FEBRUARY 2020

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Implications for the United States

EDITOR
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CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

A report of the
CSIS TRUSTEE CHAIR IN CHINESE
BUSINESS & ECONOMICS

China Innovation
Policy Series

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In 2016, CSIS launched the China Innovation Policy Series (CIPS). The purpose of this initiative is to better understand both Chinese innovation policy and the actual performance record of Chinese efforts at high-technology innovation, and on that basis, assess the implications for industry, China's trading partners, and the global economy. To address these issues, CIPS research is divided into three categories. The first is an overview of general trends in innovation in China based on examining the inputs and outputs to innovation through cross-national comparison. The second is a collection of studies on several sectors that are high priorities for China, including the digital economy, new-energy vehicles, commercial aircraft, semiconductors, artificial intelligence, and pharmaceuticals. The third is a stream of research that examines how China's technology progress is related to its overall power and international influence. Specific areas of focus include China's overall innovation performance, Chinese participation in the global R&D ecosystem, China's involvement in international standards setting, and China's effort at civil-military integration. Over the life of the initiative, reports are being issued in each area, 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 managed by the Trustee Chair in Chinese Business & Economics at CSIS. Research support originally was headed by Mingda Qiu of the Freeman Chair in China Studies (2016-2019) and is now overseen by Shining Tan, research associate in the Trustee Chair in Chinese Business and Economics.

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William A. Carter and William D. Crumpler, *Smart Money on Chinese Advances in AI* (September 2019)

James A. Lewis, *Learning the Superior Techniques of the Barbarians: China's Pursuit of Semiconductor Independence* (January 2019)

Scott Kennedy, *China's Risky Drive into New-Energy Vehicles* (November 2018)

Samm Sacks, *Disruptors, Innovators, and Thieves: Assessing Innovation in China's Digital Economy* (January 2018)

Scott Kennedy, *The Fat Tech Dragon: Benchmarking China's Innovation Drive* (August 2017)

Preface

Despite the United States and China finally reaching a Phase-One commercial agreement, the Washington policy community's concern about China's high-technology drive has not dissipated one bit. There is a widespread belief that China has quickly caught up with, and in some areas even surpassed, the United States and its allies in a range of areas, from artificial intelligence and quantum to biopharmaceuticals and space. Combining this assessment with the view of China as a fundamental strategic competitor, a straightforward policy equation emerges: the greater China's high-tech abilities, the greater the threat to the United States and the greater there is a need for a comprehensive counter strategy.

The corollary of this math has produced at least three kinds of policy proposals: 1) a massive expansion of general and targeted commercial restrictions against China, or even cutting ties altogether, which is increasingly called "decoupling"; 2) turbo-boosting the United States' own high-tech capabilities, including everything from investments in education and basic research to intensive support for specific sectors, or industrial policy; and 3) rewriting the global rules of the game regarding, among other things, exports, investment, state-owned enterprises, subsidies, data and e-commerce, and intellectual property rights.

The purpose of this report is to provide a dispassionate assessment of both parts of this equation—first by carefully examining where China's high-tech drive stands and where it is headed, and then weighing the options the United States and international community have available to respond.

The origin of this report was a closed-door seminar held in November 2018 at CSIS with experts on technology and industrial policy from the United States, China and elsewhere. The discussion examined Chinese technology abilities, recent developments in Chinese industrial policy, and potential policy options for the United States. The meeting's contents were off-the-record, but several attendees subsequently agreed to draft brief essays on one of the related topics. Contributions were drafted during 2019 and then revised just before the publication of this volume to take into account recent developments.

The final product is divided into three parts. The first examines broad trends in China's innovation drive, with an effort to reach a general conclusion about the degree of success and the implications for the rest of the world. The second section takes a more in-depth

look at a range of discrete industries and technologies. The final part provides a framework for thinking about U.S. policy options. Readers will recognize that there is no consensus among the contributors about any part of this challenge—either China's technology capabilities or U.S. policy. But hopefully this volume helps clearly identify the key issues and dividing lines that can guide policymakers and stakeholders going forward.

This report is part of the China Innovation Policy Series (CIPS), which reflects our enduring attention to understanding China's high-tech drive and its implications for the global economy and the United States. This initiative has benefitted from generous support over several years from several partners, all of whom share our mission to raise the quality of debate on critical policy questions facing the United States. I am also grateful to the attendees of the original seminar for sharing their candid views and analysis. A special thanks goes to the staff of the Freeman Chair in China Studies, particularly Mingda Qiu and Maria Krol Sinclair, for their work in organizing the initial gathering on which this volume is based. The final manuscript benefitted from editorial assistance by my colleagues Alyssa Perez and Shining Tan as well as CSIS's expert publications team. Finally, I owe a huge debt of thanks to the contributors to this volume. The contents here cover a far wider range of topics and issues than any one person could carry out alone, and it is important that the policy community see the texture of the ongoing debate from a diverse group of leading experts. The strength of this volume is entirely dependent on their contributions. Responsibility for any remaining errors is that of the editor alone.

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1. Touching the Elephant: Explaining Patterns of China's Innovation

Scott Kennedy

Handicapping China's innovation drive has never been easy, but it has never been as important as it is now. Underlying the move toward treating China as a "strategic competitor" is an evaluation of its technological capacity as both strong and menacing. If analysis finds, though, that China's efforts are less promising than perceived or that they may in some ways be supportive of the U.S. economy and national security, then an alternative, less confrontational policy approach would be more appropriate.

The most important study of the last five years that reoriented thinking in the policy community was Brown and Singh's report issued by the Defense Innovation Unit Experimental (DIUX) right after the Trump administration took office. Their core thesis was that China is in the midst of a multi-decade plan to advance its domestic technology capabilities and that technology transfers, licit and illicit, from the United States were assisting China in this effort.[1] The Trump administration itself subsequently issued two studies supporting the underlying claims. The first focused on unfair methods to acquire intellectual property, and the second concentrated on a wide range of supposedly coercive tactics to strengthen China's economy at the expense of the rest of the world.[2]

Although highly suggestive, these studies are far from conclusive. Most importantly, they focus on Chinese government policies, not Chinese commercial performance. Although Beijing is quite powerful and can push and pull Chinese research organizations and industry to engage in certain activities, it cannot dictate whether those initiatives are successful. And at the end of the day, it's the results, not China's intentions, that are most important to the United States and the global economy.

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1 Michael Brown and Pavneet Singh, *China's Technology Transfer Strategy: How Chinese Investments in Emerging Technology Enable a Strategic Competitor to Access the Crown Jewels of U.S. Innovation* (Silicon Valley and Boston: Defense Innovation Unit Experimental, February 2017).

2 Office of the United States Trade Representative, *Findings of the Investigation Into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974* (Washington, DC: U.S. Trade Representative, 2018); and White House Office of Trade and Manufacturing Policy, *How China's Economic Aggression Threatens the Technologies and Intellectual Property of the United States and the World* (Washington, DC: White House, June 2018).

Of course, when we turn to performance, there is still a wide range of opinion. Those who emphasize Chinese progress cite a variety of evidence. They point not only to China's ambitious policy plans and targets for specific technologies and a clear commitment to invest in the underlying infrastructure but also to gaudy statistics on the number of scientists and engineers, published papers, registered patents, impressive Chinese companies (from small start-ups to burgeoning unicorns), and showcase breakthroughs (such as the supercomputer that won Go and the hardware on display at the National Day military parade).

But for every China tech fan, there is an opposing critic who points to other evidence: a Chinese Communist Party (CCP) that seemingly cannot keep its hands out of anything, China's amazingly inefficient state-owned enterprises, a financial system that keeps funds from deserving entrepreneurs, a traditional culture that stresses obedience to authority and stifles creativity, shoddy corporate governance, and weak protections of intellectual property. This matrix of problems cannot but stifle innovation, so the argument goes.

This volume is no exception, with voices from both optimistic defenders and pessimistic critics. My own conclusion is that each of these perspectives carries some element of truth, but neither provides the whole picture. These conflicting interpretations are reminiscent of the story of several blind men touching the same elephant and each believing they had felt a different animal. The goal of this essay is to gain perspective by standing back a little in order to make sense of this complexity by identifying broad patterns in China's overall innovation trajectory.

A Sectoral Framework

The approach used here focuses less on Chinese ambitions and more on the commercial results and implications for others. To do so, it takes a sectoral approach to look for patterns across industries. As shown in Figure 1.1, the first step is to differentiate between sectors where China is broadly succeeding versus where it is failing. Standards for success are not purely objective and are open to disagreement but should include metrics such as progress toward "technological upgrading," a growing overall market size, improved economic productivity, and corporate profitability.

Figure 1.1: Potential Sectoral Outcomes

		INNOVATION OUTCOMES IN CHINA	
		SUCCESS	FAILURE
EFFECT ON THE GLOBAL SECTOR	CONSTRUCTIVE	A) Win-Win	C) Harmless Failure
	DESTRUCTIVE	B) Destructive Victory	D) Lose-Lose

Source: Author's original analysis.

The second step is to evaluate the implications of commercial trends in China for the United States and others. This second step is possible and necessary to undertake because China's economy is so large that any initiative it undertakes is likely to have global implications. Although much of the discussion in Washington assumes that a Chinese success inherently hurts U.S. firms and the economy more broadly, that is far from guaranteed. It is certainly possible that Chinese efforts could be globally constructive, promoting technological innovation in the sector as a whole, encouraging healthy development of transnational supply chains, and leading to improved corporate performance for Chinese and non-Chinese companies alike. Alternatively, Chinese initiatives could very well have the opposite effect, distorting market activity through overinvestment, weakening supply chains, devaluing intellectual property, and hurting good companies.[3]

Sectoral Stories

None of these outcomes, for China or the global economy, are preordained, but rather they need to be evaluated based on actual experience. Our research suggests that there are sectors that fit into each of the possible categories outlined above. Moreover, there is a set of important factors that determines one or another outcome and that translates into broader patterns. Below are four illustrative cases.

Internet Services

China undoubtedly has one of the most vibrant e-commerce industries in the world. Baidu, Alibaba, and Tencent (BAT) form the core of a dynamic sector populated by hundreds of thousands of companies and entrepreneurs. Chinese companies have gone from followers to leaders in providing a wide range of services, from Tencent's WeChat platform to video streamers such as Youku and the ridesharing firm Didi. Many are now incorporating more sophisticated elements of artificial intelligence into their services. Although the Chinese government has made developing the Internet and Internet-related sectors a high priority, it is a highly competitive sector with a wide variety of financing tools and regular unexpected changes of direction. Many of today's top firms did not exist ten or even five years ago.[4]

From a global perspective, China's initiative in the Internet services has been largely constructive. There are some subsectors where the market is closed (search) or highly restricted (cloud services), but there is substantial room for international firms. Moreover, Chinese innovations have pushed firms beyond China to adapt and improve their performance. The extent of cross-fertilization between China, the United States, and elsewhere—through companies, financing, R&D, and training—is a key characteristic of the industry.

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3 For a helpful discussion of previous studies, see Robert D. Atkinson, *Innovation Drag: China's Economic Impact on Developed Nations* (Washington, DC: Information Technology & Innovation Foundation, January 2020), https://itif.org/publications/2020/01/06/innovation-drag-chinas-economic-impact-developed-nations?mc_cid=0542118ad9&mc_eid=71186337b1.

4 For more on this sector, see Samm Sacks, *Disruptors, Innovators, and Thieves: Assessing Innovation in China's Digital Economy* (Washington, DC: CSIS, January 2018), https://www.csis.org/analysis/disruptors-innovators-and-thieves; William A. Carter and William D. Crumpler, *Smart Money on Chinese Advances in AI* (Washington, DC: CSIS, September 2019), https://csis-prod.s3.amazonaws.com/s3fs-public/publication/190930_SmartMoneyChinaAdvancesInAI_interior_v3_WEB.pdf.

This is why, despite some areas of conflict, I place the Internet services industry in category A, largely a win-win for China and the rest of the world.

New-Energy Vehicles

China has had the world's largest passenger vehicle market for over a decade, yet most cars powered by the internal combustion engine are foreign brands. Since 2014, China has made a massive push into new-energy vehicles (NEV), including hybrids, battery plug-ins, and, most recently, hydrogen fuel cells. China has by far the world's largest NEV market, with 1.2 million passenger cars produced and sold in 2019. China is also the only country to have a massive electric bus sector as well. Unlike in traditional cars, Chinese producers and brands lead the pack in terms of market share. They include traditional automakers such as Beijing Automotive and Geely and new entrants such as NIO and XPeng. There are over 400 NEV manufacturers, and Chinese companies are relevant at every stage of the supply chain. Contemporary Amperex Technology Co., Limited (CATL) is now the world's largest NEV battery producer and has been inking agreements to supply the world's leading European automakers.

Yet this impressive growth also has a dark side. The industry is driven less by consumer demand than government fiat and financing. A slew of regulations has been put in place to draw producers into the sector and push older automakers to shift to NEVs. Similarly, consumer demand has been created through rebates and restrictions on traditional cars. All told, by the end of 2018, by my calculations, the government had spent RMB 516 billion ($73.7 billion) in subsidies of one sort or another on the sector. The result has been rapid growth, but as can be seen now, government largesse, as in other sectors, has resulted in massive overcapacity. There are a lot of companies that will either go under, be acquired by stronger producers, or be kept afloat by local governments and other investors. Regardless, an expensive adjustment period awaits. Chinese firms are just starting to attempt NEV exports and dumping on the global market to unload excess supply is a real possibility. As Maria Krol Sinclair's essay in this volume shows, the expansion of China's NEV market has also put a strain on the raw materials that go into batteries, including lithium, nickel, and cobalt. In the next few years, many of the batteries currently in use will become obsolete, yet there is no cohesive system for recycling. At the same time, most of the electricity used to charge NEVs comes from fossil fuels, which is why some in China call NEVs "coal cars."[5]

The NEV sector is certainly a Chinese success, but it could very well bring a variety of deleterious consequences to the global auto sector while also doing little to resolve major environmental challenges. This is why I place the sector in the "Destructive Victory" category.

Commercial Aircraft

For four decades, China has been trying but failing to develop its own commercial aircraft industry. It certainly has enough incentive, with it being the world's fastest-growing airline passenger market and the potential broader benefits the industry can bring to its

5 Scott Kennedy, *China's Risky Drive into New-Energy Vehicles* (Washington, DC: CSIS, November 2018).

economy. China also has had substantial success in neighboring industries; it has the world's largest high-speed railway system and a fleet of top-class fighter aircraft.

Yet surprisingly, China has not been able to duplicate those successes in commercial aircraft. The Commercial Aircraft Corporation of China (COMAC) currently has one regional jet, the ARJ21, in operation, but by all accounts, the plane is poorly designed and not attractive to airlines. Hence, there are only a small number of ARJ21's in operation, and they often are sidelined by mechanical problems. China has long been developing a narrow-body airliner, the C919, to compete with Boeing's 737 and the Airbus A320. Yet the plane has been delayed repeatedly, and it is not as efficient as its main competitors. Moreover, almost every component in the C919 that keeps it aloft is a foreign import and not domestically designed. China has started developing a long-haul, wide-body jetliner, the CR929, but it is still in the early design stage and faces numerous technical and commercial obstacles to ever being available to put into service.

There are three reasons why China has struggled so mightily with commercial aircraft. First, the technical challenges are monumental and far more daunting than for high-speed rail. Not only are individual elements such as engines and avionics highly complex, but even more difficult is the systems integration task required to bring together hundreds of thousands of components from thousands of suppliers. All of this must be done in a way that is standardized, reliable, efficient, and safe. By contrast, when making fighter jets, the key goal is maximum performance; reliability, cost, and safety are of lower priority.

