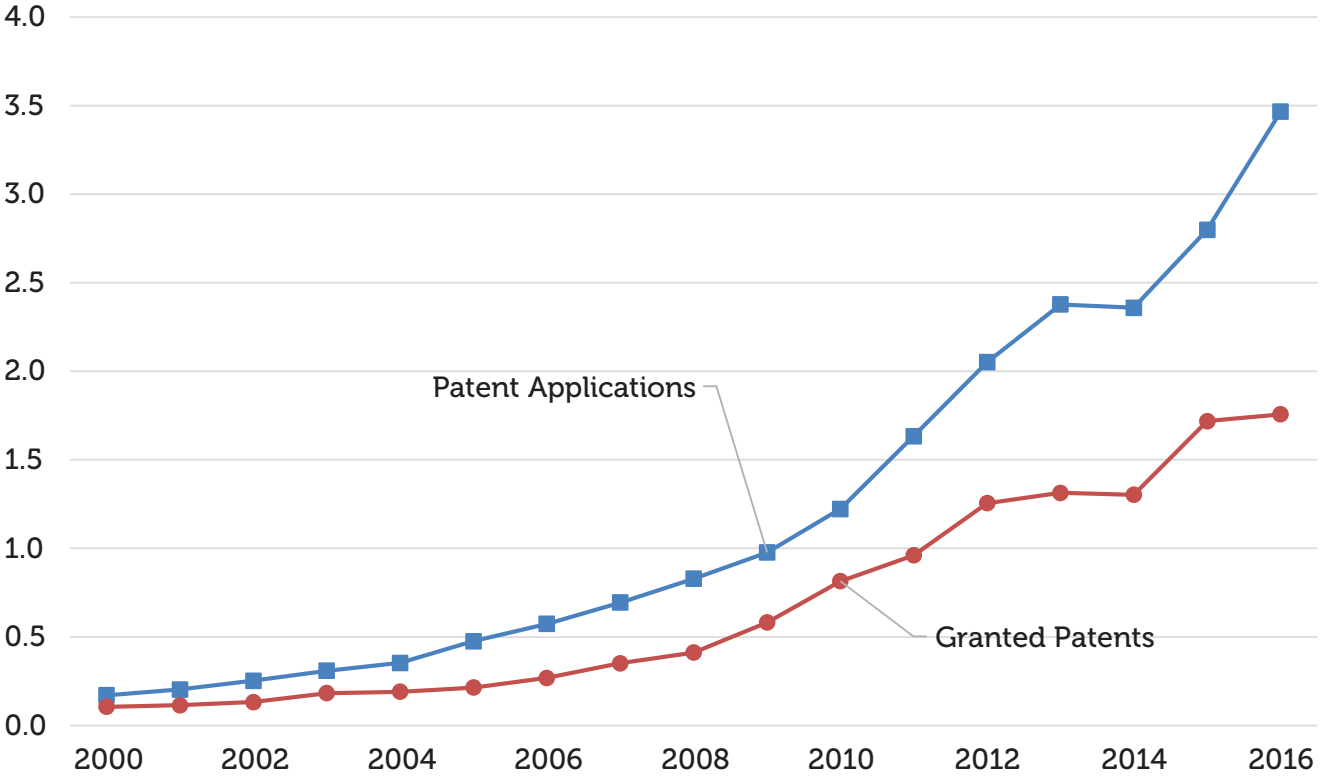
2. Scott Kennedy, Richard P. Suttmeier, and Jun Su, "Standards, Stakeholders, and Innovation: China's Evolving Role in the Global Knowledge Economy," *NBR Special Report*, no. 15 (Seattle: National Bureau of Asian Research, September 2008).

3. Software piracy has been reduced by the movement away from sales to licensing and from boxed software to cloud-based applications. *Seizing Opportunity Through License Compliance: BSA Global Software Survey*, Business Software Alliance, May 2016, http://globalstudy.bsa.org/2016/downloads/studies/BSA_GSS_US.pdf.

4. World Intellectual Property Organization (WIPO), "Intellectual Property Statistics," database, accessed April 30, 2017, http://www.wipo.int/ipstats/en/.

5. World Intellectual Property Organization, "Record Year for International Patent Applications in 2016; Strong Demand Also for Trademark and Industrial Design Protection," March 15, 2017, http://www.wipo.int/pressroom/en/articles/2017/article_0002.html; and WIPO, "World Intellectual Property Indicators," various years, http://wipo.int.

Figure 13. Patents in China (Millions)



Sources: For 2000 to 2015, China State Intellectual Property Office; for 2016, China National Bureau of Statistics.

