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**EVALUATING CHINA'S EFFORTS TO FOSTER
INNOVATION IN THE 21ST CENTURY**

by

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**EVALUATING CHINA'S EFFORTS TO FOSTER INNOVATION
IN THE 21ST CENTURY**

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ABSTRACT

Over the past thirty years, China has published various national plans and policies to foster science and technology innovation, with an emphasis on fostering an indigenous innovation capacity since the mid-2000s. In particular, these efforts include industrial policies to grow the role of private enterprises in spurring innovation as well as shifting the orientation of its education system away from instruction and lecture and towards fostering curiosity and the development of scientific inquiry. Using Chinese innovation policies as a starting point, this thesis qualitatively assesses the impacts and effectiveness of these policies at fostering innovation. It finds that on the one hand, Chinese efforts to increase activities that are consistent with innovative behavior are demonstrating some success. In particular, larger private technology firms have begun developing their own in-house research capability. Additionally, the development of an inquiry-based education system as well as the increased production of scientists and engineers could bode well for the future of Chinese research. On the other hand, China's splitting of the research and development roles between the education system and industry, respectively, has created bottlenecks in the supply of both knowledge and technologies crucial to the development of S&T innovation. This lag has prolonged China's reliance on exogenous sources of core technologies rather than developing an indigenous capacity to innovate.

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LIST OF ACRONYMS AND ABBREVIATIONS

CCP	Chinese Communist Party
CFIUS	Committee on Foreign Investment in the United States
CNKI	Chinese National Knowledge Infrastructure
FYP	five-year plan
GDP	gross domestic product
IPR	intellectual property rights
MIC2025	Made in China 2025
MNC	multi-national corporation
MLDP	Mid-to-Long Term Development Plan
NIS	National Innovation System
OECD	Organization for Economic Cooperation and Development
PCT	Patent Cooperation Treaty
PISA	Programme for International Student Assessment
R&D	research and development
S&T	science and technology
SOE	state-owned enterprise
STEM	science, technology, engineering, and mathematics
TFP	total factor productivity

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I. INTRODUCTION

Xi Jinping's ideal of national rejuvenation underpins China's ambitions to become a world leader in science and technology. Xi has acknowledged the superficial and shallow state of Chinese innovation capabilities, stating "We cannot always decorate our tomorrows with others' yesterdays."¹ Put differently, Xi's critique echoes a commonly held sentiment that Chinese firms either copy foreign technology or are brought to the frontier of technology through licensing and technology transfers, but do not have the capacity to indigenously develop their own core technologies. Given Xi and the Communist Party of China's (CCP) interest in self-reliance and advancing China toward becoming a scientific world leader, what are the national policies undertaken to foster S&T innovation and how have they shaped the state of innovation in China? This thesis studies how Chinese policy has influenced the advancement of scientific R&D in China.

This thesis finds that China has made some nascent progress toward fostering innovation, but the state-led innovation effort is far from self-sustaining and is inefficient because of how China has structured its institutions to undertake scientific research. China's national innovation system is split between two distinct sectors, each comprising a differing role in the advancement of science and technology in China. The industrial sector is responsible for developing technologies into marketable goods; this is certainly reflected in its industrial policy, which emphasizes marketization.² This emphasis on marketization has driven some Chinese firms to increase patent filings for process and manufacturing improvements as well as to produce new products and services, leading some observers to characterize Chinese firms as becoming innovative. The education sector is responsible for producing competent human capital and conducting basic and

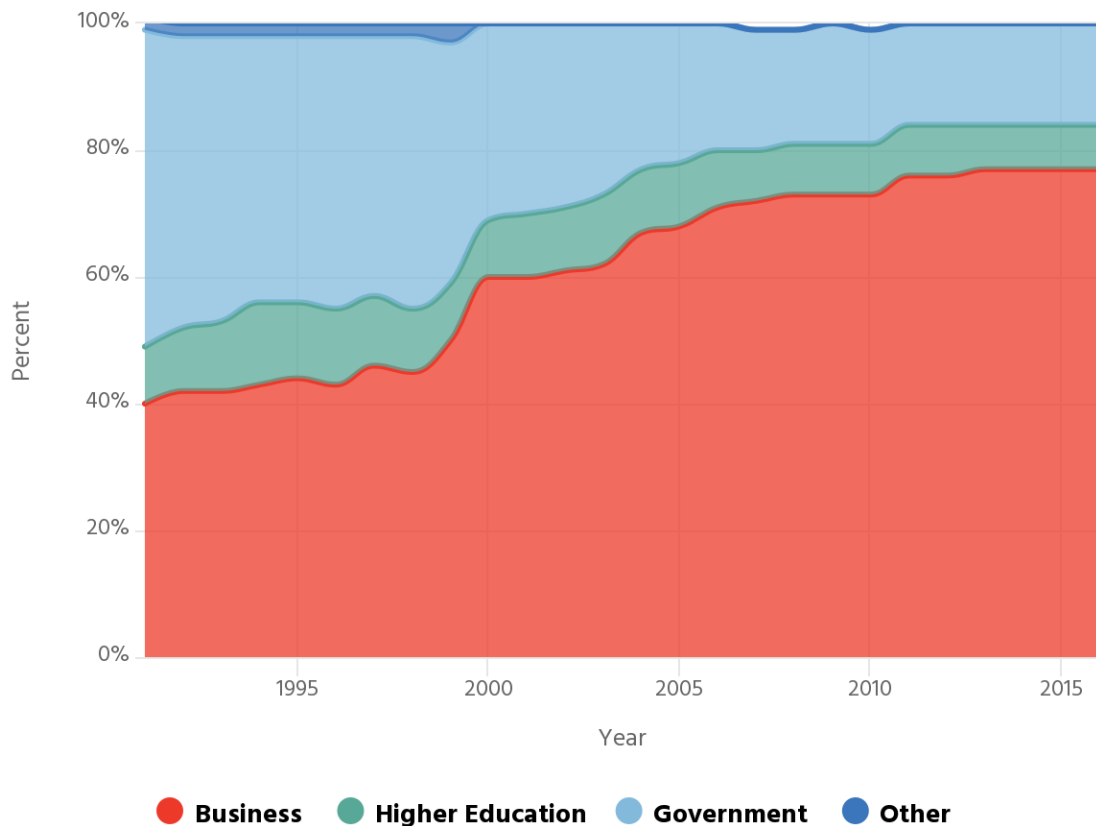
¹ Elizabeth Economy, *The Third Revolution: Xi Jinping and the New Chinese State* (Oxford: Oxford University Press, 2018), 123.

² Scott Kennedy, "The Fat Tech Dragon: Benchmarking China's Innovation Drive," 1, China Innovation Policy Series (Washington DC: Center for Strategic & International Studies, May 25, 2017), 23.

applied research.³ The progress made toward the implementation of a scientific inquiry-based education system and a retooling of universities to expand their research capacity provides the greatest source for optimism for Chinese innovation. Yet, while Chinese universities have made great strides toward becoming a world leading producer of research and publications, there is a lingering disconnect between the two sides of China's national innovation system.

This bifurcation of the innovation cycle leads to two notable dynamics that this thesis argues are salient to understanding Chinese innovation. First, because China is heavily reliant on Chinese universities and government-funded research institutes to bear the burden of research, the scale of China's research capacity is constrained by the flow of funding from government. Second, because China divides its research and development process between those two distinct sectors, its industrial sector has not built up an endogenous research capacity and is therefore largely reliant on outside core technology sourced either from the university research system and/or outside of China. While there are exceptions to this, as this thesis will discuss, the focus on product development and reliance on exogenously sourced core technology have made Chinese firms not very innovative. This is significant, because while the nominal amount of R&D funding for universities and research institutes has certainly increased, the percentage of the overall R&D funds being spent by the government has decreased, as shown in Figure 1. Simply put, because basic and applied research are so heavily concentrated in academia, which is government funded, there is both a disconnect between academia and industry as well as a supply shortage of invention and scientific discovery that keeps industry from being able to produce cutting-edge products that would be more materially evident of an increasingly innovative China.

³ Xielin Liu, Yubing He, and Peng Cheng, *Basic Research and Industrial Innovation in China*, vol. 2, Series on Innovation and Operations Management for Chinese Enterprise (Hackensack, NJ: World Scientific, 2019).



CSIS China Power Project | Source: OECD

Figure 1. Chinese R&D Expenditure by Sector⁴

A. SIGNIFICANCE

The state of innovation in China is significant for a few reasons. Volatility induced by the U.S.-China economic tensions has highlighted the perils of relying on external players to fuel domestic growth, and possible delinking creates an imperative for China to develop an independent domestic innovation capacity. Second, as China begins to shed its comparative advantage in low-cost goods, the CCP has sought to lean on innovation to fuel domestic economic growth. Finally, this hedge on innovation thus makes its success all the more crucial to bolster the CCP's legitimacy as China's ruling party.

⁴ Source: ChinaPower Team, "Is China a Global Leader in Research and Development?," ChinaPower Project, January 31, 2018, <https://chinapower.csis.org/china-research-and-development-rnd/>.

1. International Significance

The interplay between international politics and S&T innovation has become more apparent in recent years. The U.S.-China trade war has demonstrated that Chinese tech companies are vulnerable to U.S. leverage. From a developmental standpoint, evidence suggests that China continues to struggle to develop a globally competitive domestic S&T innovation apparatus, remaining reliant on the outside for its technology. On the other hand, China's ambitions to develop its innovation capabilities can be viewed as threatening toward the security interests of other nations, most notably the United States.

The trade war has highlighted how delicate Chinese companies can be when subjected to shock. The U.S. ban of semiconductor sales to Chinese telecommunications giant ZTE as well as the ban of sales of Huawei phones in the U.S. demonstrates that China is very reliant on U.S. technology for its tech products and vulnerable to U.S. leverage that could starve the Chinese tech manufacturing base of much needed technology and market access for its burgeoning tech corporations.⁵ Furthermore, tariffs on electronic consumer goods by the U.S. reinforced these shocks into the Chinese manufacturing base. Finally, the trade war not only highlighted the weakness of the current global supply chain but also hastened China's need to build its own supply chain and domestic R&D capacities that are more insulated from exogenous shocks.

The Chinese Communist Party (CCP) has long recognized China's weakness in relying on export-driven growth. Developmental plans such as the Medium-Long Term Plan (MLDP) and Made in China 2025 (MIC2025) emphasized indigenous innovation over technology transfers, and prioritized the principle of the development of dual-use

⁵ James Lewis, "Learning the Superior Techniques of the Barbarians: China's Pursuit of Semiconductor Independence," China Innovation Policy Series (Washington DC: Center for Strategic & International Studies, February 27, 2019), 6.

technologies—technologies capable of civilian and military uses.⁶ Yet, Chinese investment overseas in, for example, Silicon Valley tech start-ups not only may give access to foreign technology, but suggests that China still struggles to extricate itself from reliance on foreign innovation.⁷ On the other end, data highlighting the utility of patents originating from multinational corporations that collaborate with Chinese inventors, is greater than that of exclusive Chinese domestic inventors.⁸ This further reinforces a paradox that, as China seeks greater technological development and eventual self-reliance, it needs more foreign collaboration and integration to fuel its technological revolution.