Second, the organization responsible for leading the Chinese effort, COMAC, is a state-owned enterprise (SOE) that is well suited for top-down vertical control but ill-suited for the primary job of an aircraft manufacturer, horizontal integration. Its management system and organization create internal obstacles to success. Finally, regulation for the global aviation industry is by de facto based at 800 Independence Avenue, SW, Washington, D.C.—the headquarters of the U.S. Federal Aviation Administration (FAA). The FAA is composed of safety zealots, and although they have made progress in working with China's own civil aviation authorities over the last two decades, in my estimation, it seems unlikely that the FAA will certify the C919 any time soon. Without their golden stamp of approval, it will be extremely difficult to persuade airlines to buy and put into service this aircraft.[6]

Although a clear industry failure from China's perspective, this history has not harmed the global commercial aerospace industry at all, which is why I consider this sector a "Harmless Failure." Chinese airlines have purchased almost all of their operating aircraft from Boeing, Airbus, and others, and these airlines and their suppliers and partners continue to service these huge fleets. Moreover, the global aircraft industry has engaged in a variety of partnerships and joint ventures with COMAC and others to help build up other elements of the industry, including components, maintenance, in-air services, and financing. COMAC could continue to struggle to produce a competitive jetliner, and the global industry would not suffer in the least. The primary challenges to the global commercial aircraft sector come not from COMAC or China but from their own internal

6 Information for this section comes from research conducted over the last two years that will be published in a forthcoming CSIS report on this sector.

management weaknesses as well as new technologies and business models that could fundamentally transform the industry in the decades ahead.

Semiconductors

There is no higher priority sector in China than semiconductors. As manufacturing in China has moved upstream, from toys and apparel to electronics and equipment, and consumption of high-tech devices has grown, the demand for integrated circuits in China has exploded. Chips represent the country's single largest import. Moreover, Chinese demand is likely to continue expanding well into the future. Although domestic production has grown in quantity and quality over time, Chinese producers still lag substantially behind the world's leaders in just about every aspect of the sector, not only in chip size, but for all kinds of chips, chip design, and manufacturing equipment. Firms such as Jiangsu Changjiang Electronics Technology (JCET), Tsinghua Unigroup, HiSilicon, and the Semiconductor Manufacturing International Corporation (SMIC) have all made progress over the past five years, but they still are far behind their counterparts in the United States, Taiwan, South Korea, and Europe.

This is not for lack of trying by the firms or government. China rolled out its first industry policy on semiconductors in 1994. And, beginning in 2014, it has expanded its efforts through the creation of national and local integrated circuit funds and a whole raft of complementary policies. Firms have used this support to branch into new areas, acquire overseas firms, license technology, and hire away leading experts from other firms. Yet the bottom-line result is that China is still far from achieving anything close to overall independence or even leadership in any specific segment of the sector. At the same time, China's massive and unprecedented efforts at import substitution have hurt the global industry by distorting investment and placing undue stress on the transnational supply chains on which the industry is built. All of this is having a dampening effect on profitability and innovation for the sector.[7] Hence, the semiconductor industry best fits in the "Lose-Lose" category.

Implications

These case studies reflect a wide variation in sectoral outcomes, both in terms of success from China's point of view and implications for the rest of the world (see Figure 1.2). Additional industries could be added to this framework. This overall pattern is in part due to differences in industry organization (such as the ownership structure of firms) and relative complexity of the underlying technologies. More complex technologies are simply more difficult to master, especially for state-owned enterprises. Yet what also stands out are the differences in the extent of government intervention. In market-oriented industries with more competition, China has been more innovative and such success has generated innovation elsewhere and benefited the global economy. In other industries where the government has played a much more dominant role, losers emerge, either in China, globally, or in both. In such circumstances, innovation has typically suffered.

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7 James A. Lewis, *Learning the Superior Techniques of the Barbarians: China's Pursuit of Semiconductor Independence* (Washington, DC: CSIS, February 2019), https://www.csis.org/analysis/chinas-pursuit-semiconductor-independence; and Organization for Economic Cooperation and Development, *Measuring Distortions in International Markets: The Semiconductor Value Chain*, OECD Trade Policy Papers, No. 234 (Paris: OECD, December 2019).

Figure 1.2: Actual Sectoral Outcomes

		INNOVATION OUTCOMES IN CHINA	
		SUCCESS	**FAILURE**
EFFECT ON THE GLOBAL SECTOR	**CONSTRUCTIVE**	A) Win-Win *Internet Services* Market-oriented	C) Harmless Failure *Commercial aircraft* State-led
	DESTRUCTIVE	B) Destructive Victory *Electric vehicles* State-led	D) Lose-Lose *Semiconductors* State-led

Source: Author's original analysis.

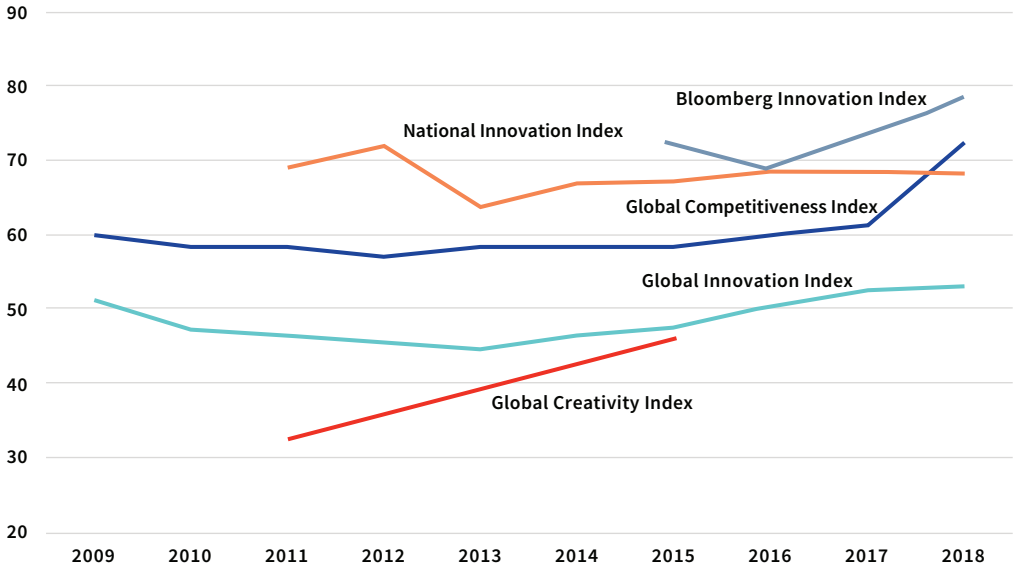
The U.S. response needs to be sensitive to this pattern. The United States needs to be particularly vigilant about those Chinese efforts that are most harmful to the global economy. The most common is in Category B, where new sectors such as electric vehicles and robotics are replicating the earlier record of steel and aluminum growth through a combination of massive state funding and protectionism. "Lose-lose" industries (Category D) such as semiconductors are also quite worrying given their centrality to the United States' economic foundations and national security. By contrast, in sectors where the consequences are more constructive, the United States should be encouraging China to continue its path in a more market-oriented direction. Not surprisingly, this advice would also be in China's interest as well.

2. A Larger but Not Leaner Fat Tech Dragon

Mingda Qiu

In 2017, the Center for Strategic and International Studies released a report that concluded China's innovation ambitions have been far greater than the actual results. As a result of a great deal of wasted effort, we called China a "fat tech dragon." Using a combination of cross-national innovation indices, country-specific data, and extensive interviews, the report found China suffers from low innovation efficiency, with substantial effort leading to relatively few high-quality outputs.[8]

FIGURE 2.1: INNOVATION INDICES: CHINA'S SCORE



Source: "National Innovation Index," http://www.most.gov.cn/cxdc/cxdcpjbg/201812/P020181228501830006619.pdf; "Global Competitiveness Index," https://reports.weforum.org/global-competitiveness-report-2018/; "These Are the World's Most Innovative Countries," January 22, 2019, https://www.bloomberg.com/news/articles/2019-01-22/germany-nearly-catches-korea-as-innovation-champ-u-s-rebounds; "Global Innovation Index," https://www.globalinnovationindex.org; and "Global Creativity Index 2015," http://martinprosperity.org/content/the-global-creativity-index-2015/.

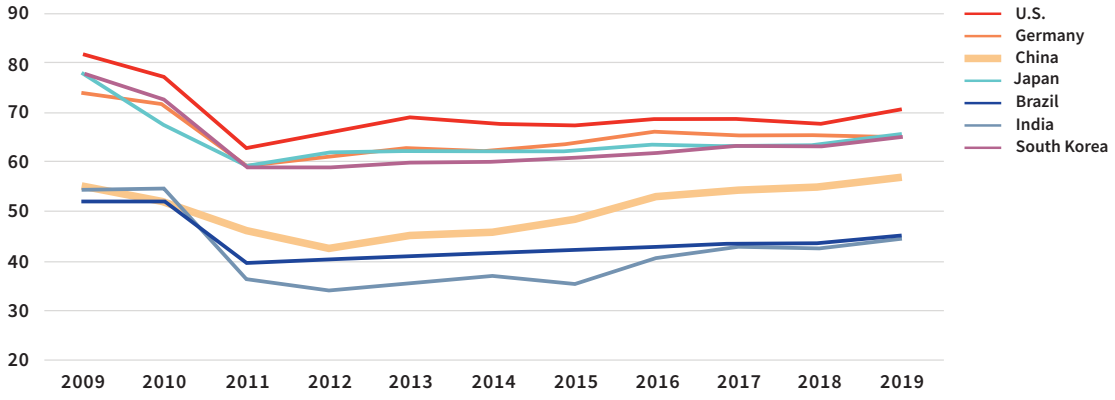
8 Scott Kennedy, *The Fat Tech Dragon: Benchmarking China's Innovation Drive* (Washington, DC: CSIS, 2017), https://www.csis.org/analysis/fat-tech-dragon.

Looking at updated data reveals that China has become more innovative but has only achieved modest gains in efficiency. There is still significant waste in resources, a phenomenon consistent with other areas of the economy.

The original report compared five prominent innovation indices measuring innovation in general and specific components that feed into innovation or its products. Four of them have been updated since then: the National Innovation Index (China's Ministry of Science and Technology); the Global Competitiveness Index (World Economic Forum); the Bloomberg Innovation index (Bloomberg); and the Global Innovation Index (World Intellectual Property Organization, Cornell University's SC Johnson College, and the European business school INSEAD).

China's overall score improved in every index (see Figure 2.1). Because the indices capture a variety of different measures, this reflects general progress in Chinese innovation.

FIGURE 2.2: SELECTED COUNTRIES' GII INPUT SCORES



Source: "Global Innovation Index," https://www.globalinnovationindex.org

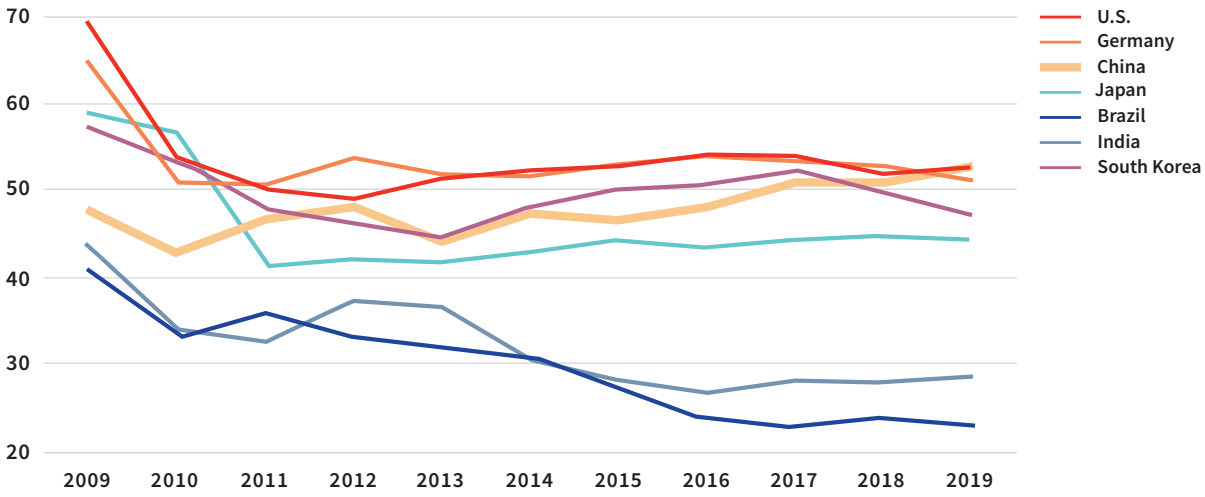
The Global Innovation Index (GII) is the most comprehensive evaluation system for innovation. It consists of 103 components, including physical measurements and survey results. China has poured more resources into innovation in the past three years, as illustrated by increases in R&D funding, tertiary enrollment, and infrastructure for information and communications. Regulatory and institutional regimes, which are regarded as inputs by many innovation indices, have improved. An increasing number of policies have been introduced to address the innovation environment, bringing China's input score closer to those of developed countries (see Figure 2.2).

China usually scored higher in inputs than outputs in the past, suggesting a level of waste in its innovation ecosystem. However, recent data demonstrates China has modestly improved efficiency in employing inputs. According to the GII, China's 2018 output score exceeds that of South Korea (see Figure 2.3), making China the highest scorer in the Asia-Pacific region. Other indices that emphasize tangible outputs, including the number of patent applications and academic papers, reveal an even greater improvement in efficiency.

While these indices demonstrate improvement in China's innovation, there is reason to doubt that China has really succeeded in cutting out waste from its innovation effort. Indices alone can be misleading, as many aspects of innovation cannot be easily quantified. For instance, the skyrocketing numbers of Chinese patent applications and grants are often cited as proof of China's innovative excellence, and they have weighed heavily as innovation outputs. However, we should not be too quick in drawing conclusions based on these numbers alone.

From January to November in 2019, China's National Intellectual Property Administration granted more than 2.3 million patents—the highest number of any country.[9] Although China is the world's largest patent producer, the quality of these patents remains low. Most of them are utility model patents that do not constitute significant new knowledge or technology. Each year, only about one-third of patents granted in China are higher-quality invention patents. Meanwhile, the proportion of Chinese applications filed abroad versus total applications remains low.[10] For every 100 patents filed by Chinese applicants, an average of only 4 are filed in a different jurisdiction, whereas for the United States, that figure is 44.

FIGURE 2.3: SELECTED COUNTRIES' GII OUTPUT SCORES



Source: "Global Innovation Index," https://www.globalinnovationindex.org

The high cost of filing abroad drives patent applicants to do so only if they see a pressing need to protect valuable products. A low level of overseas patent applications is a cause for skepticism, suggesting even applicants doubt the urgency of protecting their rights in other countries.

9 China's National Intellectual Property Administration, *Patent Work and Comprehensive Management Monthly Report* (Beijing, China: China's National Intellectual Property Administration, 2019), http://www.sipo.gov.cn/docs/2019-12/20191218100158972188.pdf.

10 "WIPO IP Statistics Data Center," World Intellectual Property Organization, https://www3.wipo.int/ipstats/index.htm?tab=patent.