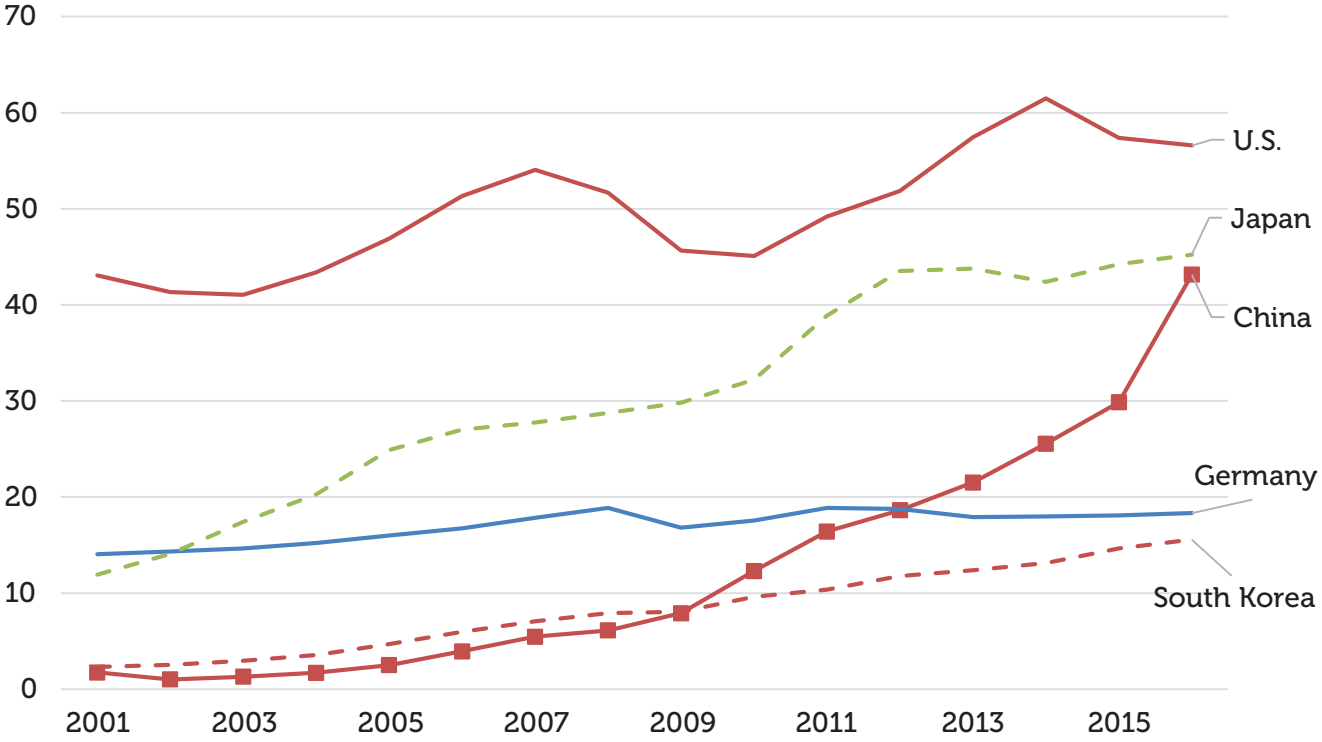
First are doubts about the basic quality of the patents. Only a minority of patents in China are invention patents. More specifically, in 2015 only 39 percent of applications and 21 percent of approvals were for invention patents; this is higher than in years past, but it still means that the majority of patents in China are for utility-model and design patents, which are granted with far less scrutiny.[6] Although Chinese file a lot of patents at home, they are far less active abroad. As shown in Figure 15, less than 5 percent of Chinese patents are filed in other jurisdictions, far less than advanced industrialized economies, and even much less than Brazil or India. Relatedly, Chinese inventors rarely obtain what are called "triadic patents," in which the same patent is successfully in the United States, the European Union, and Japan. In 2014, the latest year available, Chinese obtained only 2,582 triadic patents, a much smaller total than for applicants from the United States (14,944) or Japan (17,121).[7]

Second, the domestic value of patents in China is extremely low. In 2015, patent licensing only generated total revenues of RMB 11.7 billion ($1.75 billion), and sales of patent rights that year

6. China State Intellectual Property Office, accessed May 10, 2017, http://www.sipo.gov.cn/tjxx.

7. "Triadic Patent Families," OECD Data, accessed May 20, 2017, https://data.oecd.org/rd/triadic-patent-families.htm.

Figure 14. International Patent Applications (Thousands)



Source: World Intellectual Property Organization.
Note: International patent applications filed under the Patent Cooperation Treaty (PCT).

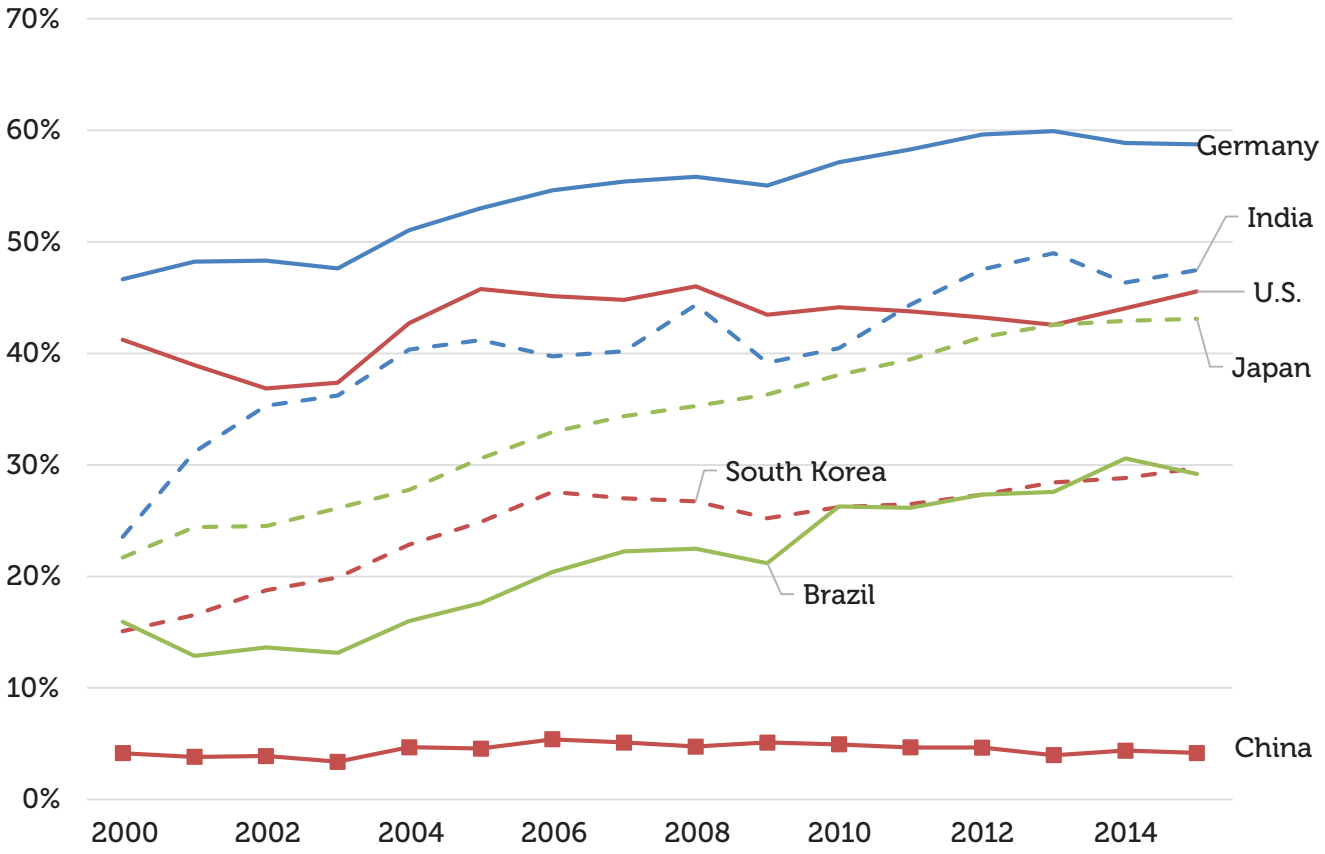
totaled RMB 9.25 billion ($1.38 billion).[8] By contrast, in the United States in 2012 (the most recent year data are available), IP licensing revenue totaled $115.2 billion. The American economy is approximately six times the size of China's, but IP's direct value to the United States is roughly 100 times greater.[9] Similarly, although domestic mergers and acquisitions have skyrocketed, according to an IP lawyer, patent and copyright portfolios are given short shrift when determining both parties' valuations and usually have little to no effect on the terms of the deal. Finally, although Chinese are taking each other to court for IP infringement in record numbers, the average award in a patent infringement case is puny, in 2016 reaching only RMB 98,000 ($14,627). By contrast, the median patent damage award in the United States over the last few years has been $7.3 million.[10] The U.S. figures may seem excessive, but the typical award in China is far from a disincentive to appropriate someone else's invention. Another sign of the low value of patent awards in China not dependent on external comparisons is the relatively higher awards given in competition cases. According to the London-based firm Rouse, the average award for competition cases in