On the other hand, as the relationship between the United States and China becomes increasingly competitive and antagonistic, Chinese investment in the U.S. companies is met with increasing distrust. Another facet of the MLDP prioritizes defense industries as key goals and have received very public support from top-level leaders such as Xi Jinping.⁹ Based on these stated objectives, Chinese interest in S&T development, whether bought or developed, can be perceived as threatening to outside observers. The build-up and/or proliferation of Chinese-made weapons composed of the technological capabilities of its chief competitors poses a threat to security interests of its competitors.

2. Domestic Significance

Broadly speaking, the slowing of the Chinese economy, which has grown at an average of 10 percent over the last 40 years, indicates a need for economic rebalancing.

⁶ Tai Ming Cheung et al., “Planning for Innovation: Understanding China’s Plans for Technological, Energy, Industrial, and Defense Development” (Berkeley: University of California Institute on Global Conflict and Cooperation, July 28, 2016), 48; FP Analytics, “Mining the Future: How China Is Set to Dominate the Next Industrial Revolution.,” *Foreign Policy Magazine*, accessed May 28, 2019, <https://foreignpolicy.com/2019/05/01/mining-the-future-china-critical-minerals-metals/>; Sean Randolph, Alice Bishop, and Sebastian Hamirani, “Chinese Innovation: China’s Technology Future and What It Means for Silicon Valley” (San Francisco, California: Bay Area Council Economic Institute, November 2017), <http://www.bayareaeconomy.org/report/chinese-innovation/>.

⁷ “Trump’s Trade War,” Online Video, *Frontline* (PBS, May 9, 2019), https://www.youtube.com/watch?v=4_xQ5JisFuo.

⁸ Andrew B. Kennedy, “China’s Innovation Trajectories,” *Survival* 60, no. 3 (May 4, 2018): 75, <https://doi.org/10.1080/00396338.2018.1470756>.

⁹ Cheung et al., “Planning for Innovation: Understanding China’s Plans for Technological, Energy, Industrial, and Defense Development,” 30.

China needs to shift away from economic growth that prioritizes capital accumulation while tolerating inefficiency to a more efficient economy that is based on S&T innovation. China's economic enrichment has priced it out of the manufacturing advantage it has enjoyed for the last 40 years, and total factor production (TFP) has decreased overall while China's national debt has ballooned thanks to capital-intensive infrastructure projects.¹⁰

Past Chinese growth trajectory was heavily reliant on exports for 30 years, but shifted toward infrastructure investment after the Global Financial Crisis. Although China did not experience a harsh recession, the global demand for Chinese goods sharply declined.¹¹ In response, the Chinese government loosened the reins on credit, leading banks to finance infrastructure building projects—projects that produce quick economic growth, but lead to diminishing returns over the long term.¹² The margins of capital accumulated will continue to decrease until this growth trajectory becomes untenable. Correspondingly, this slowing of growth is evidenced by the erosion of TFP since the global financial crisis, which peaked prior to the global financial crisis.¹³ Thus, there are two forces that have caused Chinese economy to slow. The first factor is the downturn in demand caused by the global financial crisis. The second factor is the response of easy financing for low yield investments that will accumulate debt faster than the economy can grow.

The need for fostering innovation is therefore an imperative for China's growth prospects. Because TFP continues to decrease, China needs to find ways that can minimize

¹⁰ Noah Smith, "China's Growth Machine No Longer Looks Unstoppable," *Bloomberg*, January 15, 2019, sec. Economics, para. 5, <https://www.bnnbloomberg.ca/china-s-growth-machine-no-longer-looks-unstoppable-1.1198902>.

¹¹ Arthur Kroeber, *China's Economy: What Everyone Needs to Know* (Oxford: Oxford University Press, 2016), 216.

¹² Smith, "China's Growth Machine No Longer Looks Unstoppable"; Lewis, "Learning the Superior Techniques of the Barbarians: China's Pursuit of Semiconductor Independence," 22.

¹³ Smith, "China's Growth Machine No Longer Looks Unstoppable"; Federal Reserve Bank of St. Louis, "Total Factor Productivity at Constant National Prices for China," Organization, FRED Economic Data, August 15, 2019, <https://fred.stlouisfed.org/series/RTFPNACNA632NRUG#0>; Nicholas Lardy, *The State Strikes Back: The End of Economic Reform in China?* (Cambridge: Peterson Institute for International Studies, 2019), 14; Li Ping, Wang Hongwei, and Zhang Jing, "China's S&T Reform and TFP over Past Four Decades of Reform and Opening-Up," *China Economist* 13, no. 1 (February 2018): 108, <https://doi.org/10.19602/j.chinaeconomist.2018.01.04>.

inputs resources (labor, capital, and energy) and maximize the outputs (value added), or else debt will continue to grow faster than the economic can.¹⁴ Additionally, as the age of the Chinese workforce increases and wages begin to price Chinese workers out of low-end manufacturing, the need to maximize the value added to the output makes innovation and technology, from both a process and output perspective, a necessity. Innovation and technology will help maximize efficiency and precision in production.¹⁵ Additionally, outputting technologically advanced and innovative goods and services will increase the value added. In this manner, S&T innovation-based growth will be a more sustainable growth trajectory that China needs to transition toward.

3. Political Significance

The CCP's enduring nature is notable in that many attributes its durability to a grand bargain with the Chinese people to act in their best interests. The bargain is somewhat akin to a “mandate of heaven” (天命) of imperial times which simply stated the legitimacy of the government was based on its ability to govern effectively.¹⁶ With this line of logic, the gradual liberalization of the Chinese economy since the 1980s has raised living standards and therefore entrenched the legitimacy of the CCP. Thus, as China's economy begins to slow today as a result of slowing productivity, the need to become innovative has become important to the CCP.

Innovation is politically significant because it highlights an underlying reason why it is top-down versus bottom up—legitimacy and regime survival. Social factors such as welfare, an aging society, and environmental concerns compound the problem of a slowing, less productive economy, and have led to fears that China may not be able to successfully transition its economy from a capital accumulation economy toward an efficient innovation-based economy.¹⁷

¹⁴ Cong Cao et al., “Reform of China's Science and Technology System in the Xi Jinping Era,” *China: An International Journal* 16, no. 3 (August 2018): 123.

¹⁵ Ping, Hongwei, and Jing, “China's S&T Reform and TFP over Past Four Decades of Reform and Opening-Up,” 108.

¹⁶ Kroeber, *China's Economy: What Everyone Needs to Know*, 260.

¹⁷ Cao et al., “Reform of China's Science and Technology System in the Xi Jinping Era,” 123.

There is abundant evidence to suggest that the CCP has taken an interest in innovation. The *MLDP*, published in 2006, indicates CCP recognition of the need to foster innovation well before the Global Financial Crisis, and demonstrates intent to foster innovation capabilities. *Made in China 2025* is designed to update manufacturing industry to leverage technology and improve China's manufacturing capabilities to accommodate the production of higher valued goods.¹⁸ Finally, the *13th Five Year Plan*, published in 2016, highlights the need to pursue innovation-driven development, devoting four chapters specifically on S&T innovation and establishing the foundational role innovation plays throughout the entire plan.¹⁹

B. LITERATURE REVIEW

The primary debate among academics whether Chinese innovation will succeed. Those who are optimistic emphasize quantitative evidence, such as an uptick in the numbers of scientific research publications, patent targets, or graduates in engineering and science. On the other hand, skeptics highlight structural and institutional factors that create drag on the efficiency of Chinese efforts to foster innovation. I begin the literature review begins with a discussion on the drivers of innovation—reasons that authors have highlighted for optimism. Then, I discuss various factors that impede innovation currently. Undoubtedly, as will be shown, the body of evidence presented by skeptics is more compelling than that of the optimists.

1. Drivers of Innovation

In general, authors who are optimistic about Chinese innovation talk about existing conditions that are favorable to fostering domestic Chinese innovation. The literature highlights three factors that indicate optimism. These include that the timing of reforms coincides with development of the mobile-based internet economy, top level interest in

¹⁸ Ma Huimin et al., “Strategic Plan of ‘Made in China 2025’ and Its Implementation,” in *Analyzing the Impacts of Industry 4.0 in Modern Business Environments* (Hershey, PA, USA: IGI Global, 2018), 1, <https://doi.org/10.4018/978-1-5225-3468-6.ch001>.

¹⁹ Central Committee of the Communist Party of China, “The 13th Five-Year Plan for Economic and Social Development of the People’s Republic of China” (Beijing: Communist Party of China, 2016).

S&T innovation, endowment of manufacturing capability, and the scale of population as reasons to be optimistic about innovation in China.

a. *Timing of Technological Leaps*

This theme posits that the structure of today's app-based economy places Chinese firms at the technological frontier. Shaun Rein argues that the relative parity across this sector creates opportunities for Chinese firms to be innovative and out innovate their American counterparts.²⁰ Specifically citing Chinese firms Alibaba, Baidu, and Tencent, Rein argues that the difference in timing and means in which the internet came into age between the United States and China means that while American users are oriented toward a computer-based internet, Chinese consumers' natural internet ecosystem is on mobile devices—predisposing them to be more adept at using and seeking app-based products. Correspondingly, the unrealized frontier of this sector has fostered a more innovative environment for Chinese firms and has led investors to gravitate toward more innovative start-ups rather than making a quick buck off firms looking to copycat Western businesses with Chinese characteristics.²¹

Rein's assertion is best used as a parable to argue that there are frontiers that favor Chinese innovation. The broad application of this point is that in emerging fields of science and technology, the Chinese have near parity with Western counterparts, and is developing in parallel rather than as a late-mover. Therefore, there is no copycatting but rather a need for innovation and invention. In conclusion, while many critics of Chinese innovation point to the lack of groundbreaking invention and findings, this factor, to a certain extent, refutes these arguments and highlights areas where the need to invent rather than innovate is less significant.

²⁰ Shaun Rein, *The End of Copycat China: The Rise of Creativity, Innovation, and Individualism in Asia* (New York: John Wiley and Sons, 2014), 77.

²¹ Rein, 77.

b. Top-Level Leadership Interest

A second factor highlighted to convey optimism for Chinese innovation is top-level leadership interest in S&T innovation. At the highest levels, it is clear that leaders like Xi Jinping recognize that efforts undertaken to foster innovation, thus far, have not yielded innovation independence. As quoted by Elizabeth Economy, Xi states, “Generally speaking, the foundation of our scientific and technological innovation is not solid enough; our independent innovation ability, especially in the area of original creativity is not strong.”²² At a broader level, the CCP explicitly ties innovation to its economic development model. The 13th Five-Year Plan is premised on S&T innovation and dedicates four chapters to addressing various factors of innovation.²³ Substantive data of action taken is in the uptick in R&D expenditure moving from 2.05 percent of GDP to 2.5 percent of GDP by 2020.²⁴ This is extremely significant because it signals an official CCP stance, aside from academic analysis, that innovation plays a key role going forward in Chinese economic development.