Despite the substantial number of patent grants filed for low-quality products each year, China remains a major global IP importer. According to the International Monetary Fund, China paid $35.8 billion to its trading partners in royalties and licensing fees in 2018, experiencing a deficit of $30.2 billion.[11] The deficit is especially large between the United States and China: in 2018 the United States received $8.47 billion from China in royalties and licensing fees, whereas China only collected $0.76 billion.[12] Affiliated receipts remained relatively stable over the past three years, as a similar value of IP was traded between parent companies and their subsidiaries in the two countries. However, unaffiliated receipts increased by billions of dollars each year because Chinese companies have a higher demand for IP created by unrelated U.S. entities stemming from the broad applicability or fundamental utility of those patents. Were China an innovation powerhouse, the imbalance in royalties and fees would not exist to such an extreme extent.

Many GII indicators heavily weigh top-down government efforts and neglect bottom-up innovation in the corporate world. China's overall R&D expenditure as a percentage of GDP is very close to the level of OECD countries, but corporate expenditures are far lower. Chinese-listed companies have consistently spent only about 1.5 percent of their annual revenue on R&D since 2016, whereas companies in the United States and Germany have spent more than 4.5 percent. Japan and South Korea also outperformed their neighbor, spending 2.1 and 3.3 percent of corporate revenues respectively on R&D in 2017.[13] Despite the growth of star companies such as Alibaba, Tencent, and Baidu, the limits of corporate spending in R&D is still a cause for concern in China.

In short, innovation indices show China climbing international rankings, but these numbers only show one side of the story. Looking beyond the indices shows deficiencies in innovation output compared to peer economies. China issues the highest number of patents per year in the world, but the quality remains low due to the limited genuine innovative knowledge created. The country's overall bottom-up R&D expenditure fails to match the level of other developed economies. As a result, although modestly trimmer, China is still a "fat tech dragon."

11 "Balance of Payments Statistics Yearbook and Data Files," International Monetary Fund, https://data.worldbank.org/indicator/BX.GSR.ROYL.CD.

12 "U.S. Trade in Services, by Type of Service and by Country or Affiliation," Bureau of Economic Analysis, https://apps.bea.gov/iTable/iTable.cfm?ReqID=62&step=1.

13 Author's calculation from *Bloomberg's database*.

3. China's Systemic Advantages for Tech-Enabled Innovations

Edward Tse

Most China observers would agree that, by now, China is innovative. However, views differ on how "good" China's innovation really is and how sustainable it can be.

Ridding itself of the "copycat" stigma, China gave rise to a thriving Internet and technology sector, which over the past decade grew twice as quickly as its overall gross domestic product.[14] China has also now become the world's second-largest birthplace of "unicorns," or unlisted companies valued at or above $1 billion.

Several drivers contribute to China's rapid emergence as an innovation epicenter. First and foremost, it is due to a "why not me?" (or a catch-up) mindset. Realizing the huge gap between China and the rest of the world, especially in the early days of the reform and opening, Chinese entrepreneurs were compelled to show the world that they too could succeed.

As the economy has transformed, China's societal pain points that once were hidden became exposed. Coupled with the prevalence of technology, especially the commercial application of smart devices over the wireless Internet, these new conditions provided the fertile breeding ground for innovations.

While state-owned enterprises (SOE) are typically slower in responding to these changes, entrepreneurial privately-owned enterprises (POE) rose to the occasion and took these opportunities head-on. At the same time, China's massive market allowed companies to rapidly scale up, and its hyper-competitive environment spurred companies to speed up their innovation cycles to stay ahead in the game. Along the way, Chinese companies have benefited greatly from the vast venture capital pool and angel investors. Many of the investors, in turn, have benefited from exceptional returns on their investments in China.

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14 "China's Digital Economy on the Rise: New Engine, New Opportunities," Xinhua, March 1, 2018, http://www.xinhuanet.com/english/2018-03/01/c_137009083.htm.

China's demonstrated ability to innovate has run to the opposite of the belief of many pundits, who for long have warned that for reasons such as lack of political freedom (through their own lens), a state-controlled command economy, rote learning education, and inadequate intellectual property protection, China could not be innovative. Some people even cited the small number of Chinese Nobel laureates in natural science as proof of the innate inability of the Chinese to innovate.

While none of these factors is necessarily wrong on a standalone basis, in totality, China's actual political economy presents a different case. In the past four decades since it launched reform and opening, China has gradually evolved its own three-layer tripartite development model without consciously planning for it. At the top, the central government's guiding hand sets goals and directions for the country, giving the rest of the country clear targets to follow. At the grass-roots level, private sector entrepreneurs have re-emerged and become a major force in driving the growth of China's economy. And in the middle, China's local governments channel their resources into national and local priorities, often collaborating closely with entrepreneurs who bring innovative ideas to bear. Local governments often compete with each other, but they also cooperate within regional clusters, such as the "Greater Bay Area," which consists of nine cities in Guangdong province, including Shenzhen and Guangzhou, along with Hong Kong and Macau.

The symbiosis of SOEs and POEs is a defining feature of China's economy. SOEs take initiatives on the country's mission-critical projects, such as high-speed rail, which was built from virtually nothing by its SOEs within ten years, a feat that would probably not be possible if left to the private sector. On the other hand, POEs are the main drivers of market-driven innovations, often enabled by technologies. In many cases, admittedly, SOEs enjoy greater advantages with respect to policy privileges, resources and capital, and licensing rights, but the POEs embody more agile and adaptable organizations and, as a result, are often more innovative in businesses. Without a doubt, the dual economic structure does encounter glitches with inherent conflicts at times. However, the two sides of the economy mostly complement each other, often without it being consciously designed.

Take a look at China's automotive industry as an example. Technology is making autonomous driving a commercial reality, and private entrepreneurial companies have shown that mobility-as-a-service is a large, game-changing business in China's shared economy. Meanwhile, the Chinese central government has made new-energy vehicles (NEVs) a national strategic imperative. These three major developments are all manifesting in the world's largest automotive market, profoundly changing this industry from an automotive model to an "automobility" one, in which mobility hardware becomes smart and interconnected while tech-enabled, and personalized services become an integral part of the auto consumer's experience. Companies—whether traditional carmakers or new entrepreneurial disruptors, locals or foreign, state-owned or private—are all trying to position themselves as automobility players. They often do so through new forms of partnerships or alliances, competing or collaborating in China's "new game" of automobility. Such dynamism is taking place with incredible speed and intensity and is driving rapid rounds of innovations.

Local governments are investing in smart transport infrastructure through smart city initiatives, which are essential for the commercial applications of automobility. For example, the state-level special economic zone Xiong'An New Area, which was established in 2017 and is just to the southwest of Beijing Municipality, will become a pilot zone for integrated regional transportation and the smart mobility system. Baidu signed a contract with Xiong'An in the same year for future projects in smart mobility, conversational AI, and cloud infrastructure to help the Area transform into an AI city.

Beijing also opened up the Yanchong Expressway for autonomous driving tests. The Expressway is one of the key projects for vehicle-road coordination, using advanced 5G technology to enable the dynamic interaction among vehicles and roads, which can fundamentally lower costs and lift efficiency of self-driving vehicles. For example, the laser radar required for autonomous cars costs around 10,000 yuan each, but if it is deployed on the road, the cost will be greatly reduced. Several other Chinese cities have also upgraded public roads for autonomous vehicle tests as well.

One could always nitpick that for any given component of this holistic change, China may not be at the cutting edge of the world. For example, according to annual data from California motor transport officials, Alphabet's driverless car division Waymo and General Motors' Cruise are far ahead of their Chinese counterparts in terms of miles traveled without human intervention. However, China's edge lies in its overall approach through its system advantage and ecosystem development. This is only possible through its three-layered tripartite system in the world's largest and most digitally savvy consumer base, resulting in an automobility revolution that is faster and more intensive than any other country in the world.

Let's also take a look at artificial intelligence (AI) development, which is critical for enabling automobility and many other digital arenas. No doubt the United States may be ahead in core research and development. At least for now, however, the Chinese are faster in exercising commercial applications. The sheer size of China's market allows technology developers to quickly achieve economies of scale, and the huge amount of big data enables machine learning to ramp up faster.

The collaboration of governments and businesses is just as significant. For example, China's Ministry of Industry and Information Technology (MIIT) released a three-year action plan last December that calls for breakthroughs in landmark AI products, focusing on such core competencies as intelligent sensors and neural network chips. In addition, following the lead of the central government, Baidu, Alibaba, Tencent, and iFlytek formed the "national AI squad," respectively backing the development for autonomous vehicles, cloud-empowered smart cities, medical imaging, and voice recognition.

Global trade and financial uncertainty and volatility notwithstanding, China is likely to evolve into a larger and more capable innovative economy. Of course, the pathway will inevitably involve many ups and downs. China won't always execute things perfectly, but the intrinsic nature of the China system allows for error compensation and for business innovations to improve through trials and market feedback. Importantly, innovation and entrepreneurship have become an integral part of the Chinese social-business culture. Young, daring, diverse, and often epitomized by their speed and agility, the Chinese

entrepreneurs are not afraid of using the market as a test-bed for new ideas. The near-term economic uncertainty would somewhat dampen this momentum, yet the core entrepreneurial culture will not falter.

China has evolved itself into a rather unique situation; hence, any simplistic logic—for instance equating China with the former Soviet Union within the context of the Cold War or asserting that as a one-party state, China will never be innovative—is ignoring reality. A proper analysis of China requires viewing the country in totality in multiple dimensions through multiple discontinuities over different time periods, with the recognition and acceptance that China is still evolving.

4. Racing the Paper Dragon

James A. Lewis

> *"This idea may be formulated as follows. The situation is better now than it was ten years ago; therefore ten years from now it will be better still. I will attempt to show here why I disagree with this notion."*
>
> Andre Amalrik

In 1969, Andrei Amalrik wrote: Will the Soviet Union Survive Until 1984? He was ridiculed by Sovietologists but ultimately proved to be right. Amalrik's question about the Soviet Union can now be asked of China's current rulers. The Soviet precedent is an imperfect match for China, and unlike the Soviets, China will almost certainly manage its political evolution more successfully, but we should not underestimate the brittleness of Leninist regimes, and China, as the largest of the surviving Leninist states, exhibits signs of being surprisingly brittle.

China is Leninist in the sense that victory in revolution confers on the Party having a leading role and irrevocable power. China's rulers face a dilemma. With every generation of Chinese leaders, the revolutionary legitimacy of the Party, based on victory in 1949, becomes more distant and less compelling as the basis for undisputed rule. Faced with the declining legitimacy of the revolution in justifying the Party as China's sole ruler, the Chinese Communist Party (CCP) must resort to a variety of defensive measures, such as appeals to nationalism (always powerful in China), tighter controls on information, and pervasive surveillance, to preserve its hold on power.[15]

Before assuming office, President Xi studied the reasons for the Soviet collapse—the infiltration of "Western" values, loss of control of the media, the policies of Perestroika and Glasnost. Xi is making strenuous efforts to avoid Gorbachev's fate. But what the Party needs to do for political reasons will harm continued economic growth, damage China's still nascent innovation environment, and produce a surprising degree of discontent.

The CCP has the political will to use force and technology to keep the Party in power, but authoritarianism is costly. One of Amalrik's conclusions was that Leninist states face a crippling burden to maintain the Party apparatus and heavy surveillance needed

15 A point made by Edward Friedman of the University of Wisconsin (among others).

for control.[16] One Chinese estimate puts the annual cost of the party machinery at $300 billion—and this does not include military spending or, more importantly, the cost of opportunities lost because of Party control. The measures the Party believes it needs for control can be counterproductive, as in propping up SOEs, or even more ridiculous, as when it arrests college students for being Marxists (because advocating Marxism is an implied criticism of the regime). [17]

China does not have a market economy and efforts to reinforce party dominance have made it less so. This is a significant impediment to continued growth. The Party directs a substantial proportion of investment. Politically driven government investment is counterproductive, particularly if the goal is innovation.[18] This bears more than a passing resemblance to the Soviet Economic Planning agency Gosplan. Gosplan was never able to compete with Western market economies, and as the CCP increases its presence in firms and plays a greater part in directing investment, China's economy will be less efficient and innovative.

Central planning is still second best, even if planners use artificial intelligence tools and Western market signals to guide investments. Markets are messy and seem inefficient, but technocratic or Party direction is even less efficient. Over the long term, markets outperform government agencies and government planning. Centrally directed economies are less efficient because government policy supplants market signals on where to invest. Easy access to credit allows inefficient firms to survive, draining resources from productive activities. China would do better if its companies were let off the leash to rise or fall on their own merits, but the CCP cannot take the risk.

Innovators challenge the status quo. The debate about whether China could become an innovative economy seemed to be over, but Chinese innovation blossomed in a period of relative political openness. If social and political openness is linked to innovation, what happens when openness shrinks? Political tightening, accompanied by greater state economic direction, puts Chinese innovation at risk.

China has other disadvantages. Despite its claims of parity, which even sober Chinese researchers question, China is still dependent on the West for advanced technology. Since Deng, the illicit acquisition of Western technology has been a goal of the Chinese government, first to catch up to the West and now to surpass it. China uses both licit and illicit means to achieve this. They include forced technology transfers through

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16 "Economics Professor Expelled for 'Politically Harmful' Expressions, Including Estimate of Staggering Cost to Maintain the Communist Party Apparatus," China Change, August 21, 2018, https://chinachange.org/2018/08/21/economics-professor-expelled-for-politically-harmful-expressions-including-estimate-of-staggering-cost-to-maintain-the-communist-party-apparatus/.

17 Rob Schmitz, "In China, The Communist Party's Latest, Unlikely Target: Young Marxists," National Public Radio, November 21, 2018, https://www.npr.org/2018/11/21/669509554/in-china-the-communist-partys-latest-unlikely-target-young-marxists.

18 Kou Kou and Henning Kroll, *Innovation Output and State Ownership: Empirical Evidence from China's Listed Firms* (Karlsruhe, Germany: Fraunhofer ISI, January 2017), https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cci/innovation-systems-policy-analysis/2017/discussionpaper_55_2017.pdf; Kevin Zheng Zhou, Gerald Yong Gao, and Hongxin Zhao, "State Ownership and Product Innovation in China: An Integrated View of Institutional and Efficiency Logics," *Administrative Sciences Quarterly* XX (2016), https://www.mgmt.uestc.edu.cn/upload/attach/7f698b61d656c-5646510c7509380b4a5.pdf.

mandatory joint ventures and market access requirements, foreign investment, espionage, and the theft of intellectual property (IP) to build its technology base. But Chinese policies now work against technology transfer. Indigenous innovation and national supply chains run counter to global trends to use more efficient multinational research and supply chains. More importantly, Xi's more assertive international policies have raised concerns about Chinese technology acquisitions, not just in the United States, and this slows the rate of transfer.

If there is a Chinese strategy, it could be to use government-directed investment and technology acquisitions to create national champions who thrive in a protected domestic market and compete (often with government support) in international markets. Many analysts have called this "state capitalism." There have been successful examples where state capitalism has destroyed foreign competitors. The core of this is a bifurcation: one set of rules for Chinese companies in China, another set for Chinese companies as they compete in the rest of the world. The success of state capitalism depends on two things, however: government-directed investment and foreign tolerance for a continued bifurcation of the trade and investment rules for Chinese companies.

The environment for China has become more difficult for business and investment. As a developing economy that was seemingly friendly to the West, Chinese misbehavior was tolerated in exchange for market access. This is no longer the case. Many developed economies now view China (at least privately) as a "systemic rival," and there is "a growing appreciation that the balance of challenges and opportunities presented by China has shifted."[19] The Chinese are having trouble coming to grips with the end of the time when they were rarely held accountable. This natural rise of "antibodies" to Chinese behavior is a brake on Chinese technological aspirations and to its political and economic goals. Beijing's response to a less friendly foreign environment has been public defiance and private anxiety.