8. *China Science & Technology Yearbook 2016* (Beijing: China Statistics Press, 2016), 208.

9. U.S. Patent & Trademark Office, "Intellectual Property and the U.S. Economy: 2016 Update," September 2016, https://www.uspto.gov/sites/default/files/documents/IPandtheUSEconomySept2016.pdf.

10. Chris Barry et al, "2016 Patent Litigation Study: Are We at an Inflection Point?," PricewaterhouseCoopers, May 2016, https://www.pwc.com/us/en/forensic-services/publications/assets/2016-pwc-patent-litigation-study.pdf.

Figure 15. Percentage of Patents Filed Abroad



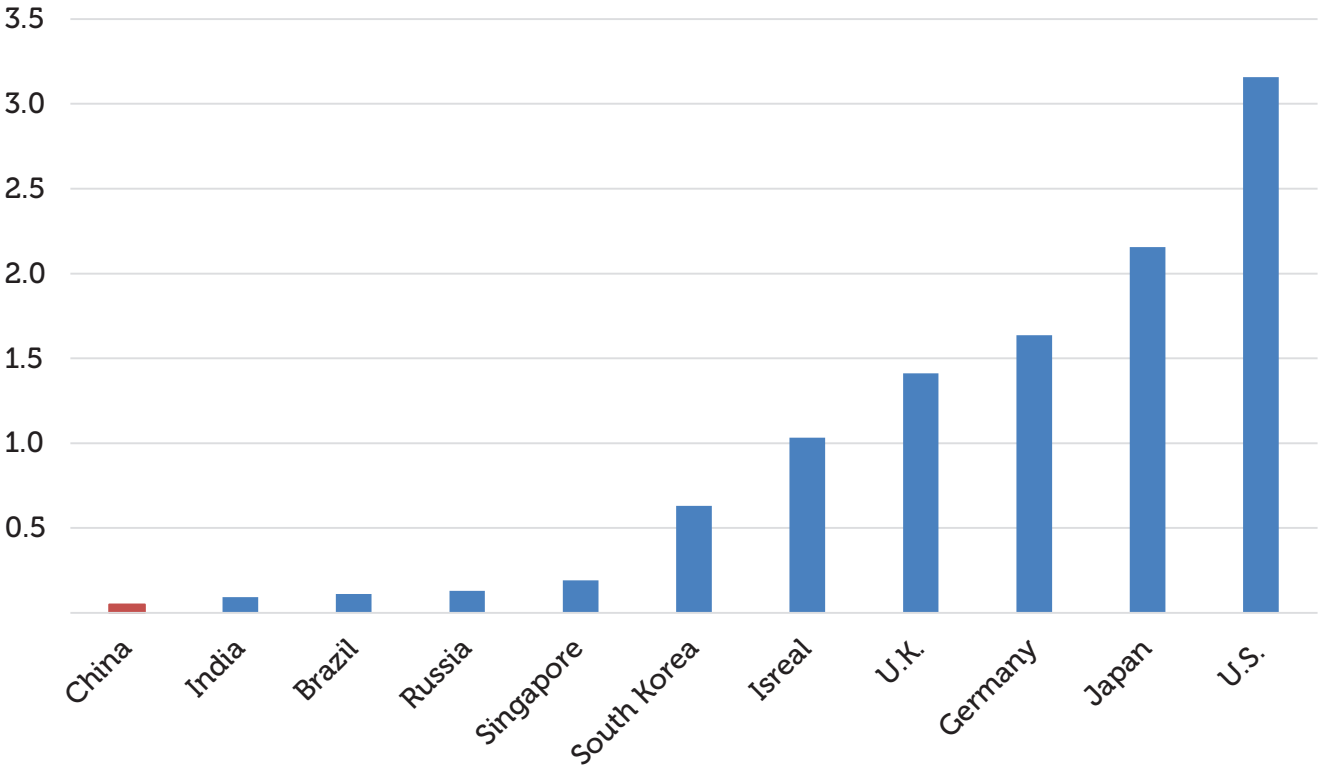
Source: World Intellectual Property Organization.