The CCP’s sanctioning of innovation is profound. Today, the salience of the U.S.-China trade war emphasizes the need for China to achieve innovation independence. Additionally, this pushes back on critical literature that suggests that the Chinese fundamentally misconceive what innovation is, and that their attempts to foster innovation are shallow and half-hearted. Xi’s own words articulate a clear vision of what innovation needs to be in China and make clear that it has yet to be achieved. The most important takeaway, however, is demonstrating a recognition of the government’s role in supporting and fostering innovation through institutional reform and investment, and the accompanying policies to do just that.

²² Economy, *The Third Revolution: Xi Jinping and the New Chinese State*, 123.

²³ Cao et al., “Reform of China’s Science and Technology System in the Xi Jinping Era,” 126.

²⁴ Economy, *The Third Revolution: Xi Jinping and the New Chinese State*, 123.

c. *Ease of Production and Marketization*

The literature highlights two existing endowments that favor Chinese innovation—localization of manufacturing capability and population. Ma et. al. indicates China has a complete manufacturing system—a factor that can help marketization of newly developed products and achieving economies of scale.²⁵ Flynn Murphy highlights how this co-location of research institutions, electronic hardware markets, and scalable manufacturers with excess capacity in Shenzhen makes electronic innovation and production extremely affordable and scalable for up-start inventors.²⁶ This kind of synergistic outcome has sparked China to attempt to build up the Pearl River Delta region into their own Silicon Valley to foster greater innovation development.²⁷

The population factor manifests in both the input and output side. On the input side, access to a large population of low-skilled labor accentuates the advantages offered by the manufacturing capabilities and “China now ranks first in the world in terms of S&T human resources and R&D personnel, accounting for 29.2 percent of the world total.”²⁸ On the flip side, Gan and Govindarajan as well as Ma et. al. highlight China’s large population as a plus as it gives fast, easy access to a large domestic market that is able to embrace newly developed products.

While many critics bash Chinese innovators for being unable to compete with foreign counterparts, this access to market demonstrates that the scale of the domestic market moderates the technological superiority a foreign competitor might have. Additionally, in the frontiers of electronics and artificial intelligence, the scale of the human capital in R&D and the ease access to electronic hardware allows China to sidestep

²⁵ Ma Huimin et al., “Strategic Plan of ‘Made in China 2025’ and Its Implementation,” 5.

²⁶ Flynn Murphy, “China’s Silicon Valley,” *Nature* 545 (May 17, 2017): S30, <https://doi.org/10.1038/545S29a>.

²⁷ Jie Gan and Vijay Govindarajan, “The Factors Behind China’s Growing Strength in Innovation,” *Harvard Business Review*, July 2, 2018, <https://hbr.org/2018/07/the-factors-behind-chinas-growing-strength-in-innovation>.

²⁸ Li Ping, Wang Hongwei, and Zhang Jing, “China’s S&T Reform and TFP over Past Four Decades of Reform and Opening-Up,” *China Economist* 13, no. 1 (February 2018): 96, <https://doi.org/10.19602/j.chinaeconomist.2018.01.04>.

the need for a global supply chain to achieve technological development and marketization of new products.

2. Skeptics of Chinese Innovation

The bulk of the literature overwhelmingly highlights reasons why Chinese innovation is being impeded. The authors' outlooks, however, range from there simply being impediments to the presence of structural challenges that must be overcome in order for innovation to succeed. Six factors are highlighted in this literature review.

a. Shaping of Innovation Norms

The literature suggests China still views itself as a developmental state. Due to its relative economic backwardness at the time of its economic reform and opening in 1978, it has been benefited from access to Western technology to catch-up with the West. This access has cut out the primary developmental processes of invention and allowed Chinese companies to take market-ready products and tailor them to Chinese consumers.

The literature is fairly consistent in how China's innovation development is characterized. Elizabeth Economy states, "Rather than adopting the traditional, and often time-consuming, Western method of research, testing, and validation, the Chinese will bring something to market and innovate based on consumer wants" and "China begins by licensing foreign technology or pursuing mergers and acquisitions to acquire desired technologies, and then innovating jointly with their new foreign partners."²⁹ This sentiment is reflected by authors such as Shaun Rein, Andrew Kennedy, and Arthur Kroeber, characterizing Chinese innovation as "efficiency-based innovation" and "adaptive innovation."³⁰

These characterizations lead to a couple of implications. The process as described by the authors indicate a difference in what Chinese perceive as innovation and how

²⁹ Economy, *The Third Revolution: Xi Jinping and the New Chinese State*, 124.

³⁰ Rein, *The End of Copycat China: The Rise of Creativity, Innovation, and Individualism in Asia*, 31; Kennedy, "China's Innovation Trajectories," 73; Kroeber, *China's Economy: What Everyone Needs to Know*, 64.

westerners characterize innovation. While all agree that Chinese are taking Western technology and adapting it for Chinese consumers, there is some difference in how the authors describe the next stage of innovation. Kroeber suggests that this process will lead to cloistered import substitution development.³¹ Rein, on other hand, suggests that the reason why domestic companies such as Alibaba, Baidu, and Wechat thrive is because of strong competition forcing these companies to be on the edge of the innovation frontier.³²

On the other hand, Economy and Kennedy both emphasize the role of investment both from the aspect of Foreign R&D Investment and Chinese investment abroad. Investment abroad buys access to the latest technology where the iterative innovation model can be applied. Foreign R&D investment often brings in research that allows both countries to access the intellectual property rights while reaping the benefits of lower labor costs of doing business in China.³³ While neither author speaks explicitly about this, they each identify the interconnected world as having a role in aiding developing China's innovation path, which begs the question of how crucial will the global economy be to supplementing China's growth in innovation in the future?

b. Funding Allocation

Investment is highlighted by a few sources, but not all as a factor affecting the efficacy of fostering innovation in China. Andrew Kennedy asserts that companies are not efficiently recapitalizing investments from patents by pointing to the lack of value being derived from newly developed products.³⁴ In other words, the commercial value and utility of Chinese patents is low. Both Kennedy and Elizabeth Economy state that government favoritism of state-owned enterprises and influence over the venture-capital industry create conditions in which investment funds neither are used as efficiently as they should be, nor are they appropriately allocated to achieve desired effect.³⁵ Scott Kennedy writes the types

³¹ Kroeber, *China's Economy: What Everyone Needs to Know*, 65.

³² Rein, *The End of Copycat China: The Rise of Creativity, Innovation, and Individualism in Asia*, 42.

³³ Kennedy, "China's Innovation Trajectories," 74.

³⁴ Kennedy, 72.

³⁵ Kennedy, 73; Economy, *The Third Revolution: Xi Jinping and the New Chinese State*, 149.

of investments these investors have generally undertaken are generally more conservative and spend very little on basic research and foundational technologies.³⁶ In other words, they focus more on things such as “new applications of products or new business models” rather than hedging on emerging “novel technologies.”³⁷

A similar trend on low basic science research can be seen on the government investment side as well. Cao et al. write “funds were mainly spent on equipment and often not enough were left for personnel.”³⁸ Gupta and Wang also talk about China’s 4 percent investment in basic science R&D is best spent on optimization of existing products rather than “developing ‘new to the world’ scientific ideas and technologies.”³⁹

In general, the literature hints that the late developer norms have shaped how investment has proliferated. Some authors emphasize the emergence of venture capital, while others emphasize the role of the government funded research in shaping investment priorities. This suggests that a difference in how authors view the role in shaping innovation; some see private investments and markets as having a greater role, while others see the government as a key influencer in shaping where frontiers in research should be.

c. Research Ecosystem

Another factor posited is that the research ecosystem incentivizes researchers to seek less risky research projects, falsify or plagiarize claims, and ultimately lessen the prospects of groundbreaking discoveries. Broadly, these incentives can be grouped into personal gains, corruption, and academic dishonesty. The result is that the ecosystem reinforces in poor practices and drags down innovation progress.

Personal gain is illustrated through policies to compel researchers to produce impactful research. While this is executed through policies governing research quality, it

³⁶ Kennedy, “The Fat Tech Dragon: Benchmarking China’s Innovation Drive,” 25.

³⁷ Kennedy, 25.

³⁸ Cao et al., “Reform of China’s Science and Technology System in the Xi Jinping Era,” 134.

³⁹ Anil Gupta and Haiyan Wang, “How China’s Government Helps— and Hinders — Innovation,” *Harvard Business Review*, November 16, 2016, para. 9, <https://hbr.org/2016/11/how-chinas-government-helps-and-hinders-innovation>.

has created a “publish or perish” research culture instead.⁴⁰ Cao et al. says, “The number of publications and impact factors in journals, in which the papers are published, have been used as the main criteria to evaluate researchers at universities and research institutes for promotion, tenure, and competition for talent programs.”⁴¹ Richard Appelbaum cites similar viewpoint on the evaluation system.⁴²

Corruption broadly explains how researchers respond to the system described above. Appelbaum and Han say that the bureaucratization of research funding allows for personal connections (*guanxi*) to influence how merit-based funding gets distributed to researchers and often trumps the authority of peer review system.⁴³ Rui Yang, speaking on academic culture in Chinese universities, states, “*guanxi* restricts free movement of staff, students and resources, and career advancement of faculty. Decision making is not based on academic merit, but personal relationships and preferential treatment.”⁴⁴ Cong Cao adds, “promotion has become a rent-seeking and rent-making opportunity for a small number of persons in the review panel who have power to partly determine the destiny of candidates.”⁴⁵ In essence, the S&T apparatus is not a meritocracy, but rather a system that rewards a privileged few for the process of research rather than the outcomes of research.

The result of this ecosystem is in spite of increases in absolute increases in scientific publications, the rates in which false science is published and discovered is also high. Andrew Kennedy remarks that China’s retraction rate of published articles is “more than twice as high as that of the United States.”⁴⁶ It suggests that Chinese science is really not

⁴⁰ Cao et al., “Reform of China’s Science and Technology System in the Xi Jinping Era,” 135.

⁴¹ Cao et al., 135.

⁴² Richard Appelbaum et al., *Innovation in China: Challenging the Global Science and Technology System*, China Today (Cambridge: Polity, 2018), 166.

⁴³ Xueying Han and Richard Appelbaum, “China’s Science, Technology, Engineering, and Mathematics (STEM) Research Environment: A Snapshot,” *PLoS ONE* 13, no. 4 (April 3, 2018): 2, <https://doi.org/10.1371/journal.pone.0195347>.

⁴⁴ Rui Yang, “Reassessing China’s Higher Education Development: A Focus on Academic Culture,” *Asia Pacific Education Review* 16, no. 3 (2015): 532.