There are inherent contradictions between China's nationalist and mercantilist policies and the goal of technological development. China needs to be part of an interconnected world to acquire technology and sustain growth, but this brings unavoidable political risks. In the nineteenth century, particularly after the Opium War, Chinese reformers sought to absorb Western technology without also absorbing Western political ideas. The CCP faces a similar problem, but it expects to avoid the fate of the Qing dynasty by using its vastly increased social control and surveillance systems that can be both oppressive and absurd, as in banning Winnie the Pooh or Peppa Pig as political threats. True great powers do not fear Winnie the Pooh.

Various bogeymen are presented to justify the CCP's monopoly rule, such as resisting a hostile hegemon seeking to contain China. While this fits with one of China's preferred narratives of victimization and resistance, it is a Cold War relic. Another argument is that without the Party, China would fragment as in the 1930s (or even the Warring States period). There are undoubtedly centripetal forces, but no popular

19 European Commission and HR/VP contribution to the European Council, *EU-China: A Strategic Outlook* (Strasbourg: European Commission, March 2019), https://ec.europa.eu/commission/sites/beta-political/files/communication-eu-china-a-strategic-outlook.pdf

support for dismantling China, and unlike the nineteenth century, there are no imperial powers eager to press fragmentation. In fact, a reasonable argument could be made that the Party's continued stranglehold on political power slows Chinese growth. Left to their own devices, private Chinese companies are powerful economic competitors and China has immense reserves of talent and skill, but giving them the independence needed for commercial success creates political risk that the Chinese system cannot easily accommodate.

Assertions that we are in a technological or economic race should not disguise the fact that this contest is ultimately political, between two very different systems of governance. Both China and the United States have advantages and disadvantages in this contest of ideas, and it is ironic that in this race, the United States has become the more ideological. Despite the homage to Mao and Marxism, which is driven by the need to preserve the Party's claim to legitimacy, China retains only the tools and tactics of Leninism, not the beliefs. The United States, in contrast, is riven by intense ideological disputes that began in the 1990s.

The deflated expectations that greet the denouement of the trade war disguise larger issues. The richest country in the world is routinely outspent by China in key areas. China allocates billions of dollars for investment in research and acquisitions for a range of technologies, seeking the advanced technologies that are key to future economic growth and military power. U.S. political leaders grudgingly allocate millions for the same efforts. Much of China's spending is unproductive, but for those areas of spending where the market will not adequately fund public goods, like fundamental research and STEM education, China is outspending the United States a thousand to one.

Both China and the United States are mature economies, where the best path for growth is when people are free to find better ways to use existing resources to produce goods and services because there are no longer abundant sources of underutilized factors of production (Schumpeter's "creative destruction"). The unspoken race is which economy will do better with the problems of economic maturity. China's complex construct of Party rule, with economic growth created by abundant labor, foreign investment, and debt and lubricated by a healthy dose of corruption (even under Xi), worked well when China was a developing economy, but it will no longer guarantee growth. The United States faces different but equally challenging problems but may be able to more easily accommodate dissent and disruption, and it does not carry the economic burden of having to squelch dissent and speech.

If the United States can ever resolve its ideological disputes, China would face a much more formidable competitor. Some analysts believe that Xi, driven by domestic political needs to buttress the Party and his own position in it, issued his challenge too early, and now the United States and other countries realize they face a powerful, unscrupulous and antidemocratic rival and this creates scrutiny and opposition that China did not previously face.

The reformers of nineteenth-century China sought to modernize while preserving imperial rule. This proved unworkable. The Party has a similar goal and using its greatly enhanced tools for social control and surveillance, it expects to succeed where the Qing failed. There

is intense debate in the West over "digital authoritarianism" and whether China's effort to restrict information and dissent through massive propaganda and censorship campaigns and by revising the technology of networks to expand control can succeed. The flaw in this effort is that China cannot afford to disconnect. While the Arab Spring scenario much feared by the Party is very unlikely, the mere existence of governance and business alternatives create pressures for change that ideological campaigns and presidencies for life only exacerbate. The digital authoritarianism debate views China through the lens of our own concerns about the failings of liberal democracy, skewing assessments of China's effectiveness.

The trajectory of Chinese reform did not end in 1949. The KMT and the CCP are in some ways twins, and while the KMT gave up its claims to sole party rule years ago, the CCP clings to it. The Party rebuilt China after the Maoist debacle and China is now one of the most powerful countries in the world—perhaps ultimately the most powerful—but not under one-party rule. At some point, the Chinese people will choose to continue on the path of reform that began in the nineteenth century—this may be what the Party fears most.

Why does the United States fear Gosplan with Chinese characteristics? One reason is that the Chinese government has not shut down since the 1970s, while the United States has shut itself down repeatedly. Another is that while the United States has spent trillions of dollars in foreign adventures since 2003, China spent similar amounts on capital formation, especially infrastructure and education. China suffers from the Party's heavy-handedness, but the United States struggles with crippling disputes over public spending and the role of government. Gosplan was not a viable competitor for the United States in the 1980s, but this is not the United States of 40 years ago. If China's problem is too much government, the U.S. problem is that it has too little.

5. China's 5G Strategy: Be First Out of the Gate and Ready to Innovate

Paul Triolo

China's Unparalleled Commitment to 5G

No country has devoted more effort to preparing the ground for the rollout of fifth-generation mobile (5G) than China. And no market is larger. For 5G handsets alone, the addressable market in China is approximately 1 billion people. For many, the first 5G handsets that debut in 2020 will be a must-have item. But the stakes are much bigger than getting better streaming high-def videos on your latest smartphone.

Burned by a costly but failed effort to set standards around prior generations of mobile networks, China determined early on that it needed to play a major role in 5G. Officials overseeing the technology industry and key companies—including phone and networking equipment suppliers Huawei and ZTE and China's leading mobile carriers—set out a decade ago to ensure that the country would be a big player in 5G. As a result, they played a key role in establishing 5G standards globally. Now, with government support, China's leading mobile technology companies are accelerating deployment of 5G networks as a national priority.

Chinese officials see 5G technology as a way for China to both upgrade its traditional industrial base for the coming digital economy and to serve as a platform for China to become a major player globally in the infrastructure that will underpin the next generation of the Internet and enable new applications such as autonomous vehicles, factory automation, and smart cities. This is the prize for Beijing: demonstrate that China can lead an infrastructure build-out both domestically and globally, and give Chinese companies and the Chinese government more of a role in how the new digital economy will be built and managed.

China's push to build full standalone 5G networks is the central pillar of this strategy. The first phase of 5G—or non-standalone 5G—will build on existing 4G networks. It will enhance the capabilities of mobile broadband, bringing faster data rates and better network performance in cities and other built-up areas, where many mobile users need to access networks simultaneously.

Full standalone 5G is a different animal. It will include two other revolutionary features in addition to faster data speeds: ultra-reliable and low latency communications and massive machine-to-machine communications for applications involving the Internet of things (IoT). It is these last two pieces where China intends to lead the rollout of 5G networks and, perhaps more importantly, the development of new applications on top of a robust 5G platform.

The catch is that building full standalone 5G networks is a massive infrastructure challenge, requiring huge investments in fiber backhaul capacity and a far higher density of antennas than previous generations of mobile networks. To ensure China's place at the cutting edge of standalone 5G, in 2013, three powerful Chinese ministries—the Ministry of Industry and Information Technology (MIIT), the National Development and Reform Commission (NDRC), and the Ministry of Science and Technology (MOST)—jointly set up a new group known as the IMT-2020 5G Promotion Group to push an all-government and all-industry alliance on 5G.

There is no real Western equivalent to the Promotion Group, which has a target date of deployment in 2020 and set out to establish collaborative work on 5G with the European Union, Japan, the United States, and South Korea. The Promotion Group represented a bid to enable China to develop, test, and field 5G networks on a large scale and with a major contribution of intellectual property that would result in Chinese companies holding key standard essential patents for 5G.

All of the key players in the massive Chinese telecommunications ecosystem are active participants in the work of the Promotion Group. For example:

- Major research institutes under the MIIT such as the Chinese Academy of Information and Communications Technology (CAICT) and the Beijing University of Posts and Telecommunications (BUPT)
- The three major Chinese operators, China Mobile, China Telecom, and China Unicom
- Mobile infrastructure equipment makers Huawei and ZTE
- Mobile device makers such as Xiaomi, Oppo, and Vivo

Other Chinese companies such as Lenovo and universities including Shanghai Jiaotong also participate. The Promotion Group has also served as a unified platform for channeling China's considerable participation in and contributions to the global standards-setting process for 5G under the 3rd Generation Partnership Project (3GPP). Perhaps most critically, the Promotion Group is a venue for discussing and planning China's strategy for rapidly deploying standalone 5G networks in major markets all over China and attempting to secure China's leadership in both building 5G infrastructure and innovating on top of it.

Illustrating how important China's political leadership considers 5G to be to the future development of the digital economy and revamping the industrial base, 5G technology has been included in virtually all of China's major technology plans and strategies. This includes *Made in China 2025* and the *National Informatization Development Strategy*,

which calls for China to "vigorously launch arrangements for fifth-generation mobile telecommunications (5G) technology research, development, standardization and industrialization."

These plans and strategies prioritize development of 5G technologies and related sectors such as IoT, big data, AI, semiconductors, and advanced manufacturing. The term 5G is also on the lips of senior leaders, including Premier Li Keqiang, who frequently point to the importance of 5G for enabling China's economic growth. The major national commissions and key ministries, including MIIT, NDRC, and MOST, crank out action plans and guidance documents on 5G development. For China and 5G then, it is an all-hands-on-deck approach. There is no doubt that a sizeable market for 5G exists in China, and it is a top-down priority that Beijing has by now invested tremendous effort and resources in as part of a new emphasis on the growth opportunities of the digital economy.

The Rollout Strategy: Get to Standalone 5G Rapidly but Carefully

China's strategy appears to be enable the country's telecommunications operators to move quickly to standalone 5G, allowing China to gain valuable time in testing and validating the technology and business models for the advanced applications that standalone 5G will enable. However, the buildout will be very expensive. One estimate is that the country would need to spend around RMB 1.4 trillion (about $200 billion) over a 5-7 year period just on all the infrastructure, including antennas and base stations, fiber optic backhaul links, data centers, and software, a roughly 70 percent increase over what the country has spent on 4G networks.

China's not-so-secret weapon in 5G is Huawei. Based in Shenzhen, the firm has grown rapidly over the past decade into the world's largest supplier of mobile infrastructure systems. Huawei is now the only company in the world that can supply the entire 5G technology stack—from handsets, to antennas, to base stations, to all the data center hardware and software to manage complex modern mobile networks. Huawei is also able to build the key radio access network (RAN) hardware and software at a competitive price and with performance parameters that carriers say are very high while giving the company high marks for innovation. Huawei has devoted large sums of money to R&D and is now positioned as one of the few companies, along with European supplier Ericsson, that can ramp up rapidly to supply 5G RAN equipment at cost and scale.

While China's leading mobile carrier China Mobile appears to be in solid financial shape and able to lead investment in and deployment of large scale 5G networks, the other two carriers, China Unicom and China Telecom, are likely to roll out 5G much more slowly and on a smaller scale. A rumor circulating in mid-2018 that Beijing was considering merging the two smaller players to reduce costs appears to have been a non-starter, and it now appears the companies will continue cooperating on infrastructure-sharing to keep costs down.

Importantly, Chinese officials are also trying to get other Chinese tech companies that will use 5G networks involved in discussions with the carriers that are focused on how new applications running on the network will allow for a reasonable return on investment given the high cost of rollout.

In 2017, China's leading so-called over-the-top (OTT) players Baidu, Alibaba, Tencent, and JD.com, and ride-hailing firm Didi Chuxing agreed to take equity stakes in China Unicom that reached nearly $12 billion. China Unicom stressed that some portion of the investments will be plowed into its 5G trial networks. Indeed, the OTT players will be key to China's ability to lead the way into the 5G era.

Baidu, Alibaba, and Tencent (BAT) all operate growing cloud service businesses and are investing heavily in artificial intelligence applications that will be vital to 5G applications like smart cities and remote medicine. The BAT are all part of consortia working on autonomous and connected vehicles, a priority sector for Beijing that will need to leverage wide deployment of standalone 5G and its ultra-low-latency communications.

The advantages of first-mover status in 5G are twofold: First, success across large networks in China will demonstrate to carriers in other big markets that the low-frequency approach favored by Chinese firms can deliver on performance. This will give Chinese companies a leg up in promoting the low-frequency approach in places such as the European Union, the Middle East, Africa, Southeast Asia, and Latin America, where carriers are likely to be much slower to move to 5G.

Second, for China itself, the upside of rapid deployment domestically of standalone 5G is huge because 5G will enable widespread use of IoT applications, smart cities, big data and AI, and upgrades to advanced manufacturing. If China successfully capitalizes on these technologies, its technology giants including equipment suppliers and over-the-top providers will also then have a leg up on exporting 5G systems and applications such as smart cities and advanced manufacturing along Belt and Road Initiative (BRI) countries to really build out the so-called Digital Silk Road of BRI.

Rollouts of 5G Networks Will Gain Steam in 2020 and 2021

The major Chinese carriers each began installing trial 5G networks in 2018, with some initial commercial deployments launched in late 2019. Each company will use a different approach to the trials, which will be focused initially on non-standalone 5G. China Mobile has the most ambitious plans, launching trial networks in five large cities: Wuhan, Hangzhou, Suzhou, Shanghai, and Guangzhou. Plans in 2018 called for installing 500 5G base stations across these cities, with subsequent expansion to 12 other smaller municipal markets—but with high numbers of potential users. China Mobile's trials are designed to test specific uniquely 5G use cases, such as autonomous vehicles, augmented reality/virtual reality (AR/VR), and smart logistics.

China Unicom has tested 5G networks in 16 cities, including Beijing, Shenzhen, Tianjin, and Shanghai. Unicom claimed it had installed 300 5G base stations in Beijing alone in 2018 and is testing the technology in additional second-tier cities such as Nanjing, Wuhan, Chengdu, Guiyang, Zhengzhou, Shenyang, and Fuzhou. Significantly, the company has an agreement with Huawei for testing network slicing—specifically for autonomous vehicles and advanced manufacturing—and for gaming, using AR/VR applications. Logistics and drones will also be part of this effort. China Telecom, the smallest mobile player, conducted small-scale pilots in 12 cities in 2018, including Shanghai, Suzhou, Chengdu, Lanzhou, Shenzhen, and Xiong'an.

How quickly China—which realistically means China Mobile—will field a full standalone 5G network is not yet clear. In early 2018, China Mobile officials claimed at the World Mobile Congress in Barcelona that their trial rollouts would be geared toward a standalone network, and that they would be designed to test massive Multiple-Input Multiple-Output (MIMO) antennas, one of the key technologies to allow for higher density of coverage, and network slicing. With the standalone standards not yet finalized, China Mobile runs the risk of getting out too far in front before interoperability issues for standalone are resolved in 2020—though some of these can almost certainly be handled via software upgrades.

China Mobile claimed it would deploy existing hardware and upgrade software to offer a "pre-commercial" customer experience in the second half of 2019, and this was rolled out last fall in major urban centers. The carrier is likely the most financially sound of any global operator, so it may be in a position to seize the baton on standalone 5G. Nonetheless, it still faces financial risks if it moves too rapidly. China Unicom and China Telecom, along with other early adopters such as SK Telecom and NTT DoCoMo, intend to go with a conservative non-standalone network rollout, with integrated 4G/5G networks, given the high cost of getting quickly to full standalone.