China in 2013 was RMB 650,000 ($97,015), more than seven times the average award for patent infringement cases that year.[11] This suggests that Chinese courts still view their role more as protecting consumers—even when those consumers are businesses and governments—than inventors.

And third, China is still a massive net importer of IP internationally. According to the International Monetary Fund, which tracks international IP license receipts and payments, China's receipts for IP licenses have risen substantially, from almost nothing in 2000 to over $1.0 billion in 2015. But China's licensing payments to others are far higher, at over $22 billion in 2015. When examined as a ratio of receipts to payments (see Figure 16), China has one of the worst ratios among countries that are major participants in international IP licensing. For every dollar China pays in fees, it receives less than a nickel. The reason is simple: in the global supply chain, China is still primarily an assembler and manufacturer, not a creator.

11. "Analysing Patent Civil Infringement Cases," CIELA database, Rouse Corporation, accessed August 1, 2017, http://ciela.cn/en/analysis/patents.

Figure 16. IP International Licensing Ratio: Receipts-to-Payments, 2015



Source: International Monetary Fund.

CONCLUSION

China's embrace of IP is positive when contrasted with the country's original disdain for property rights of any sort and widespread violation of IP rights. However, China's about-face is incomplete. The Chinese state is not entirely withdrawing, but is, in fact, strengthening its role in some regards. China's efforts to develop and obtain more IP are driven heavily by bureaucratic imperatives as opposed to market incentives. Authorities do not believe that IP should be created, traded, and defended on pure commercial principles. As China's own IP strategy documents make clear, IP is meant to serve national goals, and the government is expected to continue to play a major role in every facet of the process.

Hence, China may now be a "large" IP country, but it is still a "weak" one. Chinese annually apply for and receive as many patents as are given to any other country, yet Chinese patents often have little commercial value. Whether one is discussing licensing and royalties, mergers and acquisitions, or dispute settlement, patents do not get the respect they receive in other countries. This reflects the fact that much of the initiative to patent comes from the government and not the market. And without sufficient market support for patents and other types of IP, deep technology innovation will be hard to sustain.

05

Commercial Performance

INTRODUCTION

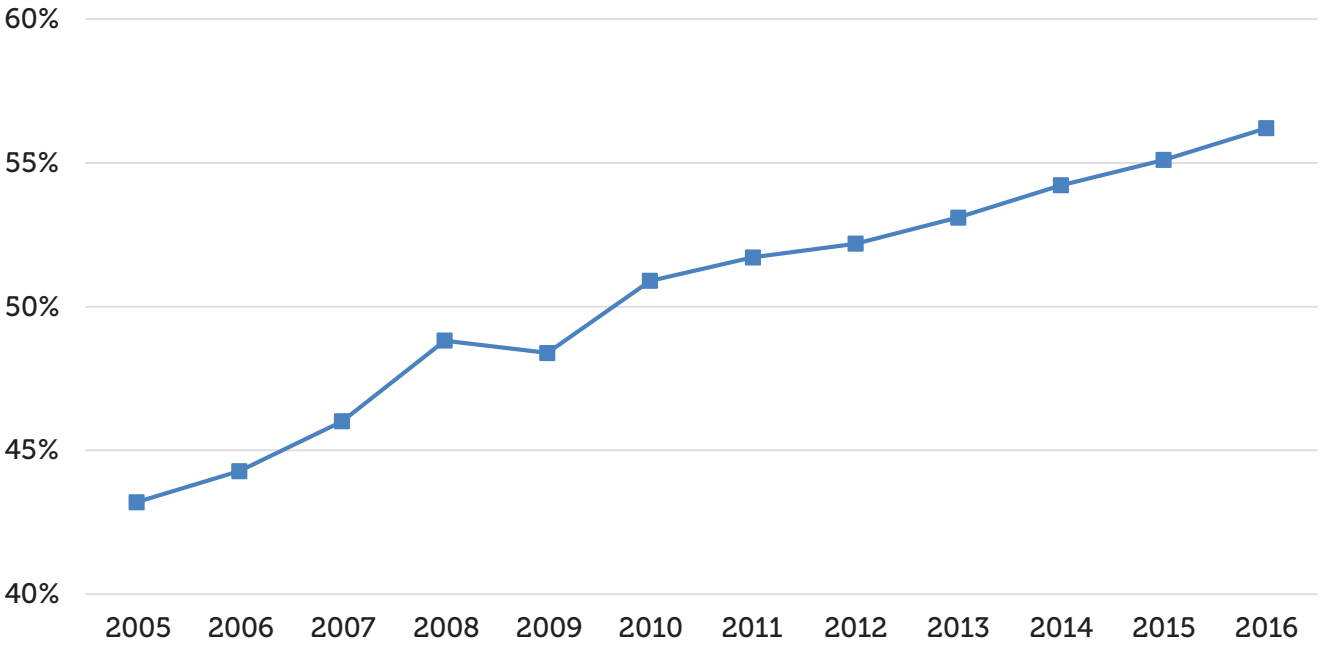
The best measure of whether all of the efforts to mobilize resources to generate innovation is the effect this activity has on commercial performance and overall trends in the economy. Training in math and science, funding for R&D, and patents mean little—to people other than bureaucrats, at least—if they do not translate into novel products that are successfully designed, built, and sold. The question this section attempts to answer is to what extent China's intensive policy focus on advanced technology is paying off and resulting in more successful Chinese companies. To do so, this section first considers broad gauges of technology's contribution to China's economy; it then turns to a more micro company-based perspective. The discussion concludes by seeking to explain the reasons for the emergence of a coterie of more visible Chinese companies in a range of sectors.