⁴⁵ Cong Cao et al., “Reforming China’s S&T System,” *Science Magazine* 341, no. 6145 (August 2013): 461, <https://doi.org/10.1126/science.1234206>.

⁴⁶ Kennedy, “China’s Innovation Trajectories,” 78.

as advanced as the statistics claim it is. It also suggests that the research efficiency as a function of investment is low.

d. Patents and Intellectual Property Protection

Patenting is often highlighted as a quantitative metric of innovation, while intellectual property is often discussed as an institutional barrier to innovation. First, there seems to be a consensus in the literature stating that while the number of patent applications has skyrocketed, Chinese patenting standards are lower and produce lower utility patents. Second, the literature is generally skeptical of the Chinese legal system to resolve patent disputes and IP infringement cases satisfactorily.

(1) Patents

One incentive that has led to a spike in patenting in China is the first to file.⁴⁷ This incentive suggests that the potential exists for a lot of junk patents. Eric Warner states, “some patents have no technological or economic value, and many patents do not lead to follow-on innovation.”⁴⁸ Elizabeth Economy expresses similar sentiment, further expressing that these patents usually lead to process innovation.⁴⁹ Andrew Kennedy says, “In 2015, domestic firms in China derived 12% of their revenue from new products, while foreign-funded firms derived 19%”⁵⁰ Scott Kennedy states, “In 2015 only 39 percent of applications and 21 percent of approvals were for invention patents”⁵¹ Another reason cited is quantitative incentives. The 13th Five-Year Plan sets a goal of reaching 1.8 million patent applications by 2020.⁵² With promotions of government officials tied to meeting targets, it is possible that the Chinese will patent for the sake of patenting as opposed to

⁴⁷ Eric Warner, “Patenting and Innovation in China: Incentives, Policy, and Outcomes” (Dissertation, Santa Monica, CA, Pardee RAND Graduate School, 2014), 14, https://www.rand.org/pubs/rgs_dissertations/RGSD347.html.

⁴⁸ Warner, 3.

⁴⁹ Economy, *The Third Revolution: Xi Jinping and the New Chinese State*, 124.

⁵⁰ Kennedy, “China’s Innovation Trajectories,” 72.

⁵¹ Kennedy, “The Fat Tech Dragon: Benchmarking China’s Innovation Drive,” 28.

⁵² Gupta and Wang, “How China’s Government Helps— and Hinders — Innovation,” para. 10.

seeking scientific advancement.⁵³ The broad conclusion is that first to file hastens un inventive patent applications and is yet another reason why the innovation culture is oriented toward process optimization rather than invention.

(2) IP Protections

Weak institutions lead to low faith that the Chinese IP system will enforce protections conferred upon patented ideas. This leads to both researchers being discouraged from conducting their research in China, as well as companies being less able to recover their R&D investments.⁵⁴ These disincentives then are reinforced through other highlighted factors such as the type of research investors want to invest in, as well as the level of rigor that researchers want to undertake in their research.

Appelbaum’s description of the two IP resolution processes suggests opacity and poor construction.⁵⁵ On the administrative process, Appelbaum states that the local authorities, the arbitrators in this method, “lack the power and authority to award monetary damages. Additionally, they cannot impose sanctions on parties who fail to comply with injunctions.”⁵⁶ On the judicial process, Appelbaum posits that it, too, is weak because the monetary compensation is low, and courts engage in protectionist policies favoring local companies. Scott Kennedy also cites this fact, stating that the average reward in 2016 was RMB 98,000 (\$14,627).⁵⁷

Dan Prud’homme’s examination of legal barriers in IP courts reveals that the burden of proof in contesting IP infringement is difficult by design, citing the fact that arbitration courts only compare to a narrow range of “prior art” in considering utility patent infringement cases, do not assign proper weight to evidence stemming from patent filings,

⁵³ Peter Drahos and Wenting Cheng, *How China Built the World’s Biggest Patent Office – The Pressure Driving Mechanism*, vol. 49, 2017, 11, <https://doi.org/10.1007/s40319-017-0655-1>.

⁵⁴ Warner, “Patenting and Innovation in China: Incentives, Policy, and Outcomes,” 16.

⁵⁵ Appelbaum et al., *Innovation in China: Challenging the Global Science and Technology System*, 170.

⁵⁶ Appelbaum et al., 170.

⁵⁷ Kennedy, “The Fat Tech Dragon: Benchmarking China’s Innovation Drive,” 29.

and penalties generally lack the punitive impact to prevent future infringement.⁵⁸ In general, he points out that overt, public displays of infringement such as at trade fairs, “contribute to the perception that China’s IPR enforcement environment is less than desirable and thus in-effect somewhat hampers patent development and related innovation in China.”⁵⁹

These viewpoints suggest low confidence in the Chinese legal system, and reinforces other themes highlighted in the literature review. Most notably, one may wonder if the weak institutions are intentional as a means of protection for domestic firms over foreign competition. Finally, if this is, in fact, the case, is there then any incentive for the CCP to reform this system to foster more inventive research?

e. State-led Innovation

The CCP has been very insistent on state bureaucracy being a fundamental aspect to energizing development. While this factor is not broadly highlighted across the literature, examination of state bureaucracy reveals that it impedes resource allocation. Cao Cong highlights that the Ministry of Science and Technology (MOST) is not adequately constituted to coordinate lines of effort and advocate for proper budgeting, stating, “The MOST is only one ministry among many within the State Council...missions in S&T has been dispersed into many ministries or ministry level organizations within the State Council.”⁶⁰ In other words, there is no one ministry that oversees all aspects of innovation within the CCP or Chinese government leading to misallocation of resources.

This miscoordination is evidenced in Elizabeth Economy’s account of the Chinese electric car market development. MOST’s “ten cities, thousand vehicles” program sought to foster competition among ten cities for electric car infrastructure adoption. Economy remarked, “Local companies and grids developed compatibility that was not shared

⁵⁸ Dan Prud’homme, “Dulling the Cutting Edge: How Patent-Related Policies and Practices Hamper Innovation in China,” *European Union Chamber of Commerce in China*, December 18, 2012, 131–33, https://mpira.ub.uni-muenchen.de/43299/1/China_patent_innovation_study2012.pdf.

⁵⁹ Prud’homme, 135.

⁶⁰ Cao et al., “Reforming China’s S&T System,” 460.

through the rest of the country. Cars purchased in one city often could not use a charging station in another.”⁶¹ At the meso/regional level, there is no coordination or cooperation that demonstrates unity of national vision, and the practice of picking winners and losers as opposed to letting the market decide leads to zero-sum competition among regions.

The CCP’s efforts to foster pseudo-capitalism through subsidies and sanctioned competition highlights the inefficiencies of its distortions. The government, not the market, signals demand and inefficiently uses its resources, subsidies, to create false competition. James Lewis states, “Centrally-directed economies are less efficient in the allocation of resources.”⁶² Referencing the Chinese electric car experience, Economy echoes similar sentiment, stating, “Beijing’s willingness to accept suboptimal technological outcomes in order for Chinese firms to capture the market—as in the case of battery technologies—leads to significant waste of resources and inefficiencies.”⁶³ In conclusion, the bureaucracy’s improper allocation of resources as well as the broader pseudo-command economy contributes to strong impediments to innovation.

f. Education System

A final factor expressed in the literature is the efficacy of the Chinese education system in cultivating critical thinking and creativity in the engineers and scientists it produces. This is certainly in line with other incentives driving research and would be consistent with innovation outcomes that emphasize process or incremental improvement rather than invention. The main theme expressed is the lack of a free-thinking academic environment, with most of the debate emphasizing the de facto institutionalization of rote learning while another perspective suggests that it is illiberal state of Chinese society.

The emphasis on rote learning is thought to be an impediment because it fosters a focus on correct answers rather than cultivating creativity and understanding in theory and process. Citing its criticality to innovation, Richard Cooper states, “The education system,

⁶¹ Economy, *The Third Revolution: Xi Jinping and the New Chinese State*, 128.

⁶² Lewis, “Learning the Superior Techniques of the Barbarians: China’s Pursuit of Semiconductor Independence,” 22.

⁶³ Economy, *The Third Revolution: Xi Jinping and the New Chinese State*, 150.

with its emphasis on rote learning and single correct answers, is not conducive to extensive innovation.”⁶⁴ Rui Yang remarks that while universities have made progress in updating infrastructure and buying the latest lab equipment, universities will not foster a the proper learning environment unless they can shed deeply rooted cultural norms placing the utility of learning in advancement rather than “interest in seeking knowledge for its own sake.”⁶⁵

Scott Kennedy says, “Universities face a variety of social and political constraints in encouraging creativity and students have limited opportunities for genuine exploratory programs in science and technology.”⁶⁶ Elizabeth Economy echoes this, stating “A number of Western observers argue that this system of parallel governance with both educators and CCP officials ‘limits rather than enhances the flow of ideas.’”⁶⁷ This suggests that not only is the education system hamstrung by the lack of creativity thinking, it is further constrained by politically motivated forces that shape what is acceptable science. The combination of unwillingness to think freely and politically entrenched limits to free thought reinforces a cycle that makes the proliferation of free thought and ultimately innovation more difficult to achieve.

C. HYPOTHESES

1. Hypothesis 1: Given the Chinese government’s heavy reliance on western technology to provide a starting point for innovation, state policies reinforce an iterative innovation culture

This hypothesis posits that the paradigm that Chinese policymakers operate under are still reflective of late-movers, rather than developed nations. As many authors have noted, the innovation culture in China is iterative and is designed to tailor goods and services to the Chinese consumer rather than being driven by technological progress. In

⁶⁴ Richard Cooper, “Can China’s High Growth Continue?,” in *The China Questions: Critical Insights into a Rising Power*, ed. Jennifer Rudolph and Michael Szonyi (Cambridge: Harvard University Press, 2018), 125.

⁶⁵ Yang, “Reassessing China’s Higher Education Development: A Focus on Academic Culture,” 528.

⁶⁶ Kennedy, “The Fat Tech Dragon: Benchmarking China’s Innovation Drive,” 18.

⁶⁷ Economy, *The Third Revolution: Xi Jinping and the New Chinese State*, 141.

this vein, this hypothesis examines whether or not Chinese innovation policies have fostered iterative innovation and whether or not the Chinese government further entrenches this culture today.

2. Hypothesis 2: SOE-dominated innovation leads to poor resource allocation and inefficient return on investment

This hypothesis posits that state policies have doubled down on SOEs even as most authors contend that market forces need to take a greater role in the allocation of resources in order to become efficient enough for economic return. Furthermore, this hypothesis suggests that China is unlikely to develop an innovative culture because the nature of SOEs do not conform to the notion of needing to be financially efficient within their business models. Thus, by favoring companies that have no inherent motivation to think out of the box in order to survive, the CCP is effectively preventing itself from transitioning to an efficient market-based economy that can maintain sustainable growth and stimulate innovation without significant state intervention.