China does have another major advantage—some of the carriers have already begun constructing the considerable fiber backhaul network that will be required to support full standalone 5G. China Tower, which finances the building of much of the mobile radio infrastructure, raised nearly $7 billion in an August 2018 IPO in Hong Kong, adding to state-backed resources for moving 5G deployment forward.

China's 5G rollout gained major momentum in late October 2019 when MIIT and three leading telecommunications carriers held a ceremony to officially launch 5G commercial services. China Telecom, China Unicom, and China Mobile all unveiled their 5G data packages shortly afterward (the author purchased a China Mobile 5G SIM card in late November and was able to get a robust 5G signal in several mainland cities he visited with a 5G capable smartphone). The debut marks a significant inflection point in China's efforts to establish itself as a global leader in next-generation networks, with its 5G market set to be the world's largest. The 5G rollout appears to be gaining some steam, with plans to cover most major urban centers by the end of 2020. Still, carriers are facing mounting challenges – including shrinking revenues following the loss of domestic roaming fees – that will mean major deployments of 5G standalone infrastructure are likely to be slower than originally envisaged. Still, political pressure to introduce 5G will remain even as carriers face uncertain business use cases and new revenue sources with a limited number of 5G-enabled handsets currently in circulation as of early 2020. This is expected to change quickly over the next three to six months. Full standalone 5G installations will initially likely be limited to areas such as corridors for autonomous vehicles and dedicated smart city infrastructure of the type going up in Xiong'an, President Xi Jinping's signature smart city southwest of Beijing.

Bans on Huawei and ZTE Could Blunt 5G Rollout

Meanwhile, just as Chinese carrier rollouts are progressing for non-standalone 5G and plans are being drawn up to deploy more complex standalone 5G, major political storm clouds are looming on the horizon for the country's two major equipment suppliers, Huawei and ZTE.

Driven by long-standing concerns over the Chinese government's potential to use the country's telecommunications equipment firms to facilitate espionage, U.S. government efforts to convince allies to bar the firms from participating in 5G network rollouts gained steam in late 2018 and throughout 2019 and now threaten to damage both companies. So far U.S. allies including Australia, New Zealand, Taiwan, and Japan have put in place legal structures that effectively ban Chinese firms from their 5G networks. This effort primarily impacts Huawei. ZTE, meanwhile, is still recovering from the effects of a temporary denial order in 2018 stemming from violations of U.S. sanctions law—the firm was getting high marks in early 2020 for compliance with the U.S. Department of Commerce monitoring that was required under a settlement reached in 2018 that removed ZTE from the Commerce Entity List.

In addition to the U.S. campaign to convince allies and other countries to ban Huawei, the May 2019 action placing Huawei on the Entity List has added another major complication for the entire global 5G supply chain and the rollout plans of carriers in Europe and China. The stakes in this unusual confrontation between the U.S. government and Chinese telecommunications firms are high and are likely to impact China's march towards 5G leadership.

There are two major risks:

First, Huawei's key markets in Europe and Asia may be significantly reduced or eliminated, cutting revenue at a time when the firm is ramping up production capacity to serve China and other large markets. Within Europe, Germany, and the United Kingdom are the two primary markets where Huawei is already entrenched, with a significant presence in existing network infrastructure. As of January 2020, the UK government appears to have decided not to ban Chinese equipment—though it remains unclear where the United Kingdom will ultimately come down on Huawei participation—London is likely to allow Huawei equipment in the RAN while barring it in the core and other sensitive parts of carrier networks. Interestingly, the United Kingdom is the only country that has attempted to make a distinction between Huawei and ZTE, allowing the former under restrictions but barring ZTE because cybersecurity authorities say they cannot mitigate risks if ZTE equipment is allowed in UK networks.

A UK decision to allow Huawei in will impact how the government in another key market, Germany, responds. As of early 2020, German chancellor Angela Merkel was fighting against mounting opposition to allowing Huawei in German networks coming from the Bundestag, including from members of her own party. The decision in Germany is likely to be kicked down the road until later in 2020. For both countries, the debate is politically uncomfortable, as a decision about whether or not to ban Huawei would involve backing a major security partner at the expense of a major trading partner—or vice-versa.

The European Union overall is struggling to come up with a position on Chinese telecom equipment firms that does not necessarily fully follow U.S. efforts to outright ban them from selling to government and commercial network providers. Like the United Kingdom, Germany has established a center to review Huawei hardware and software for security vulnerabilities. Major carriers in both countries have large quantities of Huawei gear in their networks, which they had planned to amortize and use to upgrade to non-standalone 5G.

One estimate is that Europe overall relies on Chinese firms for up to 50 percent of its telecom infrastructure. A UK decision not to ban would reflect the view of many in the UK government that security concerns around Huawei's equipment are manageable, which would allow the country's carriers access to the latest technology at a competitive cost and performance level. Another consideration is the substantial cost of changing suppliers and having to retrain engineers and operators—estimates of the cost to British Telecom of replacing Huawei equipment in its network run from $1 billion to $10 billion. This type of replacement has never been attempted at the scale and timetable that would be required to maintain existing service and would delay BT's move to 5G by many months. Carriers naturally are reluctant to change vendors after significant investments in infrastructure but also are concerned about too much vendor dependence on one supplier, such as Huawei, and at the same time are hoping to maintain vendor diversity, pushing governments to not ban individual companies. Over the longer term, carriers want the industry to evolve to allow more players to compete in the sector, particularly in the RAN.

Second, U.S. executive and congressional action threatens to impose new restrictions on the companies' ability to purchase U.S. technology. As of early 2020, the U.S. Commerce Department was considering additional restrictions on U.S. suppliers of technology to Huawei, essentially closing off loopholes in export administrative regulations that have allowed U.S. firms to continue to supply Huawei from non-U.S. locations. Two new rules—one reducing the threshold for U.S. content to trigger mandatory licensing from 25 to 10 percent and another expanding the definition of products manufactured using U.S. technology that would be subject to licensing or restrictions—generated objections from other parts of the U.S. government in late January 2020 and were on hold at the time of this writing.

For the firms' customers in Europe and around the world, even the threat of further restrictions may cause carriers to reconsider plans to use Chinese equipment, further eroding their revenue base. Huawei's revenue has already taken a hit because it cannot bundle Google Mobility Services with handsets it markets in Europe and elsewhere outside China—the firm is rushing to foster a developer community around its own version of the software suite. Huawei has already moved aggressively to design out U.S. technology from its 5G base stations and appears to have largely succeeded in finding alternatives for all key semiconductors used in its latest base station iteration. Given the centrality of Huawei, further restrictions on Huawei's supply chains—particularly if proposed U.S. rules impact key third party suppliers such as Taiwan's Foxconn and TSMC—would impact China's plans for 5G rollout over the next 2-3 years. In particular, if Huawei's chip design arm can no longer use TSMC to fabricate advanced semiconductors for its base stations, servers, and handsets, the firm's ability to continue supplying cutting edge equipment to Chinese carriers for full standalone 5G going forward would be called into some question. TSMC has said it is in compliance with U.S. export control regulations and has insisted that it would continue to service all its customers.

Meanwhile, the European Union has issued recommendations on 5G security, which are aimed largely at Chinese firms, in the form of a "toolkit." Critical to U.S. arguments over banning Huawei is the concept of "trustworthy vendors." U.S. officials maintain that the political and legal structure of the country where vendors are headquartered should be

included in any risk assessment—also sometimes called a country of origin test. Although Brussels has acknowledged that political questions around trustworthiness should be a factor in 5G supply chain decisions, it lacks authority to enforce a broad ban based on this type of issue—because, under EU rules, national security decisions remain the exclusive purview of member states. Instead, the EU has opted for the toolkit approach, providing a set of measures that members could use to improve network security and mitigate risks around 5G supply chains. Based on an EU 5G risk assessment published last year, this toolkit includes political criteria for assessing the trustworthiness of 5G equipment vendors. Nevertheless, any decision to use the policy tools developed by the European Union will remain up to individual member states.

By mid-2020, the dust should have settled, with a clearer picture emerging on both the fate of Huawei and ZTE and the likely trajectory of China's 5G plans. If both companies survive the fallout from the broader U.S.-China Tech Cold War and the shakeout in the European Union, China will march forward and be a major player in developing all aspects of the 5G ecosystem, from handsets to smart cities.

In a worst-case scenario, both major Chinese 5G players could be restricted from accessing U.S. technology. If this happens, there will be a major reevaluation of China's 5G strategy, in which case there could be considerable disruption to global 5G supply chains, likely resulting in some delays rolling out 5G in many countries, including in China.

This scenario was not on the radar at the 2019 Mobile World Congress in Barcelona but will be this year. In fact, the whole issue of Chinese vendors and their place in the global 5G supply chain will now be on the agenda of the mobile industry going forward. We are not yet quite into the 5G era, but the geopolitics of 5G mean that it looks like it will take longer and cost more to get there.

6. Artificial Intelligence: A Resurrection of Indigenous Innovation Policy

Xiaomeng Lu

Artificial intelligence stands out as one of the most prominent areas of focus of Chinese technology policy in the past couple of years, a period that saw a resurgence of the techno-nationalist indigenous innovation strategy.

Recent Developments

Surprisingly, the much-anticipated implementation of China's cybersecurity law was not fully realized in 2018. When the law took effect on June 1, 2017, many expected China to finalize its data localization regulation and roll out critical information infrastructure protection rules within a year. However, the working level progress of shaping and implementing these policies was stalled by both the corruption investigation of the flamboyant former cyber czar Lu Wei and the frequent leadership changes at the Cyberspace Administration of China.

The lack of progress in implementing China's cybersecurity law also reflects President Xi Jinping's personal interest in shifting from the forward-looking issue of cybersecurity to the perceived urgent priority of domestic technology capacity building. In his first term, Xi announced, "There is no national security without cybersecurity," propelling the launch of the cybersecurity law aimed at addressing one of the biggest challenges of the twenty-first century.

However, as the U.S.-China strategic relationship has grown more confrontational, Xi has transferred his attention to more urgent matters, such as ZTE's sanction violation crisis and the vulnerabilities it revealed.

The U.S. government's momentary ban on U.S. suppliers selling components to ZTE led to the near-collapse of one of China's leading technology companies. This showed to Xi that although China seems big and powerful, it is actually a relatively weak tech

dragon that still relies heavily on the United States. When addressing a conference of China's leading scientists and engineers on May 28, 2018, Xi Jinping said:

> Practice has repeatedly told us that core technologies can't be asked for, bought, or begged for. Only by taking core technologies in our own hands can we fundamentally safeguarded our national economic security, national defense security, and other securities.[20]

In Xi's view, the ZTE case presented a salient example of the fundamental change in the U.S.-China technology relationship, with the United States turning from a key partner and stakeholder in China's success to a possible dragon slayer upon which the survival of China's tech sector dangerously relies. Consequently, Xi's efforts to put out these fires distracted him from the long-term and arguably more important issue of cybersecurity strategy.

Artificial Intelligence: President Xi's New Favorite Industry

Despite the lack of attention on the cybersecurity law, President Xi didn't lose interest in technology issues. In fact, he displayed quite a bit of enthusiasm for next-generation technology and made an unprecedented amount of references to AI over the course of 2018.

His first display of interest in AI was very subtle. When Xi delivered his 2018 New Year speech, there were two AI-related books visible on the shelf in the background: Pedro Domingo's *The Master Algorithm: How the Quest for the Ultimate Learning Machine Will Remake Our World* and Brett King's *Augmented: Life in the Smart Lane.*

Shortly after the ZTE crisis, Xi gave two speeches on indigenous innovation that forcefully pushed for domestic technology capacity building and resurrected the spirit of the "indigenous innovation" policy first enunciated in 2006 but little mentioned since 2011. In the second speech, Xi highlighted the need for China to create domestic technologies in industrial machinery and high-end chips along with basic software, hardware, algorithms, components, and materials through local research and homegrown development.[21] He also tied the future destiny of China to the development of AI, quantum computing, mobile telecommunications, the Internet of Things, and blockchain technology.

In late October 2018, President Xi dedicated a Politburo study session exclusively to AI, urging Chinese scientists, academics, and technologists to seize the historical opportunity of the next generation of technology development.[22] He also called for the domestic academic community to independently create secure and controllable Chinese AI to leapfrog its strategic competition and change the international order.

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20 By highlighting "other securities," Xi is likely alluding to internal public security and domestic stability. See "Xi Jinping's Speech at the Large Meeting of the Two Academies' Academicians (Full Text)," Xinhua, May 28, 2018, http://news.sina.com.cn/c/xl/2018-05-28/doc-ihcffhsu4677507.shtml.

21 Ibid.

22 Xi Jinping, "Push Forward Healthy Development of Our Country's New Generation of AI," Xinhua, October 31, 2018, http://www.xinhuanet.com/politics/leaders/2018-10/31/c_1123643321.htm.

Incompatibility between Exclusive Indigenous Innovation and AI Breakthroughs

However, the harsh reality is that exclusively domestic innovation that lacks outside cooperation and competition will not produce the next breakthrough in technologies such as AI. These two policy objectives are inherently incompatible with each other. There is no doubt that China has had some success in independently growing military technologies through top-down, closed government initiatives. However, in the commercial space, the invisible hand of the market plays a significant role in creating what Xi called "core technologies," such as high-end semiconductors and sophisticated AI algorithms. The Chinese government's AI development fund and the Thousand Talents Program expand the role of the visible hand and leave less space for true innovation. Xi's speeches will further exacerbate the trend of China's government trying too hard to force innovation, which will ultimately result in wasted resources and increasing government debt in the near future.

Despite significant hype over China's AI potential, Chinese tech companies, big and small, are struggling to deliver promised technologies and generate returns for investors. Major Chinese tech players' development is mostly based on U.S. chips and U.S. software platforms. There is no sign of them producing a great leap forward in AI. For example, as Lozada details in his contribution to this volume, although Baidu has the ambition to build an operating system for autonomous cars, its prototype technology is miles behind that of its U.S. competitors. In the meantime, the company went through three executives in charge of the autonomous car project over just the past three years and lost the star AI engineer, Andrew Ng, in 2017.

For AI start-ups, the venture capital (VC) market in China cooled down in 2018.[23] According to ABI Research, in 2017, Chinese AI start-ups raised $5 billion compared to $4.4 billion raised by firms in the United States. However, in the first six months of 2018, VCs only invested $1.6 billion in China, less than one-third of the U.S. levels in the same period. New venture capital activity continued to remain stagnant in 2019 as well, driven in part by a slowing economy as well as greater restrictions on high-tech collaboration adopted by the United States.

This alternative perspective is, in fact, nothing new to the ruling elite of China. In 2011, the argument against exclusive indigenous innovation helped change the mind of former President Hu Jintao, who announced the de-linking of Chinese government procurement preference to indigenous innovation by domestic firms. As recent as May 2018, Chinese Prime Minister Li Keqiang stated:

> Administrative planning can't produce invention and creation. We must respect the rule of science and resist the attempt to take short cuts . . . It is imperative to give scientists sufficient time and space to release their creativity in full.[24]

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23 Louise Lucas, "China's Artificial Intelligence Ambitions Hit Hurdles," *Financial Times*, November 14, 2018, https://www.ft.com/content/8620933a-e0c5-11e8-a6e5-792428919cee.

24 "Li Keqiang: Fundamental Research Rooted in Invention and Creation, Not from Administrative Planning," China Government Net, May 31, 2018, http://www.gov.cn/xinwen/2018-05/31/content_5295129.htm.