THE MACRO VIEW

The official analysis put forward by the Chinese government is that its focus on indigenous innovation is working exceedingly well. In addition to the National Innovation Index introduced earlier in this report, authorities marshal an array of evidence to support their claim. The core statistic they cite is the Science & Technology Progress Contribution Rate (STPCR), which essentially measures the proportion of the economy supported by science and technology in one way or another. Not surprisingly, the STPCR has risen almost continuously since it was first calculated in 2005 (see Figure 17). China's 13th Five-Year Plan set the target of the STPCR reaching 60 percent by 2020.[1] To be frank, this statistic is essentially meaningless. It is constructed in such a way that it

1. Scott Kennedy and Christopher K. Johnson, *Perfecting China, Inc.: The 13th Five-Year Plan* (Washington, DC: CSIS, May 2016), 25, https://csis-prod.s3.amazonaws.com/s3fs-public/publication/160521_Kennedy_PerfectingChinaInc_Web.pdf.

Figure 17. China's Sci-Tech Progress Contribution Rate (STPCR)



Source: China National Bureau of Statistics, Xinhua News Agency.
Note: Percentage rates are calculated based on indices in the National Innovation Index.

would be almost impossible to fall unless there was a massive economic contraction (such as the one that occurred in late 2008 and early 2009). Moreover, it offers no insight into whether the economy as a whole is becoming more productive. Chinese experts themselves recognize the STPCR's weaknesses, but many want to keep using it because it is easy to calculate and its continued upward rise reflects positively on the Ministry of Science and Technology.

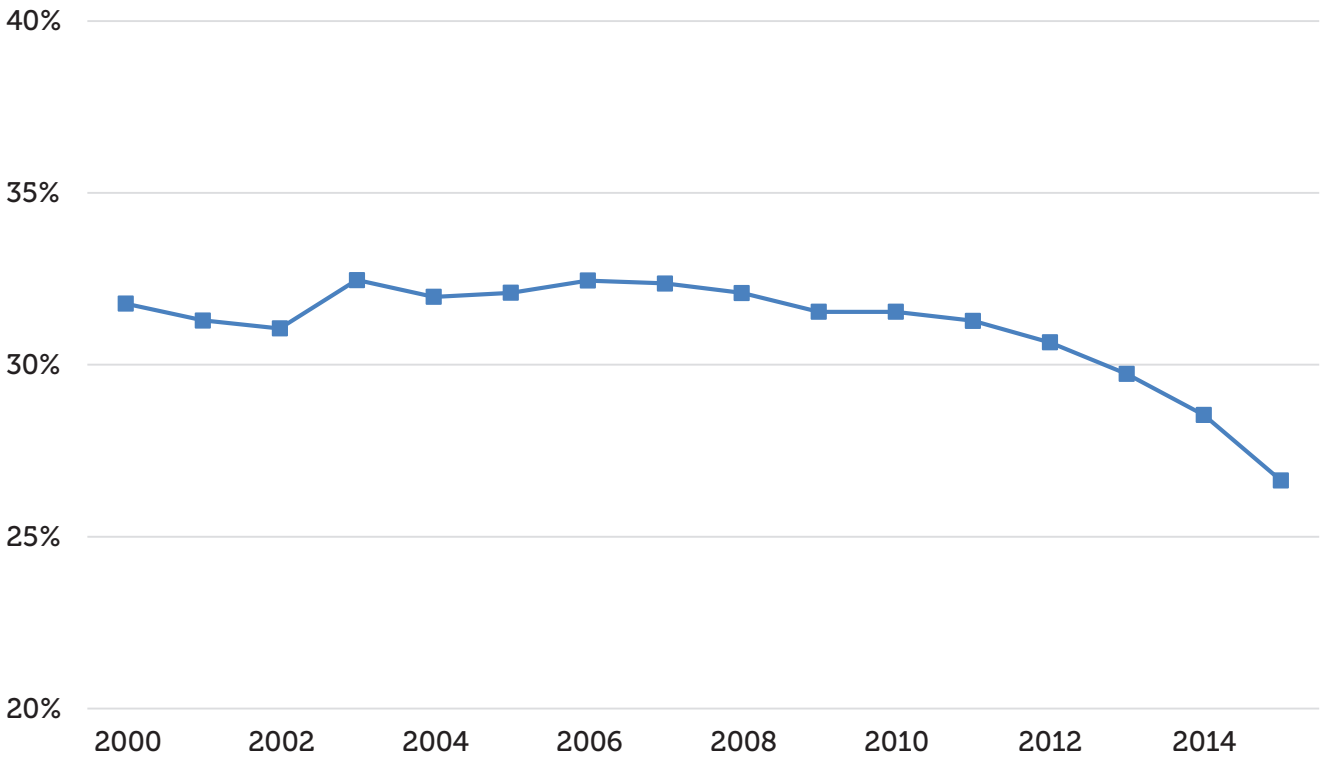
Others are not bound by such constraints. Instead, a better approach would be to look at trends in value added and exports. These broad measures paint a more complex picture than the STPCR. Manufacturing value added (MVA) has risen continuously over the past 15 years, from only $385 billion in 2000 to over $3.3 trillion in 2015. However, as Figure 18 shows, the overall economy has grown so fast that MVA has actually fallen as a proportion of the entire economy over the past decade.[2] Similarly, China's high-tech exports have grown rapidly in absolute terms, but have remained steady as a share of total exports (see Figure 19).