3. Hypothesis 3: Quantitative Target Policies leads to overcapacity in targeted sectors, which leads to inefficiencies

This hypothesis contends that while China has fostered innovation through quantitative targets, these efforts have created excess capacity that is not optimally allocated thereafter. This thesis will deal with investment into education, scientific research, and product development. In particular, this hypothesis posits that in spite of the increased output of scientists, engineers, targeted products, patents, and research publications, the resultant output is not effectively being utilized by industry and academic institutions to increase the pace of innovation.

4. Hypothesis 4: New frontiers of technology are allowing China to become a world leader in some areas of innovation in which they have the benefit of being a first starter

As the literature review highlighted, the advent of the internet to most Chinese was largely on mobile platforms and thus China is inherently predisposed to being on the

cutting edge of telecommunications technology and app development. This hypothesis posits that there are new frontier technological areas such as mobile platform development, AI, and genetics where China is leading the way in innovation. It contends that the mode and timing of how certain industrial sectors came to age in China as well their attractiveness toward investors have made China the focal point of innovation efforts going forward.

D. ORGANIZATION OF THESIS

Because China's national innovation system is organized into two entities—industry and university-research institutes, this thesis examines the distinct innovation policies pertinent to each entity. Chapter II examines Chinese industrial policy. It further subdivides industrial policy between the state sector and the private sector—first noting what the policies are for each sector, and then describing the effectiveness of innovation policy at getting Chinese firms to become innovative through the development of endogenous research capacities. Chapter III examines Chinese educational policy from compulsory education levels (primary and secondary) to higher education and research levels. Again, the format is similar—first examining the policies themselves and then characterizing their effectiveness at fostering innovation. Lastly, Chapter IV concludes by providing an assessment on the prospects of Chinese innovation going forward, offering potential actions that the Chinese government could take to more efficiently foster innovation, and examining the implications that Chinese innovation poses for US policy.

While many quantitative indicators exist at evaluating the innovativeness of a country, I've chosen to assess China on the basis of the qualitative development of research capacity. The data that I present is largely derived from reports and journal articles that explore the effectiveness of Chinese industrial and educational policies as well as a couple of books that explore sector-specific innovation outcomes. Within these articles, the characterizations of firm level behavior across sectors, case studies, descriptions of the direct effects of policies, as well as trend data on investments, publications, and production were the most substantial evidence in confirming my hypotheses. Another interesting observation while conducting my research is that much of the information published by Chinese state-sponsored sources or with ties to state entities tend to be make more

optimistic assessments and projections, while sources outside of the Chinese government tend to largely offer critical assessments of Chinese innovation. This difference manifests because Chinese sources highlight strengths and weaknesses that are evaluated against their policy goals. On the other hand, Western sources tend to use developmental state theory as the standard in which they are evaluating Chinese innovation progress. Overall, though, both sets of sources identify that the institutional set-up of China's innovation system creates drag on R&D processes, and this consensus makes Chinese sources worth using to yield a more balanced, nuanced understanding of China's innovation.

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II. INDUSTRIAL POLICY AND RESULTS

A. INTRODUCTION

The purpose of this chapter is to conduct a comparative study of the state innovation policies for SOEs and for the private sector to explore how the PRC is fostering innovation through industrial policy and how the approaches might differ between the two sectors given the differing baseline conditions of each sector. The PRC is extremely interested in S&T innovation as reflected in policy documents by the Central Committee and the State Council. These policy documents set quantitative targets to increase investment in R&D and increase the contribution to innovation.⁶⁸ Generally speaking, state sector innovation policies serve two functions in the sense that they seem to invoke more of a reform-oriented approach rather than a developmental approach towards spurring innovation, as well as placing emphasis in strategic industries that may either have enormous capital requirements or niche markets. Private sector innovation policies, on the other hand, emphasize prioritizing resources towards the developmental part of the research and development equation. The goal is thus towards the speedy development and marketization of commercial applications. Overall, Chinese industrial policy comes up short in fostering the development of in-house R&D capacity in firms of both public and private sectors which is necessary for firms to become indigenously innovative or in other words—self-sufficient from exogenous sources of core technology.

When it comes to research on this topic, there are generally two schools of thought. On the one hand, data provided primarily by Chinese sources suggests that Chinese policy are largely effective. In the state sector, they note the success of measures taken to increase SOE efficiency such as overhauling executive evaluation and the correlation between decreasing state equity and return on asset.⁶⁹ In essence, the argument is that policy to

⁶⁸ State Council of the People's Republic of China, "'13th Five-Year' National Science and Technology Innovation Plan," Government, Central People's Government of the People's Republic of China, July 28, 2016, http://www.gov.cn/zhengce/content/2016-08/08/content_5098072.htm.

⁶⁹ Minggui Yu, Huijie Zhong, and Rui Fan, "Will Performance Evaluation Boost SOE Innovation?," *China Economist* 12, no. 6 (2017): 100–113, <https://doi.org/10.19602/j.chinaeconomist.2017.06.08>.

increase the efficiency of the state sector has caused firms to become more innovative because revenues from new products and nominal investment in research and development have increased. In the private sector, the data suggests that the weak regulatory framework actually works to the advantage of tech start-ups and entrepreneurs by lowering barriers to entry and small businesses are flourishing.⁷⁰ Consequently, iterative innovation, a form of incremental product alteration that caters to demands of niche regional markets, is predominant because lower barriers allows for greater collaboration as well as collectivization of research and resources. As a result, the open innovation ecosystem is considered by China-leaning researchers to demonstrate that China is, in fact, becoming more innovative.

Certainly, there is some merit to how the iterative nature has helped to build some of China's largest and most successful companies such as Alibaba, Tencent, and DJI. However, I agree more with data indicating that Chinese efforts to spur innovation are very modest because the broader trend is that R&D tends to be under-resourced and undervalued by both public and private sectors. These sources note the very inefficient nature of China's top-down innovation system. In the state sector, state favoritism toward SOEs and state patronage system for national champions skews allocation of resources through preferential credit, first pick of China's talent, and expedient access to public resources through political connections.⁷¹ Furthermore, in spite of efforts to reform through diversifying ownership, these efforts do not improve the efficiency of SOEs to the level of a purely private enterprise. On the other end, the resource vacuum of SOEs leaves few alternatives for private firms leaving the private sector to seek low impact innovations out of necessity rather than deliberate decision. In particular, I find that resources are poorly distributed and poorly managed, knowledge diffusion efforts are ineffective because there are not many technologically advanced firms to receive knowledge from, and as a result of

⁷⁰ Jim Demuth, *Shenzhen: The Silicon Valley of Hardware*, Online Video, Documentary (WIRED, 2016), <https://www.youtube.com/watch?v=SGJ5cZnoodY&t=2128s>; George Yip and Bruce McKern, *China's Next Strategic Advantage: From Imitation to Innovation*, Kindle (Cambridge: MIT Press, 2016).

⁷¹ Appelbaum et al., *Innovation in China: Challenging the Global Science and Technology System*; Lardy, *The State Strikes Back: The End of Economic Reform in China?*; Douglas Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China's Technological Development* (Oxford: Oxford University Press, 2016).

the first two factors, few firms are establishing in-house R&D capabilities. Overall, I find this data to be more supportive of the assertion that neither state nor private sectors are feeling compelled to increase their emphasis on R&D as evidenced by the lack of Chinese firms that have seen any significant uptick in R&D investments. Correspondingly, I find that there is little activity that indicates significant development in the R&D capacity among firms except for a few large private tech firms with the requisite capital and corporate culture to dedicate R&D, which has proven fruitful.

I begin this chapter by first laying out my selection criteria for the policy which I examined. Next, I highlight themes that are present in central government and CCP innovation policy—first for SOEs and then the private sector. Finally, I discuss the outcomes of these policies, first on SOE then private sector, contrasting the range of foreign and Chinese opinions on Chinese S&T innovation.

B. METHODOLOGY AND SELECTION CRITERIA

Because this chapter is primarily focused on Chinese attempts to foster *indigenous innovation*, I will be evaluating Chinese innovation policy since 2012. This is for several reasons. First, since Xi Jinping has ascended to power, there has been a resurgent focus on state-led growth.⁷² Because this chapter is a comparative study of the state and private sector, this thus makes 2012 a good lower limit to scope my research. Secondly, it succeeds the global financial crisis which matters because it is a period that has been characterized by slowing economic growth. This has created some urgency in seeking reform policies to help foster innovation. Finally, this period can be characterized by the emergence of big tech in China. This includes the emergence of firms such as Alibaba, Baidu, Tencent, Xiaomi, and Huawei as national champions and/or key players in Chinese innovation. The emergence of these firms thus creates good context to understand the market mechanisms at work and how state policy leverages this ecosystem in their innovation policies.

To form the foundation of my policy research, I utilized a list of 19 national policy publications compiled by Chinese state researchers, which makes for a comprehensive

⁷² Lardy, *The State Strikes Back: The End of Economic Reform in China?*, 18.

list.⁷³ Further research beyond the below policies revealed while there may be more policies that speak to S&T innovation in China, these 19 documents express all of the major strategies pursued by the Chinese government to foster innovation. A list of these documents is listed in Table 1.⁷⁴

Table 1. S&T Innovation Policy 2012–2017.⁷⁵

S&T Policy and Measures	Reform Objectives
1. In 2012, the CPC Central Committee and the State Council issued the <i>Opinions on Deepening Institutional Reforms of Science and Technology and Expediting the Development of a National Innovation System</i>; 2. In 2012, the Report of the 18th CPC National Congress established an innovation-driven development strategy, calling for “deepening institutional reform of science and technology, integrating technology with the economy, and creating a market-oriented innovation system with enterprises as the backbone”; 3. In 2013, the State Council General Office issued the <i>Opinions on Enhancing the Status of Enterprises to Be the Backbone of Innovation</i>; 4. In 2013, the Third Plenary Session of the 18th CPC Central Committee adopted the <i>Decisions of the CPC Central Committee on Key Matters Concerning the Comprehensive Deepening of Reforms</i> (“Decisions”); 5. In 2015, the CPC Central Committee and the State Council issued the <i>Opinions on Deepening Institutional Reforms and Implementing an Innovation-Driven Development Strategy</i> (“Opinions”); 6. In 2015, the 93rd Executive Meeting of the State Council adopted the <i>Opinions on Promoting the Policy Measures of Mass Entrepreneurship and Innovation</i> (“Opinions on Mass Entrepreneurship and Innovation”); 7. In 2015, the Fifth Plenary Session of the 18th CPC Central Committee adopted the <i>Suggestions on the Formulation of the 13th Five-Year Plan for National Economic and Social Development</i>; 8. In 2016, the CPC Central Committee and the State Council issued the <i>Outline of National Innovation-Driven Development Strategy</i> (hereinafter “Outline of Innovation Strategy”); 9. In 2016, the State Council General Office issued the <i>Notice of the State Council General Office on the Promulgation of the Action Plan for the Transfer and Transformation of Scientific and Technological Results</i>;	To call for implementing an innovation-driven development strategy; to identify the objectives of S&T reform and to conduct top-level designs of reform. Reform priorities include macro-regulation, technological resources allocation and innovation, production education-research cooperation and R&D commercialization, attraction and cultivation of innovators and entrepreneurs, as well as innovation incentives and risk dispersion. To depict a blueprint for improving China’s national innovation system and innovation ecosystem and “turn China into an innovation-based country

⁷³ Ping, Hongwei, and Jing, “China’s S&T Reform and TFP over Past Four Decades of Reform and Opening-Up,” 94.