As an ancient Chinese proverb goes, “It is better to travel ten thousand miles than to read ten thousand books.” Maybe it is time for President Xi to put down his AI books for a moment and take a few trips overseas to learn first-hand about the global innovation eco-system of collaborative competition.

7. Autonomous Vehicles with Chinese Characteristics

David Hathaway and Patrick Lozada

China is the world's largest market for automobiles and ride-hailing services, and it is increasingly one of the largest investors in autonomous and connected vehicle solutions. On this last front, the Chinese government is increasingly taking an active role in pushing forward autonomous vehicle (AV) technology. In the process, it is creating a unique ecosystem separate from global players. Whether automated vehicle fleets and other innovations will produce resource efficiencies, achieve environmental sustainability, and generate opportunities for investors depends on China solving a potential contradiction between their vision of walling off a separate Chinese ecosystem for autonomous mobility and their dependence on independent, private-sector innovation. This case demonstrates some unique strengths China has in developing a domestic AV sector while also examining the mismatch between China's traditional top-down approach to industrial policy and the tools required to develop and implement complex, connected systems such as AVs.

China has ambitious goals for the development of autonomous driving. According to targets set out in government planning documents, 50 percent of all vehicles produced in China should have autonomous capabilities by 2020. By 2025, 80 percent of new cars should have autonomous capabilities, and 15 percent should be highly autonomous vehicles that largely drive themselves. Since 2016, the government has taken a number of steps to begin making this vision a reality, including creating a minister-led commission under the National Leading Small Group for Building a Powerful Manufacturing Country to coordinate work between government departments, issuing strategic plans for the AV sector, formally legalizing limited road testing for autonomous vehicles, and developing plans to create a web of new China-specific standards for connected and autonomous vehicles.

Characteristics of China's AV Ecosystem

Chinese government regulations and the broader realities of China's political economy have created a unique ecosystem for autonomous vehicles in China that will substantively impact the engineering solutions and business models that companies

can adopt as they look to build and market AV systems in the country. Elements of this ecosystem include:

Chinese ownership of core technology: Chinese industrial policy under President Xi has been characterized by a growing emphasis on technological self-reliance, which extends to the auto sector. The mid-to-long-term plan for the automotive industry notes that the automotive supply chain—particularly as it relates to microchips and vehicle electronics—should be "secure and controllable." These requirements have traditionally been used to exclude foreign participation in technology-related sectors.

China-specific standards: China has detailed plans to release China-specific standards for AVs that will make market access more challenging for foreign players by requiring them to alter AV systems for the China market. In 2017 and 2018, China's Ministry of Industry and Information Technology (MIIT) released three separate plans that laid out a list of more than 100 target standards for AV technology and associated services. These plans note that Chinese AV standards should serve China's broader *Made in China 2025* industrial policy goals and be designed along "indigenous and controllable" principles. For example, autonomous vehicles will be required to use the relatively untested BeiDou Global Navigation Satellite system over the global GPS standard that most vehicles use.

Cybersecurity focus: Vehicle data is likely to be classified as "critical information infrastructure" under China's cybersecurity law. Combined with the fact that mapping data is classified as a state secret and cannot leave the country, Chinese AV data is likely to be kept within the country. This makes China a less attractive destination for testing and will limit Chinese players as they consider expanding beyond China.

Pervasive data collection: Data collection by the government and private firms is pervasive in China. Companies like Alibaba with its City Brain project are increasingly centralizing data from omnipresent surveillance cameras, individual cell phones, and other sensors to optimize public services and control traffic flow. Pervasive data collection has the potential to act as a force multiplier for autonomous vehicles in conjunction with central government promotion of artificial intelligence (AI), AV and electric vehicle data centers, and cloud technology. The centralization of these capacities and the requirement in China's national testing law that AVs upload data in real time is likely to lead to a model where AVs are dependent on instructions from a municipal hub that controls routing choices, monitors vehicles, and facilitates traffic flow. This contrasts with a more decentralized model in countries like the United States, where AVs are more likely to make localized decisions based on data collected by the vehicle itself in dialog with mapping services that have more limited information about each individual vehicle.

Local infrastructure-first deployment: China's national autonomous vehicle testing regulations have yet to fully legalize AV testing across China. Rather, they provide a framework for local governments to legalize testing within specific testing zones. Local governments have in turn responded by launching capital intensive infrastructure projects. Authorities in Shanghai, Beijing, and Shenzhen are investing in 5G and DSRC-enabled smart stoplights, signs that can be clearly read by vehicle cameras, and automotive data centers that store and collect in real-time testing data.

Cities are also experimenting with other administrative tools that could facilitate AV deployment. Some "new cities" like the Xiong'an New Area southwest of Beijing are considering setting aside dedicated sections of the city for AV use. Indeed, China already has significant experience limiting vehicle use by origin and class; it may well be able to leverage this administrative experience to create AV-only zones in major metropolitan areas.

Implications for the Future of AVs in China

Private companies have taken the government's cue and plowed billions into developing domestic AV solutions: Baidu has launched a $1.5 billion autonomous vehicle fund to invest in AV technologies; legacy OEMs such as government-owned SAIC have started pilot testing programs; and dozens of new startups, including Pony.ai and Xpeng, have sprouted up to work on key elements of vehicle technology. However, the success of this domestically generated technology has so far been limited. According to reports submitted to the California Department of Transportation for 2018, AVs from Chinese market leader Baidu required approximately 51 times more manual interventions than AVs from U.S. market leader Waymo, and Baidu has a tiny fraction of Waymo's testing miles.

China is also likely to be limited by the restrictive regulatory ecosystem that it has created for itself. The barriers put on the use of foreign technology will slow the country's development of AV technology. Baidu, Xpeng Motors, and other Chinese AV players rely heavily on chips by foreign companies such as NVIDIA and LiDAR sensors from companies such as Velodyne. If China were to apply "secure and controllable" rules to these technologies or use standards to promote the use of a domestic alternative, Chinese AVs would likely remain inferior to global market leaders, putting their ultimate success in jeopardy.

While China's widespread data collection and its infrastructure-first approach are likely to support the development of AV technology in China, the benefits of these investments will have limits and they will funnel AV development down a different path than other markets. While technologies such as Alibaba's City Brain have led to improvements in traffic flow and municipal services on the local level in cities such as Hangzhou, these improvements are limited to the political boundaries of that city. Local governments are often disincentivized from sharing data with one another because of intercity bureaucratic competition. This is doubly true of technology companies. Alibaba and competitors such as Tencent often fiercely limit access to information generated through their respective platforms for competitive reasons. One could imagine that access to Alibaba's City Brain data could be limited to the company's own autonomous driving testing fleet or that data generated by Baidu Maps would be kept from Pony.ai-enabled vehicles. Breaking down these barriers will require significant interventions from the government that will come at the cost of both financial and political capital.

China's drive for autonomous vehicle leadership is also exposed to ongoing trade tensions with the United States and other countries. The United States is currently considering expanding export controls on a range of technologies to China, including computer vision, artificial intelligence, geospatial positioning, semiconductors, and mobile electric power. While the full list of controls has not been released, the U.S. Commerce Department's Bureau of Industry and Security (BIS) in January 2020 took preliminary action to

limit the export of software "specially designed to automate the analysis of geospatial imagery," a class of software which as defined could impact AV technologies. Per the 2018 National Defense Authorization Act and subsequent regulations released by the Treasury Department, these export control restrictions would also subject Chinese entities pursuing investments in these industries to a review by the Committee on Foreign Investment in the United States (CFIUS). Acquiring foreign technology through mergers and acquisitions was one of the strategies outlined in MIIT's 2018 Draft Intelligent and Connected Vehicle Strategy. Combined, these updated export and investment restrictions have the potential to significantly hamper China's AV plans.

These challenges are not insurmountable. China's innovative private sector and its growing expertise in fields related to AI and big data mean that the country has the potential to be a market leader in AV technology. The barriers that may be most challenging for the country to overcome, however, are not technical in nature; they are political. Successful deployment of AVs will require a regulatory framework that limits restrictions on foreign players and allows the private sector room to take advantage of the size of China's transportation market to develop innovative solutions.

8. Exporting U.S. Innovative Capacity to China? A Case Study of Semiconductor Manufacturing Equipment

Alexander Hammer[25]

Over the past two decades, semiconductors have almost always been within the top five U.S. exports to China.[26] These exports are well documented, as they have been part of an interdependent global supply chain that has combined high-value semiconductor research and design (mostly from U.S. firms) with lower-value assembly, testing, and packaging (mostly in China). What is less well-known, however, is a related development featuring U.S. exports to China of equipment used to manufacture such semiconductors. This article sheds light on the growing prominence of such capacity-building exports to China and explores the market and state-led factors that have led to their growth. It also considers the implications of these trends, given how dominant U.S. suppliers have historically been in this industry.

Trends

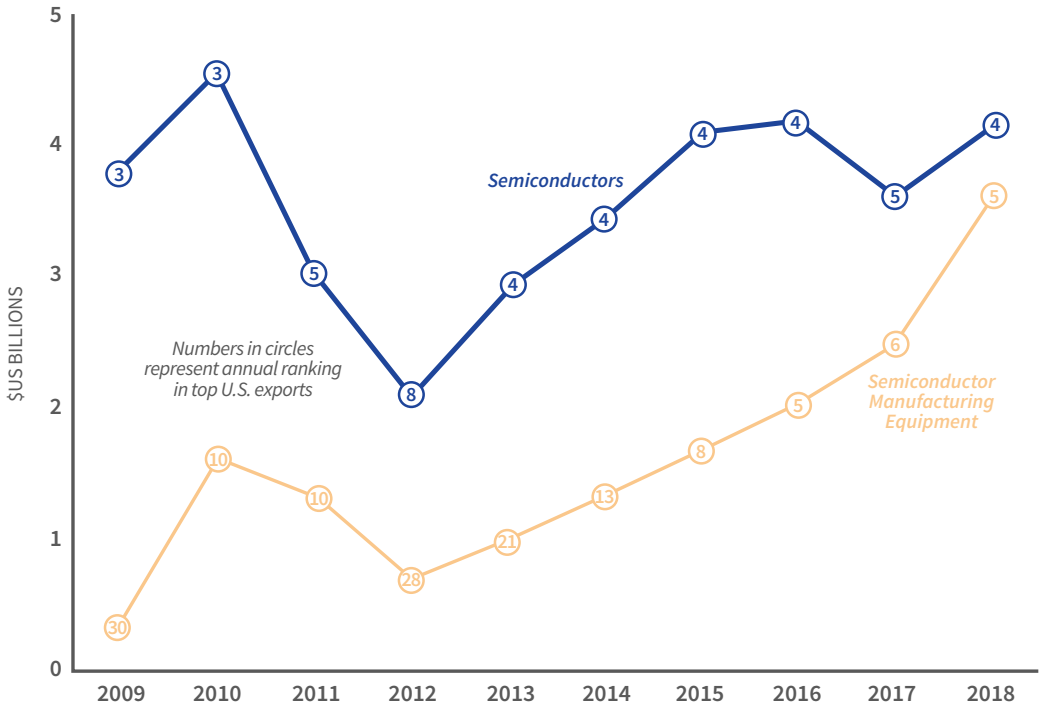
U.S. exports of semiconductors and semiconductor equipment to China have been robust over the past decade. Figure 8.1 describes both categories' export values and rankings relative to all U.S. exports at the 4-digit HS classification level. U.S. semiconductor exports to China are high in both absolute terms ($2-$5 billion per year) and in relative terms when compared to other U.S. exports to China. While U.S. semiconductor manufacturing equipment exports have not been as high, their growth has been more consistent and larger in value terms over the past decade. According to the latest available year of data (2018), U.S. semiconductor equipment exports to China have nearly matched U.S. semiconductor exports to China in value terms. Since 2015, moreover, semiconductor

25 The views expressed in this paper constitute those of the author and not those of the U.S. International Trade Commission or any of its Commissioners.

26 The only exception being 2012, when semiconductors represented the eighth largest type of U.S. exports to China.

manufacturing equipment has become a top ten U.S. export to China and remains one of the largest forms of U.S. capacity-building exports to that country.

FIGURE 8.1: TOP U.S. EXPORTS TO CHINA (BY HS-4 CATEGORY)



Source: "DataWeb," USITC, https://dataweb.usitc.gov/.

China is the largest market for U.S. exports of semiconductor manufacturing equipment and most of China's related imports come from the United States.[27] China is also the world's largest importer of semiconductors, accounting for a majority of global demand (58.5 percent).[28] While China only produces 9 percent of the semiconductors it consumes, the gap between its consumption and domestic production has begun to shrink. PWC and other industry analysts project a continued narrowing of China's consumption-production gap, given persistent trade war conditions, Chinese government initiatives, and sustained global demand for electronics and their increasingly concentrated semiconductor content.[29]

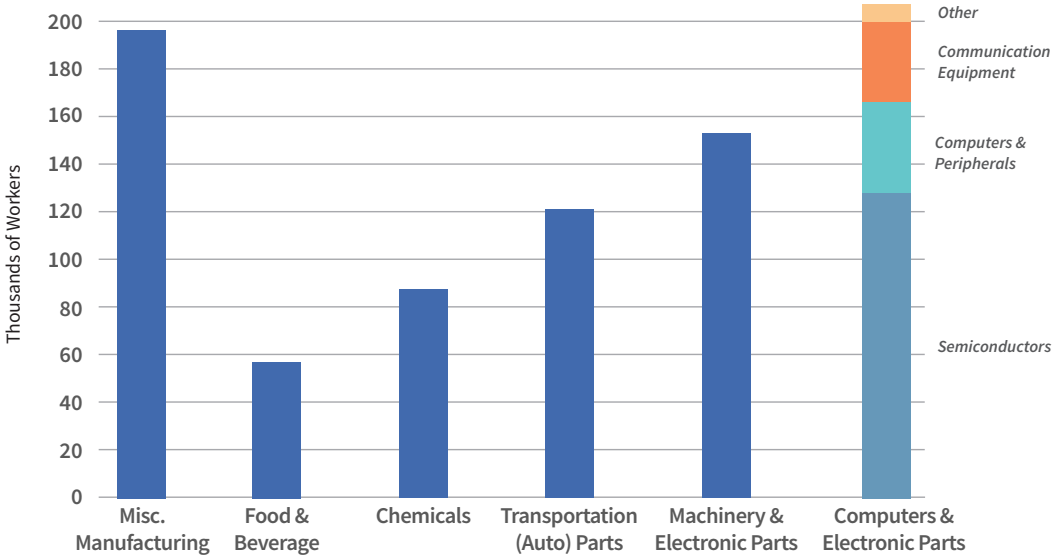
Motivation

The robust growth in U.S. semiconductor manufacturing equipment exports to China stems from a combination of market and state-directed factors. With respect to market

27 See USITC Dataweb and China General Association of Customs *databases*; "China's Impact on the Semiconductor Industry: 2017 Update," PWC, January 2017; U.S.-China Economic and Security Review Commission, *Trends in Trade*: *U.S.-China Goods Trade 2012-2017* (Washington, DC: USCC, July 2018).
28 PWC, "China's Impact on the Semiconductor Industry: 2017"; U.S.-China Economic and Security Review Commission, *Trends in Trade*.
29 PWC, "China's Impact on the Semiconductor Industry: 2016 Update," January 2017.

activity, an increasingly fragmented semiconductor manufacturing process has positioned many U.S. firms at the initial stages of the supply chain, where more advanced, high-value research and design take place.[30] China's role in this supply chain has mostly been in the lower-value assembly, testing, and packaging segments.[31] To maintain their edge in an increasingly competitive industry, U.S. firms have been offshoring (to U.S. affiliates) and outsourcing (to specialized firms) increasing production to China, where manufacturing costs are cheaper and proximity to final assembly in electronics has become paramount. Figure 8.2 demonstrates how important China has been for U.S. semiconductor manufacturing firms. It shows that affiliates of U.S.-based firms employ some 118,300 Chinese workers in semiconductor manufacturing, which is more than any other offshored manufacturing sector in China.[32] These firms have been importing increasing amounts of semiconductor manufacturing equipment from the United States. Chinese customs statistics even show that the majority (62 percent) of Chinese imports of U.S. semiconductor equipment come from U.S. and other foreign-invested firms in China,[33] with the balance coming from state-owned enterprises (SOEs).