There are, though, other reliable indicators that show a more unambiguous positive change. High tech's contribution to manufacturing value added has increased somewhat, rising from 8.8 percent in 2010 to 14.2 percent in 2014.[3] In addition, the share of high-tech sector income generated from domestic Chinese enterprises has climbed continuously since 2008, reaching 46.6 percent in

2. "World Bank National Accounts Data, and OECD National Accounts," World Bank World Development Indicators, accessed June 1, 2017, http://data.worldbank.org/indicator/NV.IND.MANF.ZS; and "National Accounts Main Aggregates Database," UN, last updated December 2016, https://unstats.un.org/unsd/snaama/cList.asp.

3. China's Science and Technology Statistics, accessed June 1, 2017, http://www.sts.org.cn/.

Figure 18. China's Manufacturing Value Added (Percent of GDP)



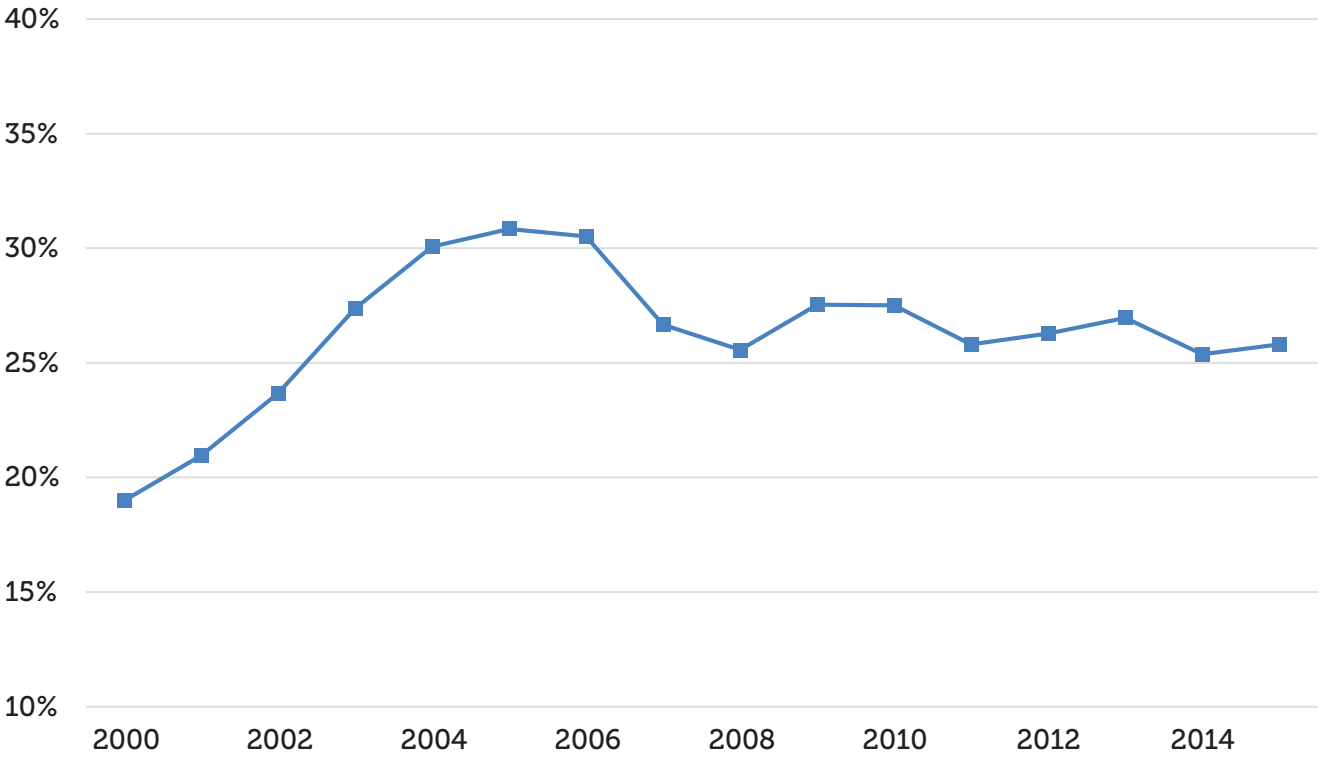
Sources: For 2000 to 2013, the World Bank World Development Indicators; for 2014 and 2015, UN National Accounts Main Aggregates Database.

2014, the most recent year for which we have available data.[4] More telling is the picture that emerges when looking at the contribution domestic companies make to high-tech exports (see Table 4). In comparative terms, foreign-invested companies contribute a much larger share to China's high-tech exports than in just about any other country in the world, which is the result of the rush of investment in China after the PRC joined the WTO in late 2001. However, over the last decade the share of high-tech exports from domestic companies has gradually climbed, reaching 19 percent in 2015. This trend is widespread, as the domestic share of exports has risen over the last few years for a large number of products.

This is a mixed picture, indeed. Domestic companies seem to be raising their contribution to the economy relative to foreign-invested firms, but the contribution of manufacturing value added and high-tech exports to the economy had not grown at an equal pace. Could it be that China is just running in place?

4. The Ministry of Science and Technology also reports that income from high-tech sectors has grown as a share of total manufacturing, from 12.0 percent in 2011 to 13.0 percent in 2014. "2014 Analysis of Our Country's Hi-Tech Industry Development Situation," Ministry of Science and Technology, accessed June 30, 2017, http://www.sts.org.cn/tjbg/gjscy/gjindex.asp?Page=1.

Figure 19. China's High-Tech Exports (Percent of Total)



Source: World Bank World Development Indicators.

THE MICRO VIEW

Another way to approach this question is to look at the commercial performance of specific Chinese companies. It is easier than ever to identify successful and prominent Chinese companies in a wide range of high-tech industries, as they increasingly manufacture and provide services under their own brand names (see Table 5). That said, it is far from clear that these companies have all prospered as a result of intensive R&D and technology innovation.