⁷⁴ Although the Medium-Long Term Development Plan (MLP or MLDP) is perhaps the foundational policy document, which discusses indigenous innovation, I have chosen to omit it because the execution of its initiatives falls outside the window which I am investigating. Although the 13th FYP is cited in the policy section, I do not go into in-depth analysis of the 13th FYP, 13th Science and Technology Five Year Plan, or Made in China 2025 because these are largely a statement of goals rather than a discussion of strategies and tactics.

⁷⁵ Source: Ping, Hongwei, and Jing, “China’s S&T Reform and TFP over Past Four Decades of Reform and Opening-Up,” 94.

S&T Policy and Measures	Reform Objectives
10. In 2016, the State Council General Office issued the <i>Implementing Opinions on the Development of Demonstration Bases for Mass Entrepreneurship and Innovation</i>; 11. In 2016, the State Council General Office issued the <i>Notice on Promulgating the Plan for the Division of Work for Key Tasks under the Opinions of the State Council on Invigorating the Country through Intellectual Property Rights in the New Situation</i>; 12. In 2016, the State Council released the <i>Notice of the State Council on Promulgating the 13th Five-Year Plan for National Science and Technology Innovation</i>; 13. In November 2016, the General Office of the CPC Central Committee and the State Council General Office released the <i>Opinions on Implementing the Distribution Policy with the Orientation to Increase the Value of Knowledge</i>; 14. In 2017, the State Council released the <i>Notice of the State Council on Promulgating the 13th Five-Year Plan for National Intellectual Property Rights Protection and Use</i>; 15. In 2017, the State Council General Office released the <i>Notice of the State Council General Office on Promulgating the Overall Plan for the Pilot Reform of Integrated Intellectual Property Rights Management</i>; 16. In 2017, the State Council released the <i>Notice of the State Council on Promulgating the Opinions of the NDRC on Deepening the Priority Tasks of Economic Institutional Reform in 2017</i>; 17. In 2017, the State Council General Office released the <i>Notice of the State Council General Office on Promulgating the Scheme for Deepening Reforms of the Scientific and Technological Incentive System</i>; 18. In 2017, the State Council General Office released the <i>Implementing Opinions on Developing the Second Group of Mass Entrepreneurship and Innovation Demonstration Bases</i>; 19. In 2017, the State Council released the <i>Opinions of the State Council on Implementing an Innovation-Driven Development Strategy and Further Promoting Mass Entrepreneurship and Innovation</i>.	by 2020 and a leading nation of science and technology by 2050”.

C. POLICY OVERVIEW

PRC innovation policy since 2012 has focused on increasing the innovative capacity of China through the development of indigenous innovation. This involves increasing access to resources, improved incentives, and an increased focus on developing R&D capacity. This approach is bifurcated; on the one hand, it involves decreasing the state sector’s dominance to enable more balanced distribution of resources, while on the other hand, it involves lowering barriers for the start-ups and private firms to be able to innovate. The grand vision is thus a market-oriented innovation apparatus where a state sector exists to supplement areas where the market does not signal demand. This section highlights themes that are repeatedly seen across various policy documents. It proceeds by first highlighting SOE policy followed by private sector policy.

1. SOE Policy

Broadly speaking, SOE innovation policies are reform policies undertaken to foster a more suitable environment for innovation to succeed. The policy highlights mixed ownership, integration of SOEs into capital markets, development of evaluation systems for SOE executives, and defining the role of SOEs within the innovation system as broad categories or themes. This policy prescription for SOEs suggests two things. First, the state sector is not going away any time soon, and, second, China is attempting to use the state sector to undertake its longer-term, capital intensive research where risk can be blunted by the support of the state.

A prerequisite to foster SOE innovation as outlined in the CCP policy guidance is to reform the behavior of SOEs toward more corporate-like behaviors through mixed ownership and construction of incentives to foster innovation.⁷⁶ The basic idea is to introduce other ownership stakes and decrease the state's stake in SOEs, creating a broader set of interests than the state's objectives. The envisioned idea is that the private stake in the company should impose some measure of corporate responsibility rather than the overwhelming preference that the political stake outweighs the corporate stake. The remaining state ownership stake should still retain the ability to utilize the resultant company's resources for politically necessary purposes.

Getting SOEs to look like private firms is a logical first step, and leveling the playing field between the state and private sectors is an important second step. In doing so, the state has targeted a de facto SOE lifeline—preferential credit. Chinese policy voices ambitions of getting SOEs to stop relying on state funding, and rely more on the market to

⁷⁶ Central Committee of the Communist Party of China, "Decision of the Central Committee of the Communist Party of China on Several Major Issues Concerning Comprehensively Deepening Reform," Government, Central People's Government of the People's Republic of China, November 15, 2013, sec. 2, http://www.gov.cn/jrzq/2013-11/15/content_2528179.htm.

facilitate greater efficiency.⁷⁷ One way of interpreting this type of policy is that it is another way of getting SOEs to behave more like private firms, but another interpretation of this is that it is designed to allow private firms greater access to the same resources through fairer competition.⁷⁸

Although Chinese policy focuses heavily on SOE reform, some attention is given toward incentivizing innovation. One effort emphasizes the need to create proper incentives to ensure that at the firm level and individual level, contributors are rewarded for their contributions toward research.⁷⁹ Another line of effort is focusing on the evaluation mechanism to properly incentivize innovative behavior as well as a focus on R&D investment⁸⁰ Chinese policy also identifies the need to have a system that properly captures value of initiative and risk taking but tolerates failure.⁸¹ These steps are important because they attack the lack of SOE interest in R&D. A commitment to developing breadth and depth in R&D will be the key to adding value to innovation outcomes.

The final theme highlighted is defining the envisioned role of SOEs. The 13th FYP clearly defines a role that moves away from providing a social or public good toward a more strategic commanding heights role which is consistent with the logic of maintaining

⁷⁷ Bank of China Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Finance, Ministry of Commerce, China Banking Regulatory Commission, “八部委印发《关于金融支持工业稳增长调结构增效益的若干意见》[Eight Ministries and Commissions Issued ‘Several Opinions on Financial Support for Industrial Stable Growth and Adjustment Structure’],” Government, 上海市通信管理局【Shanghai Communications Administration】, February 19, 2016, para. 12, http://shca.miit.gov.cn/html/Item_168/info_1769.html.

⁷⁸ Central Committee of the Communist Party of China, “Several Opinions of the CPC Central Committee and the State Council on Deepening the Reform of System and Mechanism and Accelerating the Implementation of Innovation-Driven Development Strategy,” Government, Central People’s Government of the People’s Republic of China, March 23, 2015, sec. 4, http://www.gov.cn/xinwen/2015-03/23/content_2837629.htm.

⁷⁹ Central Committee of the Communist Party of China, sec. 5.

⁸⁰ Central Committee of the Communist Party of China, “The Central Committee of the Communist Party of China Issued the Outline of the National Innovation Driven Development Strategy,” News, Xinhua.net, May 9, 2016, sec. 5, http://www.xinhuanet.com/politics/2016-05/19/c_1118898033.htm.

⁸¹ Central Committee of the Communist Party of China, “Several Opinions of the CPC Central Committee and the State Council on Deepening the Reform of System and Mechanism and Accelerating the Implementation of Innovation-Driven Development Strategy,” sec. 9.

them but shaping them to be more efficient.⁸² This is supported by other policy, which expresses a desire for SOEs to focus on the key areas of market deployment where resources cannot be effectively allocated.⁸³ This suggests that SOEs still serve a role that can service the economy, and sectors where starting capital requirements are extremely high such as the aerospace industry are areas where SOEs can serve some benefit for fostering innovation.

2. Private Policy

In contrast to SOE innovation policy, which is about restraining and scaling down SOEs, private sector innovation policy is about promoting the role of small private firms in fostering innovation. Many documents stress the need for the market to play a dominant role in resource allocation.⁸⁴ For private enterprises and entrepreneurs, the CCP's strategy for fostering innovation is largely about setting favorable conditions for small and medium enterprises (SMEs) to thrive by leveling the playing field with SOEs.⁸⁵ The strategy is notable because many recent policy documents note the need for “double creation [双创]” or the need to rely on both entrepreneurship and innovation in order to facilitate a successful transition from high speed growth to high quality growth.⁸⁶ This suggests that it is not necessarily the cutting edge innovation that China is after, but the requisite market conditions which will force efficiency and iteration that will eventually over the long term drive innovation. The relevant themes of private sector innovation policy are the increased

⁸² Central Committee of the Communist Party of China, “The 13th Five-Year Plan for Economic and Social Development of the People’s Republic of China,” chap. 11.

⁸³ Central Committee of the Communist Party of China, “Several Opinions of the CPC Central Committee and the State Council on Deepening the Reform of System and Mechanism and Accelerating the Implementation of Innovation-Driven Development Strategy,” sec. 3.

⁸⁴ Central Committee of the Communist Party of China, “Decision of the Central Committee of the Communist Party of China on Several Major Issues Concerning Comprehensively Deepening Reform,” sec. 1.

⁸⁵ Central Committee of the Communist Party of China, “Several Opinions of the CPC Central Committee and the State Council on Deepening the Reform of System and Mechanism and Accelerating the Implementation of Innovation-Driven Development Strategy,” sec. 2.

⁸⁶ State Council of the People’s Republic of China, “State Council on Promoting the High-Quality Development of Innovation and Entrepreneurship Opinions on Creating an Upgraded Version of ‘Double Creation,’” Government, Central People’s Government of the People’s Republic of China, September 18, 2018, sec. 1, http://www.gov.cn/zhengce/content/2018-09/26/content_5325472.htm.

institutionalization of the IPR protection system, introducing more financial incentives through tax breaks and more comprehensive investment support.

First, there is a recognized need for an improved intellectual property protection system. One line of effort calls for fixing arbitration methods through the establishment of a more credible court system capable of adjudicating civil, criminal, and administrative types of IPR cases, as well as mechanisms to break local protectionism in courts of IPR offenders.⁸⁷ Another line of effort is to shorten the time horizon from patent application to confirmation which is useful for small-scale innovators trying to get a product from development to market quickly.⁸⁸ A notable initiative is developing patent insurance to help protect inventors against infringement losses of royalties.⁸⁹ It goes without saying that the weak institutional capacity to enforce IPR protections makes this type of reform the low hanging fruit to foster innovation for the private sector, as IPR protections are likely to be a bigger deal for private firms than larger SOEs that enjoy the clout of government support and softer budgetary constraints.