FIGURE 8.2: COMPOSITION OF U.S. AFFILIATE EMPLOYMENT IN CHINA'S MANUFACTURING SECTOR



Source: U.S. Bureau of Economic Analysis (Latest data, accessed Feb 2020)

30 Semiconductor Industry Association, Proposed Determination of Action Pursuant to Section 301: China's Acts, Policies, and Practices Related to Technological Transfer, Intellectual Property, and Innovation: Docket Number USTR-2018-0005 (Washington, DC: Semiconductor Industry Association, July 2018), 8.

31 PWC, "China's Impact on the Semiconductor Industry: 2016 Update," 1.

32 Alexander Hammer, "The Size and Composition of U.S. Manufacturing Offshoring in China," USITC Executive Briefing on Trade, June 2017.

33 These come from both wholly-owned foreign-invested firms and joint-ventures. Data are from China's General Association of Customs.

China's government has attempted to indigenize a more robust semiconductor industry given concerns about over-reliance from U.S. and other global suppliers.[34] As part of their *Made in China 2025* technology development plan (which replaced the former *Strategic Emerging Industries* program), domestic semiconductor firms have been encouraged to lead globally competitive technologies by 2030.[35] In 2014, Chinese authorities published plans to promote domestic semiconductor production[36] and in 2015 announced a $161 billion state-sponsored National IC Fund to support domestic innovation in all supply chain segments.[37] In 2016, moreover, China's government invested another $6.6 billion to expand its domestic semiconductor industry through M&A activity.[38] All these initiatives have placed upward pressure on demand for U.S. semiconductor manufacturing equipment.

Implications

U.S. semiconductor firms have had market-based incentives to increase their semiconductor production in China, including cheaper manufacturing costs and better access to end-users.[39] The Semiconductor Industry Association has even argued that in the absence of the option to manufacture in China (say in the case of prohibitive tariffs), U.S. firms would "reduce the U.S. competitive edge in more advanced and high-value research, design and manufacturing."[40] These factors, and the growth of the digital economy that will rely upon increasing concentrations of semiconductor content in electronics, suggest that the demand for U.S. equipment needed to produce such semiconductors in China is likely to remain strong. Probably only a prolonged trade war (which would continue to impact the entire semiconductor supply chain), or an expansive export control program, could reverse such trends.

Chinese government efforts to build its domestic semiconductor industry are also likely to provide sustained demand for semiconductor equipment imports.[41] This was the finding of a Department of Commerce market report as it relates to China's National IC Fund and presumably other policies like it.[42] Moreover, Chinese government procurement programs favoring domestic purchases are also likely to increase such demand, at least in the short-run.

Given U.S. semiconductor firms' dependence on manufacturing in China, Chinese government measures to develop its domestic semiconductor industry, and interfirm technology transfers that have taken place through the semiconductor manufacturing process, concerns have been raised about the long-term viability of U.S. firms in this

34 International Trade Administration, *2016 Top Markets Report Semiconductors and Semiconductor Manufacturing Equipment: Country Case Study* (Washington, DC: International Trade Administration, 2017), 2.
35 Alexander Hammer, "'Made in China 2025' Attempts to Re-Stimulate Domestic Innovation," *USITC Executive Briefing on Trade*, September 2017; "Unofficial Chart of Localization Targets Set in Made in China 2025 Technology Roadmap," U.S.-China Business Council, July 4, 2017.
36 These plans were published as "Guidelines to Promote National Integrated Circuit Industry Development."
37 Congressional Research Service, China-U.S. Trade Issues (Washington, DC: CRS, July 2018), 80; International Trade Administration, *2016 Top Markets Report*.
38 Congressional Research Service, *China-U.S. Trade Issues*, 80.
39 Alexander Hammer, "Why Have U.S. Firms Offshored to China?" *USITC Executive Briefing on Trade*, June 2017.
40 Semiconductor Industry Association, *Proposed Determination of Action*, 8.
41 "Chip Wars," *The Economist*, December 7, 2018.
42 International Trade Administration, *2016 Top Markets Report*, 4.

industry. However, there still exists a deep technological divide between the research and design stages of production that U.S. firms have specialized in and those conducted in China. The stages where China has been prominent (assembly, testing, packaging) still constitute only 10 percent of the value of the final product and, according to the Semiconductor Industry Association, do not possess highly valuable intellectual property.[43] Simply acquiring technology from existing semiconductor manufacturing equipment imports does not readily translate into competitive research and design activities for semiconductors. Moreover, the magnitude of the capital investments that are being perpetually made in the research and design segments of this dynamic industry also serves as a barrier to entry of sorts. Intel, by way of reference, spends four times as much on semiconductor R&D as the entire Chinese chip industry and only represents one of several prominent U.S. semiconductor firms.

Given that the U.S. semiconductor industry is still so far ahead of China's and that migration of certain components of the industry abroad is helping the United States strengthen its overall place in the industry, the United States and other advanced industrialized economies will need to carefully weigh the potential benefits and downsides of policies that could fundamentally change this commercial landscape.

43 Semiconductor Industry Association, *Proposed Determination of Action*.

9. Seizing the Means of Production: Cobalt and the Electric Vehicle Sector

Maria Sinclair

On May 2, 2018, CEO Elon Musk announced Tesla's plans to sharply reduce the amount of cobalt in its electric vehicles (EV). This was highly unusual and likely very expensive, given the fact that cobalt is generally used in the world's most advanced EV because of its high energy density. But Tesla's impetus to divest from cobalt is real because cobalt's recent dramatic price rise and the industry's poor regulation have frustrated global EV makers. In addition, research on new battery technologies is still ongoing, and the monetary payoff is likely years away, leaving EV producers in a cobalt-dependent trap for now. There are many other reasons why buying cobalt has gotten harder as demand has increased and supply has shrunk. But China's acquisition of key cobalt assets and its close government-business ties have worsened this problem.

China has a near-monopoly on cobalt.[44] China is the largest battery producer in the world, but Chinese companies have generally produced inferior LFP (lithium ferrophosphate) batteries, rather than higher-quality cobalt alternatives. However, these metrics fail to describe the vulnerability of the EV supply chain under China's monopolization of cobalt.

In the case of cobalt, Chinese government policy can greatly impact the global market. In 2016, LFP was the most widely used battery configuration worldwide despite lower efficiency. The reason why a less efficient product has a higher market share is that most producers in the world were responding primarily to Chinese policy incentives. Their profit margins were based on government subsidies for EVs, which were doled out regardless of battery quality. In other words, most of the producers in the world were reacting to the demands of the Chinese government, not the demands of any market. Once the government's criteria were tightened to include battery density, producers reacted. As a result, the most widely used battery chemistry is now quickly switching to cobalt variants.

44 Heidi Vella, "Inside China's Move to Monopolise Cobalt," *Mining Technology*, June 4, 2018, https://www.mining-technology.com/features/inside-chinas-move-monopolise-cobalt/.

On top of China's monopoly on cobalt, the Chinese government also has had a domestic subsidy policy that leverages China's dominance in key supply chain links in order to achieve national priorities for its EV industry. These moves have resulted in discriminatory and negative effects on the EV industry writ large, particularly on end-stage carmakers.

Why does it matter that China has a monopoly on cobalt? Batteries are the most technically complex and costly parts of EV. Within battery production, battery materials, including cobalt, are the most expensive components.[45] As demand for minerals used to produce batteries increases, minerals will take up a growing share of the production cost of batteries. As a result, the overall production cost of EVs will significantly increase. By 2040, Bloomberg projects 35 percent of all new cars sold will be EVs.[46] High demand for cobalt in EVs, as well as new applications for cell phone and computer chips, may drive cobalt prices up 4,500 percent by 2030. This is significant enough that if one country or company eliminates cheap and ready access to cobalt, EV producers' ability to compete will be cut off at the knees.[47]

Chinese firms now globally control almost all cobalt refineries, a lion's share of raw production, and have influence over cobalt's main regulatory and pricing body—in short, every major aspect of cobalt production. By country, China also buys the largest share of cobalt. If previous experiences are a guide, this could be a problem. China's similar foray into another burgeoning high tech, solar panels, resulted in its gaining a monopoly that weakened the global market, killing firms that could not compete with Chinese prices. A similar but distinct pattern has emerged for EVs.

China was able to become the world's number one producer of processed cobalt despite producing less than 1 percent of the world's raw cobalt because of its strong relationship with the Democratic Republic of Congo (DRC). The DRC is one of the richest countries in terms of natural resources, holding an estimated $23 trillion in mineral wealth, but its extreme poverty rate was 73 percent in 2018, one of the highest in sub-Saharan Africa, reflecting the paradox of colonization. As of mid-2018, the DRC produced 58 percent of the world's cobalt, and by 2025, that number is expected to climb to 73 percent as supplies outside the DRC dwindle. Chinese enterprises ranked first for global cobalt production volume.[48]

Over the past two decades, China has purchased seven of the DRC's top ten mines and produces more than 80 percent of the world's refined cobalt with them. Chinese firms made quick gains over competitors in the DRC's raw cobalt market by offering resources-for-infrastructure deals, which trade Chinese investment in infrastructure for minerals.[49] These deals have been criticized by the IMF for their risk to the global

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45 Michael Sanders, "Comparing Li-ion to Lead Acid Batteries & Other Storage Options: Future Predictions" Avicenne Energy US, March 7, 2018.

46 "Electric vehicles to be 35% of global new cars sales by 2040," Bloomberg New Energy Finance, February 25, 2016, https://about.bnef.com/blog/electri-vehicles-to-be-35-of-global-new-car-sales-by-2040/.

47 Henry Sanderson, "Electric cars: the race to replace cobalt," *Financial Times*, August 20, 2018.

48 Thomas Wilson, "We'll All Be Relying on Congo to Power Our Electric Cars," Bloomberg, October 26, 2017; "Research Report on Global and China's Cobalt Industries, 2019-2023," ResearchandMarkets.com, June 2019, https://www.businesswire.com/news/home/20190719005314/en/Global-Chinas-Cobalt-Industries-Report-2019-2023-Featuring.

49 Stefan Marysse and Sara Geenen, "Win-win or Unequal Exchange? The Case of the Sino-Congolese Cooperation Agreements," *The Journal of Modern African Studies* 47, no. 3 (September 2009): 371-396, https://doi.org/10.1017/

market. For example, in 2017, DRC leaders allowed a sale of 13,800 tons of cobalt to the Chinese company GEM. That single sale accounted for one-tenth of global cobalt output that year. Such deals bypass traditional trading on the open market and generally account for high volumes of resources over the long term, further limiting an already low supply of the mineral.

Another chokepoint in China's EV supply chain monopoly is Chinese battery firms' purchases from other producers. In March 2018, GEM announced that it would purchase one-third of cobalt mined by Glencore, equivalent to half the world's production in 2017. Battery industry leaders such as Sam Jaffe of Cairn Energy called the outcome of such deals akin to a game of musical chairs, in which Chinese battery manufacturers have taken all but one of the seats.[50]

To get a sense of the government's more direct impact on the global EV market, it's important to understand the extent of control that the Chinese government has over Chinese battery and EV manufacturers. Kennedy and Qiu estimated that government support in the EV sector totaled 48 percent of total sales in China.[51] Chinese EV and battery manufacturers are therefore largely driven by government demand rather than market demand.

The government's control over Chinese EV and battery manufacturers became apparent shortly after December 30, 2016, when the Ministry of Science and Technology of China (MOST) and other ministries released Circular 958.[52] 958 required batteries to have a level of energy density that only cobalt batteries could reach, therefore necessitating cobalt buying. The policy affected 70 percent of passenger vehicle models produced in China at the time. Prior to that policy, most Chinese battery producers used cheap lithium-phosphate batteries with lower energy density. When the policy came out, these producers (again the majority of the world's battery producers) all rushed to buy cobalt. Driven largely by Chinese demand, global cobalt prices rose 68 percent in the first quarter of 2017.

Another key contributor to China misusing its monopoly over cobalt is the London Metallurgical Exchange (LME), which managed the price spike poorly. By way of background, in 2012, China's Hong Kong Stock Exchange (HKSE) acquired the LME for the confusingly large sum of £1.4 billion (over 1,800 times the LME's profit in 2011), leading some to question HKSE's motives to purchase the Exchange and its relations with Beijing.[53]

"We have been issued with numerous assurances that this is a Hong Kong entity, not a Chinese entity," a person close to the LME told the *Financial Times* in 2012.[54] Still, many

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s0022278x09003978.

50 "What if China corners the cobalt market?" *The Economist*, March 24, 2018.

51 Scott Kennedy and Mingda Qiu, "China's Expensive Gamble on New-Energy Vehicles," CSIS Commentary, November 6, 2018.

52 "Notice on Adjusting the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles" (Guanyu Tiaozheng Xin Nengyuan Qiche Tuiguang Yingyong Caizheng Butie Zhengce De Tongzhi Caijian 958), PRC Ministry of Industry and Information Technology, December 30, 2016, http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c5449722/content.html.

53 Robert Cookson, Jack Farchy and Leslie Hook, "HKEX walks fine line with LME's China strategy," *Financial Times*, June 18, 2012.

54 Ibid.

of the firm's internal conflicts have stemmed from its closeness to China. Less than three months after the new program was finalized, a competitor found and reported evidence of forgery in Chinese warehouses included in the program. Such violations would generally lead to more careful consideration and delay before new programming deals. If nothing else, as Jeremy Grant pointed out back in 2012: " [the deal] signals the start of a shift away from the west to Asia in how prices are fixed between buyers and sellers."[55]

Another example of how LME's close relations with China are troublesome is that, in 2017, as cobalt prices were spiking, trade publication and pricing organization *Metals Bulletin* announced higher prices of cobalt than LME prices for the first time. It also found that the cobalt supplier Yantai Cash apparently caused the pricing differential.[56] The basis of Yantai's cheaper product is extremely troubling: the company was found to have violated numerous child labor laws in the DRC during the time it was on the LME. At best, the LME is in a period of instability while it pivots toward Asia. At worst, the PRC government holds significant sway over LME decisions and has been using its ownership of the exchange to benefit PRC firms.

Regardless of the government's intent, Chinese domestic policy can have an adverse impact on foreign competitors because of its sheer proportion in the global market coupled with the tight relationship between government policy and Chinese companies' behavior. Whether or not Chinese EV companies win against Tesla and VW, both of which have raised concerns over cobalt access, its mining firms and refineries will continue to profit from EV's rise so long as other companies use cobalt en masse. Despite domestically producing almost no raw cobalt, China's control over cobalt has basically been assured. It seems plausible that such a pattern could repeat with similarly immature markets.