There are several methods analysts have used to systematically identify highly innovative firms. The first is to measure to what extent companies have made inventions and filed patents. Using this approach yields a long list of Chinese companies in a large number of sectors that are ranked quite highly.[5] However, when one breaks down these lists of supposed leaders in various industries, genuinely successful companies sit side by side with companies with a high pile of patents but almost no market share. This reinforces the impression that Chinese organizations seek to file patents regardless of the commercial benefits simply because it is encouraged by the government.

5. A leader in this approach is the Derwent World Patents Index, accessed May 15, 2017, http://ip.thomsonreuters.com/product/derwent-world-patents-index.

Table 4. High-Tech Exports from Domestic Companies (Percent of Total)

	2000	2005	2012	2013	2014	2015
Total Average	**15**	**8**	**11**	**12**	**16**	**19**
Medicines	74	73	58	58	57	59
Medical Equip & Appliances	28	14	34	35	38	41
Airplanes	76	61	83	81	72	73
Communications Equipment	6	11	26	26	31	26
Electronic Appliances	17	7	6	9	11	16
Semiconductors	6	14	13	12	13	14
Integrated Circuits	5	2	5	9	10	12
Complete Computers	9	1	1	1	1	3
Computer Components/ Parts	7	4	1	1	2	7
Computer Peripherals	7	4	10	12	14	17

Source: *China Statistics Yearbook on High Technology Industry 2016,* 8, 23.

Chinese companies look much less prominent when using other measures. Pricewaterhouse Coopers' (PWC) "Global Innovation 1000" ranks companies both by how much they invest annually in R&D and through a survey of business executives asking them to identify the most innovative companies. By either method no Chinese company has made it among the top highlighted firms since the first report was issued in 2005.[6]

6. "The Innovation 1000," PricewaterhouseCoopers, accessed May 20, 2017, https://www.strategyand.pwc.com/innovation1000#/tab-2015.

Table 5. Prominent High-Tech Chinese Companies

Companies	Product	Companies	Product
Vivo, Oppo, Xiaomi	Mobile phones	Goldwind	Wind turbines
Lenovo	Laptops & PCs	Trina Solar	Solar cells
Huawei, ZTE	Telecom equipment	HikVision	Security cameras
Midea, Haier	Home appliances	Geely, BYD	Autos
Alibaba, Tencent, JD	E-commerce	DJI Innovations	Drones
Baidu	Search	China Railway Corp	High-speed rail
Didi	Ridesharing	Tsinghua Unigroup	Semiconductors

The most prominent way that Chinese companies stand out in any commercially meaningful sense is by their growing market share, mainly in China but also on occasion in other markets in developing countries and advanced industrialized economies.[7] However, their commercial prominence does not appear to be based on intensive R&D spending or pursuit of patents. This is not out of the ordinary; PWC analyzed data on approximately 10,000 companies worldwide, and it found no statistical relationship between R&D spending and any kind of commercial metric, including sales growth, profits, and shareholder returns.[8]

EXPLAINING CORPORATE SUCCESS AND FAILURE IN CHINA

The story that emerges from the combined picture of the macro and micro views, particularly in light of the data about cautious spending by investors and the low value of patents, is that Chinese companies have not risen to prominence on a wave of deep-rooted technology innovation. Instead, it appears their growing prosperity is the result of three factors. The first is incremental innovations involving applications and customization. Chen and Wen's description of "good-enough innovation" in China's mobile phone market could apply to many sectors.[9]

7. For example, Nikkei releases an annual survey that covers 55 major products and services. See "More Chinese Companies Becoming Global Market Leaders," Nikkei, July 4, 2016, http://asia.nikkei.com/Business/Trends/More-Chinese-companies-becoming-global-market-leaders.

8. "The Innovation 1000."

9. Shin-Horng Chen and Pei-Chang Wen, "The Evolution of China's Mobile Phone Industry and Good-Enough Innovation," in *China As an Innovation Nation*, ed. Yu Zhou, William Lazonick, and Yifei Sun (Oxford: Oxford University Press, 2016), 261–282.

The second source of commercial success is effectively taking advantage of China's scale, both in terms of pursuing a low-margin, high-volume pricing strategy and utilizing the massive amounts of data that come from having so many customers in multiple localities, let alone in a single country. Despite rising costs, China is still the world's most competitive manufacturing country, a prerequisite to this strategy's continued success.[10]

The third and final source of recent Chinese corporate success is protectionism. Although many Chinese companies have genuinely improved their performance, they have done so under the protective umbrella of an assertive government that has restrained competition from foreign rivals in many of the sectors mentioned in this report. Multinational corporations not only have highly advanced technologies, they appreciate the need to "build to market" and likely would gain market share if barriers were lowered further.

In short, China's commercial success has outstripped its progress in technology innovation. This outcome has come at a substantial cost in terms of extravagant R&D spending and underutilized patenting activity, not to mention the strains placed on China's diplomatic relationship with its trading partners. The final section summarizes the findings of this report and considers the implications for foreign businesses and governments.

10. "2016 Global Manufacturing Competitiveness Index," Deloitte Touche Tohmatsu, September 2016, https://www2.deloitte.com/us/en/pages/manufacturing/articles/global-manufacturing-competitiveness-index.html.

06

Implications

A FAT TECH DRAGON

These are fat years for innovation in China. The campaign to spur innovation has been accompanied by massive spending and intensive bureaucratic activity. This environment provides firms, investors, and research organizations with amazing opportunities to feast from a rich buffet of support. And as whenever the buffet is so plentiful, many will eat a well-balanced meal, but others will overindulge, resulting in poor health and wasted sustenance that could have been better managed.