Given that private firms do not enjoy the ease of access to state coffers, policies also call for the construction of more finely targeted financial incentives designed to make conducting research easier and more valuable. Chinese policy takes two tactics. First, tax breaks increase incentives to invest in research.⁹⁰ One policy put forth seeks to reward venture capitalist for investing in unlisted high-tech small and medium sized enterprises

⁸⁷ Central Committee of the Communist Party of China, “Several Opinions of the CPC Central Committee and the State Council on Deepening the Reform of System and Mechanism and Accelerating the Implementation of Innovation-Driven Development Strategy,” sec. 2.

⁸⁸ State Council of the People’s Republic of China, “State Council on Strengthening the Implementation of Innovation-Driven Development Strategy Opinions on Further Promoting the in-Depth Development of Mass Entrepreneurship and Innovation,” Government, Central People’s Government of the People’s Republic of China, July 21, 2017, sec. 2, http://www.gov.cn/zhengce/content/2017-07/27/content_5213735.htm.

⁸⁹ General Office of the State Council, “The General Office of the State Council on the Promotion of the Second Batch Notice to Support Innovation-Related Reform Initiatives,” Government, Central People’s Government of the People’s Republic of China, December 23, 2018, sec. Annex 1, http://www.gov.cn/zhengce/content/2019-01/08/content_5355837.htm.

⁹⁰ State Council of the People’s Republic of China, “State Council’s Opinion on Vigorously Promoting Mass Entrepreneurship and Innovation in a Number of Policies and Measures,” Government, Central People’s Government of the People’s Republic of China, June 11, 2015, sec. 4, http://www.gov.cn/zhengce/content/2015-06/16/content_9855.htm.

(SMEs) by awarding tax holidays for investing for a duration of at least two years.⁹¹ Other tax breaks mentioned are designed for researchers themselves. Broad categories of expenses including enterprise labor, direct inputs, depression expenses, licensing fees, trial fees, and application/registration fees are eligible for tax deduction.⁹² Cumulatively, these tax breaks represent a concerted effort to move the incentive emphasis from shareholders, profit, and balance sheets, and focus on increasing investment in more robust research and development.

Second, the Chinese government support private firms through risk reduction which increases the time horizon of financing mechanisms.⁹³ The short time horizon which is the norm of financing in China leads to risk averse choices from the investors as well as researchers. To rectify this, two initiatives from a 2018 policy document describe “comprehensive life cycle financial service [全生命周期金融综合服务]” and promoting “fault tolerance [容错机制]” in equity funds.⁹⁴ Another monetary incentive put forth is innovation vouchers which is simply subsidization of SME costs to locate its operations at science parks and other innovation hubs.⁹⁵ Science parks are thought to help lower the costs for innovation and facilitate the diffusion of knowledge through the co-location of collaborating researchers, co-location of universities and research institutes, developmental

⁹¹ State Taxation Administration, “Announcement on Issues Related to Corporate Income Tax for Corporate Partners in Limited Partnerships,” Government, State Taxation Administration, November 16, 2015, para. 4, <http://www.chinatax.gov.cn/n810341/n810755/c1919741/content.html>; Ministry of Finance, “Notice on Pilot Policies on Venture Capital Enterprises and Angel Investment Individuals,” Government, Ministry of Science and Technology of the People’s Republic of China, April 28, 2017, sec. 1, http://www.most.gov.cn/mostinfo/xinxifenlei/fgzc/gfxwj/gfxwj2017/201705/t20170503_132604.htm.

⁹² Ministry of Finance, “Notice of the Ministry of Finance and the Ministry of Science and Technology of the State Administration of Taxation on Improving the Pre-Tax Deduction Policy for Research and Development Expenses,” Government, Ministry of Science and Technology of the People’s Republic of China, November 5, 2015, sec. 1, http://www.most.gov.cn/kjzc/gkjzc/kjjryss/201511/t20151105_122282.htm.

⁹³ State Council of the People’s Republic of China, “State Council on Strengthening the Implementation of Innovation-Driven Development Strategy Opinions on Further Promoting the in-Depth Development of Mass Entrepreneurship and Innovation,” sec. 3.

⁹⁴ General Office of the State Council, “The General Office of the State Council on the Promotion of the Second Batch Notice to Support Innovation-Related Reform Initiatives,” sec. Annex 1.

⁹⁵ State Council of the People’s Republic of China, “State Council on Strengthening the Implementation of Innovation-Driven Development Strategy Opinions on Further Promoting the in-Depth Development of Mass Entrepreneurship and Innovation,” sec. 3.

operations, and manufacturing operations.⁹⁶ Overall, this is another effort to curb perverse incentives and make investing in R&D more of a given and less of a choice for capital challenged private firms.

D. POLICY RESULTS

This section highlights the range of assessments on how successful Chinese policy is at achieving the outcomes the set forth in their policies. Generally, I find that Chinese authors are inclined to emphasize the successes with nuanced critiques while many but not all outside authors tend to emphasize the institutionalized barriers to innovation. There are some reforms that have been enacted which demonstrate qualitative trends of fostering innovation, but it is still too early to say, quantitatively, if they are having an impact on S&T innovation. Overall, although both sectors are having some level of success at micro level reforms and process innovations, I find that there is no structural realignment of resources and no shift in focus toward substantive R&D suggesting that Chinese innovation policy is not truly fostering innovation. There is also a debate on what constitutes innovation. On the one hand, process improvement that improves the manufacturing efficiency or efficiency of use for the end user of a product is considered by some to be innovative, while others use the term innovation synonymously with invention which would impose a higher standard for evidence of innovation. Based on the intent of Chinese policy which calls for self-reliance, I tend to side with the latter definition which leads a more bearish outlook on Chinese innovation. I proceed by first discussing the range of opinions on SOE reform policy, followed by discussing the range of opinions for private-sector policies.

1. SOE Outcomes

The approach of SOE innovation policy is to achieve greater operating efficiency through mixed ownership and corporate accountability which is intended to make more capital available to dedicate towards research and development (i.e. innovative activities). In essence, SOE innovation policy could be thought of as SOE reform policy as well.

⁹⁶ State Council of the People's Republic of China, sec. 3.

Though this approach is not exclusively an innovation policy, it is a prerequisite to China's top-down innovation strategy if China expects SOEs to bear the burden of basic research and making scientific breakthroughs that may have not have immediate commercial application. Therefore, if China's goal is to create a self-sustaining indigenous S&T innovation base, it must find a way to impose discipline and a corporate mindset upon SOEs. I find two differing interpretation of the results. First, some analysts who have focused on the successes note that mixed ownership of SOEs has netted some uptick in efficiency and that SOE executive evaluation overhauls have increased the efficiency of SOEs. These analysts infer that Chinese firms are becoming innovative based on increasing returns on newly produced intellectual property and these trends are a result of reform policies that impose discipline upon SOEs. However, I tend to agree with bearish authors who highlight that the spikes in investment of the last ten years has further entrenched SOEs, who in spite of some efficiency gains, maintain in their state-favored positions and continue to lag in the substantive development of true R&D capacities. I first discuss the optimistic perspectives and then discuss the pessimistic perspectives.

a. *Optimistic Perspectives*

Generally speaking, some data, mostly published by Chinese researchers, indicates that SOEs are becoming more efficient and innovative. To begin, data shows that by the end of 2018, 66 percent of subsidiaries under central SOEs and 47 percent of provincial SOEs and their subsidiaries had achieved mixed ownership.⁹⁷ The evidence linking the correlation between privatization of SOEs and innovation is far from comprehensive, but does suggest that privatization is consistent with theory claiming that privatization of SOEs or imposing some level of corporate governance would create more efficiency and therefore more innovation. First, to measure efficiency, one study examined the differences between return on investment of firms that had always been private, firms that had been

⁹⁷ Zoey Ye Zhang, "China's SOE Reforms: What the Latest Round of Reforms Mean for the Market," *China Briefing*, May 29, 2019, para. 39, <https://www.china-briefing.com/news/chinas-soe-reform-process/?hilit=%27SOE%27>; Huang Qunhui, "How 'New SOEs' Come of Age: Four Decades of China's SOE Reform," *China Economist* 13, no. 1 (2018): 76, <https://doi.org/10.19602/j.chinaeconomist.2018.01.03>.

privatized, and SOEs.⁹⁸ The results are shown in Figure 2. Although the performance of former SOEs is not nearly as comparable to that of private firms, the relative improvement over SOEs supports the theory that reform or privatization will lead to a slight increase in efficiency. Data of patent stock from 2000–2011 demonstrated that privatization led to a significant increase in the patent stock in the five years after privatization and private firm patents were cited more internationally, but these trends were also subject to the quality of IPR protections afforded in the city in which these firms were located meaning that more globally exposed cities are likely to have more robust IPR protections as opposed to more insulated cities further inland.⁹⁹ While patent stock might well have increased, there is no context provided to suggest how this uptick compares to private domestic firms.

Figure 2 compares the return on asset rate among three differing categories of enterprises.

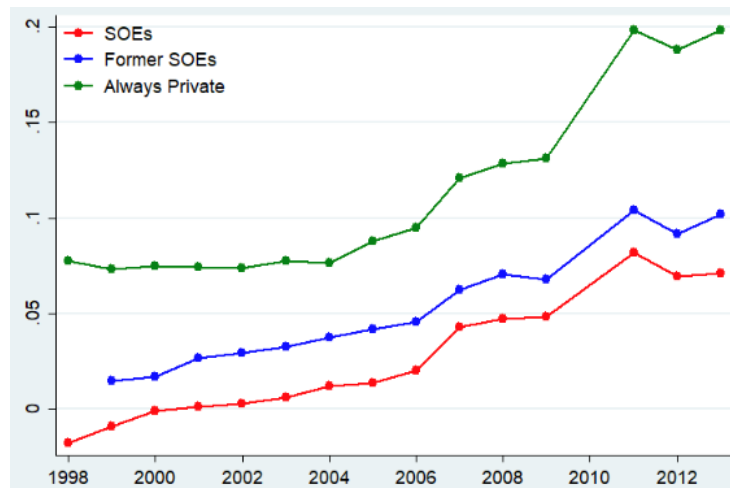


Figure 2. Return on Asset Invested¹⁰⁰

⁹⁸ Ann Harrison et al., “Changing the Tiger’s Stripes: Reform of Chinese State-Owned Enterprises in the Penumbra of the State,” Non-governmental organization, Center for Economic and Policy Research, April 7, 2019, <https://voxeu.org/article/reform-chinese-state-owned-enterprises-penumbra-state>.

⁹⁹ Lily H. Fang, Josh Lerner, and Chaopeng Wu, “Intellectual Property Rights Protection, Ownership, and Innovation: Evidence from China,” *The Review of Financial Studies* 30, no. 7 (2017): 5, <https://doi.org/10.1093/rfs/hhx023>.

¹⁰⁰ Source: Harrison et al., “Changing the Tiger’s Stripes: Reform of Chinese State-Owned Enterprises in the Penumbra of the State.”