Some analysts have compared cobalt to the 2010-2011 price spike of rare earth metals following China's monopolization of these commodities. It can be further argued that cobalt has the capacity to escalate even beyond that of rare earths if China tries to take advantage of its monopoly. Cobalt is a good litmus test for China's ambition in Latin America, Africa, and the resource-rich developing world. The ultimate question seems to be: "What are China's global ambitions?" At least in the case of EVs, a better framing might be: "Given China's voracious ambitions, what are the global consequences?"

There are already ramifications of the supply chain's dominance by a single player: in 2018, global production volume of cobalt increased 20 percent year over year, but within the DRC, production increased a staggering 40 percent year over year, driven largely by Chinese EV battery demand and dependent on illegal mining, which is quite dangerous. Without these illegal mines, price fluctuations in the cobalt chain based on Chinese demand upswings in the last two years would have been much worse.[57] Put succinctly by Reuters' Andy Homes, "the cobalt market "needs Congo's 'illegal' miners."[58]

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55 Jeremy Grant, "Mystical numbers in HKEx bid for LME," *Financial Times*, June 26, 2012.

56 Ritzema "2017 Review: Battery Boom, Brand Developments, Artisanal Concerns Prompt *Metal Bulletin* cobalt spec review," *Metals Bulletin*, December 29, 2017.

57 Andy Home, "Why the cobalt market needs Congo's 'illegal' miners," Reuters, July 12, 2019, https://www.reuters.com/article/us-congo-cobalt-ahome/why-the-cobalt-market-needs-congos-illegal-miners-andy-home-idUSKCN1U-71VS.

58 Marcelo Azevedo, Nicolo Campagnol, Toralf Hagenbruch, Ken Hoffman, Ajay Lala, and Over Ramsbottom, *A Tale of*

Cobalt's role in the EV supply chain, therefore, serves as a case study for how high-tech, high-value supply chains should be monitored and analyzed in the future. More weight should be placed on who is set to profit the most across the whole supply chain rather than focusing on end-state products or producers. We should not expect the separation of China's private sector and its government. Other than technological bottlenecks affecting all competitors, attention should also be paid to strategic bottlenecks that benefit some end-stage competitors more than others.

Two Commodities: Cobalt and Lithium (New York: McKinsey & Company, June 2018), https://www.mckinsey.com/~/media/mckinsey/industries/metals%20and%20mining/our%20insights/lithium%20and%20cobalt%20a%20tale%20of%20two%20commodities/lithium-and-cobalt-a-tale-of-two-commodities.ashx.

10. Trading Iron Curtains for Chinese Walls: Is It Different This Time?

Kevin G. Nealer

Sino-U.S. relations are complicated and bound to become more so with the passage of time. It was ever thus. For those who have been involved directly and indirectly since recognition in 1979, there are two durable truths.

First, relations were never easy. There was never a mythic time when naivety fostered a belief that engagement would become convergence. Elements of the business and academic communities may have held out versions of this hope. No U.S. company with exposure to China built its business plan around that expectation. "China becoming America" was never a fiction in which policy practitioners of either U.S. political party could indulge. On Capitol Hill and with each successive administration, the focus was on advancing U.S. interests and creating incentives for China that resulted in improved U.S. economic and security options in Asia. To imagine otherwise is a failure of scholarship and experience.

Second, it is the beginning of wisdom to appreciate that most of the challenges in the relationship today are the products of U.S. and allied policy successes, not failures, in managing China. In the 40 years since Chinese reforms began, more than half a billion people have migrated from the countryside and poverty to the cities and the middle class—the largest global movement of human beings at any time, including the two world wars. Having the legitimacy of the Chinese Communist Party dependent on rising wages and expectations of improving quality of life is an artifact of U.S. and allied policies. Overreliance on the external sector as an essential ingredient of Chinese growth was preferable to the two alternatives: 1) An autarkic, authentically (Soviet-style) Communist China where its military did not occupy the basement of modernization priorities or 2) An enormous failed state with nothing to lose.

The Japan, South Korea, and Taiwan trade and investment neuralgia of the 1980s previewed the challenges that come with such an outward-focused growth strategy by a major competitor, but that experience differed in powerful ways. First, China is a security competitor, not a partner. Almost as important, the pace and economic weight of China's transformation is unprecedented. Finally, the continued dominance of

Communist authoritarianism and an increasingly bold and ambitious intelligence and military doctrine make China a unique challenge.

China became a stronger actor and the features of a repressive dictatorship became more ingrained through expansion of the security state and unparalleled coercive use of technology. WTO membership, World Bank and International Monetary Fund participation, and the start of open access to global capital markets were imperfect guard rails to China's behavior, and those global norms have been exploited by Beijing.

Three decades of stagnant U.S. wages and globalization's inexorable reach have eroded U.S. support for business as usual with China. U.S. and European companies went on record in the last two years of the Obama administration, chronicling the lack of reciprocity and fundamental unfairness of China's mercantilism with a bill of particulars that included regulatory protectionism and a system favoring China's domestic champions over foreign competition. China lost the political protection of corporate interests, exchanging tacit support for a new choir of voices now critical of an imbalanced playing field, no longer offset by low wage production and acceptable earnings, or the illusion of opportunity in the local market. The distrust extends beyond the experience of the private sector. It now includes nongovernmental institutions, advocates of rule of law, civil society groups, environmental organizations, religious communities, and human rights advocates. All of these have been marginalized or excluded from past hopes of any roles in encouraging features of civil society.

The real change in bilateral relations has not been because of rising U.S. populism or the diminished trust in China by the U.S. corporate sector. Those would have been manageable if bracketed by broader shared interests and habits of cooperation. But the X factor transforming the relationship is Xi Jinping's shift toward more statist economic policies (*Made in China 2025* and the increased preference for Chinese companies over foreign competitors), heightened reliance on repressive social policies, and assertive foreign policy actions. These necessarily give rise to policy antibodies in the economic, security, and intelligence communities in the United States, Asia, and globally. From an U.S. viewpoint, broken promises in the South China Sea, the hack of over 20 million U.S. government employees' personal data, and Xi's efforts to fortify the Communist Party and foster a nationalistic "China dream" all have been built on an indifference to risk and a willingness to test U.S. resolve on multiple fronts. Xi's aggressive efforts to make up for the "lost decade" of the Hu-Wen era are deepening an allergic reaction in the U.S. and allied policy communities.

As is true of any biological immune system, the risk is not that U.S. policy will react, but that it will overreact. That was dramatically true of the U.S. response to 9/11; Xi's over-reach could produce corresponding excesses.

U.S. restraints on commercial deals with China are relatively narrow, but nothing new. The Tiananmen-era sanctions and other limits on munitions and dual-use technology remain in effect. What Xi's policies have fostered is an overdue examination of export controls and technology transfers policies as well as a new class of investment restrictions. Chinese intelligence programs have undermined trust in educational

exchanges, particularly in STEM fields and required stepped up counterintelligence responses. These are the direct result of China's discriminatory intellectual property policies and its asymmetric, offensive approach to commercial espionage.

Changes in law and practice at the Committee on Foreign Investment in the United States (CFIUS), as amended by the Foreign Investment Risk Review Modernization Act (FIRRMA), are a direct response to unprecedented Chinese reach into U.S. companies.[59] The 1990s Japanese recycling of trade deficit dollars elicited an overreaction against the willingness of Japanese private investors' to pay beyond market prices for iconic U.S. assets.[60] Chinese investments are different both because of their origin and in being a government and corporate effort to gain competitive advantages in advanced technologies—often in product lines where China has underperformed. An ally acquiring golf courses and recording companies is very different from a security competitor accumulating composite materials technologies and data analytics capability.

As noted, there is the risk of an overreach that undermines the United States' pride of place as a premier destination for global capital. But another risk is failure to execute on a more vigorous policy to push back against China's worst instinct because it is unilateral. Ongoing reports of Chinese cybercrimes offer fresh evidence that multilateral responses to Chinese technological aggression are the only option.[61]

That is also true of any response in the global investment arena. More capital moved around the world in the first months of 2019 than the total value of all good and service trade last year. Regardless of the long-term direction of U.S.-China relations, there is no U.S. response to Chinese investment outreach or technology acquisition that can succeed without the support of Europe, Japan, Australia, and other allies. The global nature of technology and capital markets does not allow unilateral strategies. Sanctions and various kinds of penalties are meaningless unless others participate.

The Trump administration has devalued alliances and taken steps to reduce U.S. reliance on the partnership structures that have sustained U.S. interests since 1945. That choice is purposive, part of Trump policy, and essential to the president's "promises kept" approach to foreign policy fundamentals. Those who point to selective portions of the National Security Strategy or other documents not originating in the White House are free to take comfort in the belief that multilateral institutions like the WTO and NATO are U.S. assets. That is not what the president says or what those closest to the policy decisions believe.[62]

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59 Stephanie Zable, "The Foreign Investment Risk Review Modernization Act," Lawfare, August 2, 2018, https://www.lawfareblog.com/foreign-investment-risk-review-modernization-act-2018.

60 Laura Myers, "Golf Course Fiasco for Japanese Investor, Sign of More Profound Problems," Associated Press, February 21, 1992, https://apnews.com/fc8e4d7b11c348bbe86176a28205d0eb.

61 Ryan Lucas, "Justice Department Charges Chinese Hackers In Bid To Curtail Cyber-Theft," National Public Radio, December 20, 2018, https://www.npr.org/2018/12/20/678587956/justice-department-charges-chinese-hackers-in-bid-to-curtail-cyber-theft.

62 Zachary Cohen, Michelle Kosinski, and Barbara Starr, "Trump's Barrage of Attacks 'Beyond Belief', reeling NATO Diplomats Say," CNN, July 12, 2018, https://www.cnn.com/2018/07/11/politics/trump-nato-diplomats-reaction/index.html.

China management going forward cannot be a return to an economic and technological Cold War. But the Cold War was managed to a successful conclusion through alliances that limited Soviet aggression and constrained the adversaries' options. Current U.S. policy diminishes the opportunity for such virtuous outcomes and undermines the significant advantages U.S. leadership confers.[63]

63 Michael Beckley, Unrivaled: *Why America Will Remain the World's Sole Superpower* (Cornell University Press, 2018).

11. For Cooperative Innovation, China Must Lead the Way

Craig Allen

Today, just over 40 years after the reestablishment of diplomatic relations between the United States and China, we are at a historic inflection point defined by more and more competition and less and less cooperation. Both countries have actively traded economic blows, and we have demonstrably proven that we are most capable of hurting each other. There are voices on both sides clamoring for economic decoupling amidst a severe collapse of trust, and that trust deficit is most starkly on display in the realm of technology and innovation.

Forty years ago, China's science and technology institutions had collapsed. Today, Chinese scientists and engineers are expanding human knowledge in healthcare, space, and almost every other field of science and technology. In many respects, China's technological transformation has been a boon to the United States. First as a manufacturing partner and then as a market, a source of funding, and a partner in innovation, China has been indispensable to the U.S. technology sector. It is impossible to imagine a Silicon Valley without China.

But U.S. concerns over China's policies and practices in the high-tech sphere are very real. The U.S. Trade Representative's Section 301 report accurately identifies a suite of anti-competitive and unfair practices that cannot continue if cooperative innovation is to thrive. Excessive techno-nationalism in China has led to forced and coerced technology transfer, intellectual property theft, and cyber espionage by state-affiliated actors to obtain proprietary technologies. China also maintains outlier interpretations of Internet sovereignty, blocks data flows, and diverges from the normal protocols of e-commerce in ways that are extremely disruptive to global business and supply chains.

In the absence of sufficient Chinese reforms, the legal and diplomatic tools available to the United States are largely defensive. Beyond the punitive Section 301 tariffs, which are at least partly intended to create negotiating leverage, policymakers have also reformed our foreign investment review process and enhanced our export controls regime in ways that essentially seek to safeguard U.S. technology by walling it off. These measures are likely to significantly curtail Chinese investment in U.S. high-tech firms, making proprietary

technologies less accessible to Chinese investors but also reducing the pool of venture capital available to high-tech U.S. startups. They will also diminish business opportunities by narrowing permissible sales to Chinese customers, limit opportunities for collaborative research and development, and restrict U.S. companies' access to talent by curtailing employment of Chinese experts. In short, we have embarked down a path toward decoupling our high-tech industries and isolating our innovators from each other. This may increase protection of our respective technologies, but it also is likely to dull both of our countries' cutting edge and undermine technological advancement overall.

There are steps China can take to right this course—steps that are in its own economic interests as well as ours. Forced tech transfer and poor intellectual property protections no longer serve today's China any more than they serve the United States, given its own status as a leading hub of global innovation. It is demonstrably to China's own domestic benefit to address the problems articulated in the 301 investigation by better protecting intellectual property rights across the board, forbidding the use of forced technology transfer, and taking strong measures to prevent cyber intrusions for commercial gain. To continue to advance technologically and to sustain the economic growth necessary to escape the middle-income trap, China must also allow greater market access by foreign companies, reduce state intervention in the economy, lower wasteful subsidies, and spur healthy competition in its markets.

It just so happens that these are the same issues being discussed as a part of our bilateral negotiations, but these issues are also the focus of broader constituencies. Indeed, the challenges of adapting economies and workforces to an increasingly interconnected and high-tech world are global, and they are better served by leveraging multilateral tools than hunkering down behind nationalistic lines. China is famed for its technocratic leadership and has successfully brought that expertise to bear again and again to realize the country's momentous development. What are the rules of the road for technology cooperation? What are the rules of the road for technology competition? How do we enforce those rules? We need a robust multilateral dialogue on these issues, and China should be a leading voice.

One clear way for China to address many of these issues and assert its voice more constructively is for the Chinese government to rigorously, fairly, transparently, and even generously implement all of its WTO commitments—giving its trading partners what they bargained for when China joined the WTO in 2001. Chinese negotiators tell us that they have implemented their WTO commitments, but this is true only in the narrowest possible interpretation, and it has been done in a highly nationalistic and mercantilist manner.

The WTO disciplines cover most, though not all, of the concerns recognized in the United States' concerns. With a more energetic implementation of its WTO commitments, China will have met the great bulk of the demands put forth by the United States as a part of the bilateral negotiating process. Fully embracing China's WTO commitments is also 100 percent compatible with Xi Jinping's vision—as repeatedly expressed in speeches in Davos, Bo'ao, and Shanghai—to make China a leader of the multilateral trading system. And by assuming true leadership in the global trading regime, China can ensure that the world's major economies carry out the crucial work needed to adapt and modernize the WTO for the digital age.

In the past, both the United States and China have considered joining the Trans-Pacific Partnership (TPP), and thus it would also make enormous sense for both countries to use and promote the TPP standards as a "level-set" measuring tool for resolving our technological and economic differences. Almost all of the issues that our trade negotiators are currently struggling with in the bilateral negotiations are precisely addressed in the TPP documents, including state-owned enterprises, intellectual property rights, forced technology transfer, subsidies, data flow across borders, investment, and many more. The regional standards set by TPP are still 100 percent valid and should inspire our negotiators to address the issues that are mistakenly characterized as bilateral problems.

History shows that the United States and China can both choose to make progress together, or we can both choose to struggle together. Currently, we are struggling together. Both of our economies are slowing sharply, facing severe cyclical and structural challenges, in part because of our trade disputes and our festering mutual distrust. As President Carter recently put it on the eve of the anniversary of the reestablishment of diplomatic relations, "The United States and China need to build their future together, for themselves and for humanity at large." Both sides are responsible for putting the relationship back on a cooperative path. China can do that by making positive policy changes that respond to the United States' complaints, bringing it into compliance with both the letter and the spirit of its WTO obligations, and, as a result, creating a genuinely innovative economy.

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