China's goals are admirable, but its strategy has clear weaknesses. Funding has flowed liberally, but because the current environment fosters not deep innovation but expanded market share for domestic firms, innovation has become a secondary concern. The section on general trends showed that although innovation inputs are gradually rising, there has been less growth in output performance. It is possible that China is following a natural pattern in which inputs rise first and then are met with a parallel rise in outputs. But another, more likely possibility is that this lag is an abnormal and unnecessary result of China's government-led effort that is based on massive spending directed toward undeserving targets.[1]

There is an alternative, more positive story that could be told and one that we did hear from several interview sources.[2] China's innovation drive is highly inefficient and not based on new inventions and technological breakthroughs, but perhaps China is pursuing a different path to high-tech success than the current advanced economies. China's intellectual property may not be particularly valuable, but there has been a large accumulation of tacit knowledge by Chinese

1. This question was first raised in Linda Jakobson, "China Aims High in Science and Technology: An Overview of the Challenges Ahead," in *Innovation with Chinese Characteristics: High-Tech Research in China*, ed. Linda Jakobson (New York: Palgrave Macmillan, 2007), 1–36.

2. Some of these points were reinforced and elaborated on by some of the participants at the initial presentation of results of this report, held at CSIS, May 25, 2017, https://www.csis.org/events/fat-tech-dragon-baseline-trends-chinas-innovation-drive.

factories, and these skills are diffused across the supply chain, particularly in industry clusters, such as the Pearl River Delta.[3] Given Chinese consumers' tastes and consumption capacity, introducing products that are incrementally better than previous editions may make better business sense than spending endlessly on R&D to develop the most advanced products that would not be affordable or useful in China. And although there is a highly visible level of waste created through top-down initiatives, the campaign-like atmosphere that such action creates spurs greater private activity that yields results. From this perspective, even large mistakes and waste may facilitate learning that results in more productive investments down the road. Moreover, given China's size and financial resources, it may be able to afford more failures and debt than smaller countries pursuing high-tech success.

Although this glass half-full story has merit, there is no doubt that China's approach has been costly, and that there has been a low rate of metabolism of inputs relative to overall performance. Even if the Chinese state means to create a predictable environment that rewards incremental progress, given the amount of likely waste, it is not clear that this environment has fostered the kinds of investments that would be most beneficial to the economy. And, of course, this does not consider the consequences for companies and countries with tighter budget constraints who have achieved success through a more competitive innovation environment. China's size requires observers to judge the country's performance based on the consequences not only for Chinese companies, but for entire sectors and the global economy.

LOOKING AHEAD

Despite this somewhat skeptical general conclusion, there is likely to be substantial variation across sectors. The government's approach may have different consequences in different industries. China's chances for innovation success vary across sectors because of its different economic fundamentals. For example, some industries have higher barriers to entry than others, and some are likely to benefit more than others from China's large market size. The CIPS project's attention to multiple industries, to be shared in forthcoming reports, will allow us to test this hypothesis and look for patterns of innovation that are harder to detect when looking at the economy as a whole.

Regardless of the level of support they receive from their government, Chinese companies will face growing challenges in their interactions with multinational businesses and in overseas markets. Given the scope and depth of the Chinese government's support for developing indigenous technologies, it may be increasingly difficult for outsiders to distinguish between well-run, independent Chinese companies that are entirely successful of their own accord and those that have benefited heavily from state support. Industrial policies do not only benefit SOEs; private Chinese companies could run into far more obstacles for their exports and outward investment than is currently the case.

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3. See Jacqueline Senker, "The Contribution of Tacit Knowledge to Innovation," *AI & Society* 7, no. 3 (September 1993): 208–224.

Foreign governments and multinational businesses likewise need to decide how to strategically respond to China's approach. They could take a firm stand in opposition, as appears to be the case with several chambers of commerce and industry associations. They could try to take a more positive tone but influence the approach at the margins—for example, by advocating for a different mix of spending priorities or gradually increasing the pace of market liberalization. Or they could go along with the strategy as best they can. In short, they need to decide if they want to expand the size of the cake available to themselves and other foreign market participants at the risk of losing an opportunity for any piece of the market. Alternatively, they could accept a smaller piece of the cake, because a thin slice of the China market, even crumbs, adds up to a lot, particularly in a world where other countries are growing at a much slower place.

This calculus is far from straightforward, and it is not the same for any two countries, sectors, or companies. Many interview subjects expressed deep concern about the trajectory of Chinese high-tech policies, but there was no consensus about how to respond. Some welcome a stern American response even if it results in a trade war. Others are worried about being caught in the crossfire as victims of retaliation. One of the greatest challenges going forward will be how companies and associations can engage in continued discussion to see if greater consensus is possible, and if not, what are the ramifications for groups that have different positions. The answers to these questions are still far from clear, yet the stakes could not be higher. If others are not careful, they could end up under the heavy foot of a fat tech dragon.

About the Author

Scott Kennedy is deputy director of the Freeman Chair in China Studies and director of the Project on Chinese Business and Political Economy at CSIS. He is a leading authority on China's economic policy and its global economic relations. His areas of focus include industrial policy, business lobbying, multinational business challenges in China, Chinese participation in global economic regimes, and philanthropy. He is the author of *The Business of Lobbying in China* (Harvard University Press, 2005), the editor of *Beyond the Middle Kingdom: Comparative Perspectives on China's Capitalist Transformation* (Stanford University Press, 2011), the coauthor (with Christopher K. Johnson) of *Perfecting China, Inc.: China's 13th Five-Year* Plan (Washington, DC: Center for Strategic and International Studies, May 2016), and the editor of *Global Governance and China: The Dragon's Learning Curve* (Routledge, 2017).

Prior to joining CSIS, Kennedy was a professor at Indiana University (IU) for over 14 years. From 2007 to 2014, he was director of the Research Center for Chinese Politics & Business, and he was founding academic director of IU's China Office. From 1993 to 1997, he worked at the Brookings Institution. Kennedy received his PhD in political science from George Washington University, his MA in China studies from Johns Hopkins School of Advanced International Studies, and his BA from the University of Virginia.

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CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

1616 Rhode Island Avenue NW
Washington, DC 20036
202 887 0200 | www.csis.org