Other Chinese data shows similar results. One data set found that by achieving mixed ownership, the innovation efficiency of the “hybrid” firm improved and exceeded that of foreign firms to include firms from Hong Kong and Macao as well as private firms.¹⁰¹ Specifically, the measure of innovation efficiency used by this study was calculated by the ratio of new product sales revenue and total sales revenue for a given year.¹⁰² This is problematic, as the private policy section will show, because the bulk of Chinese innovations are process innovations and utility patents which have lower standards for originality than invention patents.¹⁰³ Thus, one should interpret this data with skepticism. Other data suggests that overhauling the evaluation system in which SOE executives are rated on has led to increased innovation efficiency as well.¹⁰⁴ By analyzing a change in evaluation criteria in which SOE executives are evaluated on from *return on asset* to *economic value added*, central SOE’s level of innovation, as measured by patent output, improved suggesting that this may be a viable alternative to SOE privatization.¹⁰⁵ This set of data provides, in my opinion, the most compelling evidence yet that a SOE reform initiative is working. Indeed, the State-owned Assets Supervision and Administration Commission (SASAC), charged with overseeing SOEs, has latched onto the idea of evaluation overhaul and introduced further measures to report R&D investment as profit for SOE executives.¹⁰⁶ The ultimate implication of these results is that Chinese leaders are looking for politically tenable and expedient ways to avoid massive upheavals that would uproot many political interests while maintaining the intent of innovation policy in these reforms.

¹⁰¹ Wang Yewen and Chen Lin, “An Empirical Research on Mixed-Ownership Reform and SOE Innovation: Evidence from China’s Industrial Enterprises,” *China Economist* 13, no. 3 (2018): 51, <https://doi.org/10.19602/j.chinaeconomist.2018.05.04>.

¹⁰² Yewen and Lin, 45.

¹⁰³ China Power Team, “Are Patents Indicative of Chinese Innovation?,” Non-governmental organization, China Power, February 15, 2016, paras. 14–15, <https://chinapower.csis.org/patents/>.

¹⁰⁴ Yu, Zhong, and Fan, “Will Performance Evaluation Boost SOE Innovation?”

¹⁰⁵ Yu, Zhong, and Fan.

¹⁰⁶ Xinhua, “China Renews Evaluation Methods for SOE Leaders,” *Xinhuanet.Com*, March 10, 2019, para. 5, http://www.xinhuanet.com/english/2019-03/10/c_137883868.htm.

b. *Skeptical Perspectives*

Contrary to the optimistic data suggesting that SOEs are becoming very innovative, I contend that SOE reforms are neither imposing efficiency nor contributing to S&T innovation. Four points illustrate this assertion. First, mixed ownership does not lead to private sector-like behavior. Second, institutional capacity is weak to regulate self-interested behavior of mid-level bureaucrats colluding with local officials. Third, this collusion leads to resource misallocation, and, fourth, it creates avenues for state patronage which stifle SOEs' proclivity for R&D.

The way in which mixed ownership have been executed refutes the argument that mixed ownership will impose discipline upon SOEs. Four points comprise this argument. The first is that equity diversification simply increased the number of shareholders, but did not add diversity of ownership.¹⁰⁷ The implication here is that the diversity of shareholder is meant to form a broader coalition of interests rather than a narrow state-dominated scope of interest, which continues to reinforce state goals that may run counter to market logic. Second, the perception that mixed ownership is a means for privatizing state assets has led to some aversion toward SOE reform.¹⁰⁸ Because administrating SOEs are a means of state power, selling off state assets could be considered by some to be diluting state power. Third, SOE reform has lagged because of a lack of government administrative reform.¹⁰⁹ This suggests the central government lacks the institutional capacity to fully execute SOE reforms leading to the subpar results. Finally, the introduction of independently appointed board of directors for central SOEs have found it difficult to impose discipline upon SOE executives as tools such as shareholder litigation.¹¹⁰ This is due to a lack of regulatory resources in addition to the weak institutional design.

¹⁰⁷ Qunhui, "How 'New SOEs' Come of Age: Four Decades of China's SOE Reform"," 82; Gary Jefferson, "State Owned Enterprise: Reform, Performance, and Prospects," in *SAGE Handbook of Contemporary China*, ed. Weiping Wu and Mark Frazier, vol. 1 (London: Sage Publications, 2018), 136.

¹⁰⁸ Qunhui, "How 'New SOEs' Come of Age: Four Decades of China's SOE Reform"," 82.

¹⁰⁹ Qunhui, 82.

¹¹⁰ Jefferson, "State Owned Enterprise: Reform, Performance, and Prospects," 137.

Part of this lack of institutional capacity results from interests in maintaining SOEs either due to their means as a revenue generation or outstanding liabilities. Nicholas Lardy discusses the investment boom that resulted from the global financial crisis. He suggests that an aggressive reform program to rein in overleveraged SOEs could lead to a high level of defaults and could meet resistance at the local level where local banks and financial institutions have done the bulk of financing for these SOEs.¹¹¹ Another countervailing force is the interests of local bureaucrats who are incentivized to find ways to create GDP growth.¹¹² Thus, attempts to undo the conditions created over the last 10 years of easy credit and overleveraged firms that cannot pay off debts will have to overcome entrenched interests protecting them at lower levels.¹¹³ Although the central government seems intent on achieving a more equal playing field for private firms, it is likely that institutional weakness that enable lower echelons of government to protect SOEs persists and blunts the impact that SOE reforms may be able to achieve. Other data sets have demonstrated comparable results showing that SOE return on asset is consistently less than that of private firms and the gap is in fact widening.¹¹⁴ Figure 3 illustrates this through a comparison of R&D intensity, a measure of innovation efficiency calculated by dividing R&D investment by revenue. In spite of increased R&D investment, the revenue generated off of these new products is still considerably and consistently lower than other technologically advanced countries such as Japan, South Korea, Germany, and the United States. Another notable

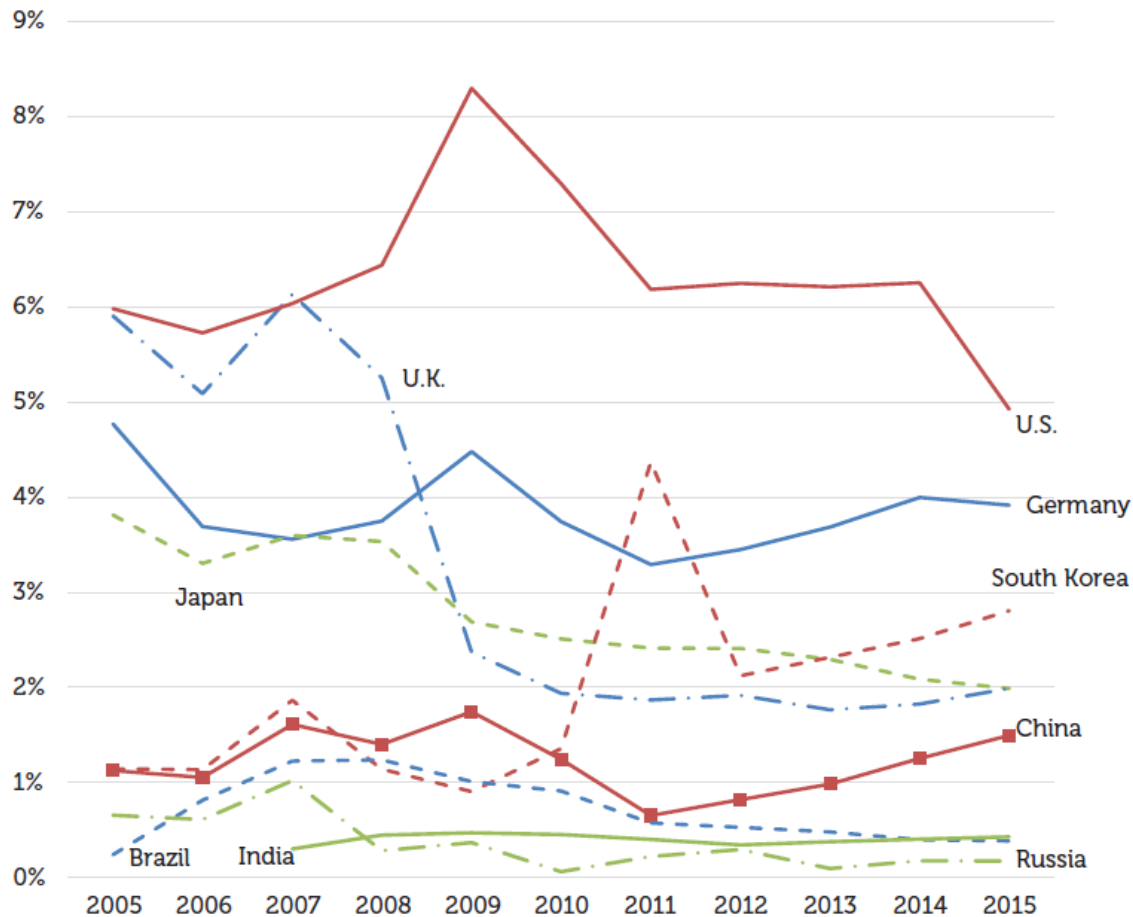
¹¹¹ Lardy, *The State Strikes Back: The End of Economic Reform in China?*, 122.

¹¹² Lardy, 125.

¹¹³ Paul Clifford, *The China Paradox: At the Front Line of Economic Transformation* (Berlin: DeGruyter Press, 2017), 77; Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China's Technological Development*, 49.

¹¹⁴ Nicholas Lardy, "China's SOE Reform—The Wrong Path," non-government organization, Peterson Institute for International Economics, July 26, 2016, <https://www.piie.com/blogs/china-economic-watch/chinas-soe-reform-wrong-path>; Yukon Huang, "Rethinking China's State-Owned Enterprises," Non-governmental organization, Carnegie Endowment for International Peace, November 21, 2014, <https://carnegieendowment.org/2014/11/21/rethinking-china-s-state-owned-enterprises-pub-57298>; Sea-Jin Chang and Sandy Yuan Jin, "The Performance of State Owned Enterprises in China: An Empirical Analysis of Ownership Control Through SASACs" (Singapore: National University of Singapore, 2016), <https://bschool.nus.edu.sg/cgio/research/state-owned-enterprises/>; Hong Cheng, Hongbin Li, and Tang Li, "The Performance of State-Owned Enterprise: New Evidence from the China Employer-Employee Survey" (Stanford, CA: Stanford Center on Global Poverty and Development, January 29, 2018), <https://kingcenter.stanford.edu/sites/default/files/publications/1037wp.pdf>.

point about this figure is that it includes aggregate R&D to include that of private firms, which one should expect to help China's R&D intensity, but there appears to be little effect.



R&D Intensities of various countries. R&D Intensity is investment divided by revenue

Figure 3. R&D Intensity¹¹⁵

Another issue that arises as a result of the central-local push-pull phenomenon is resource misallocation. Lardy highlights the fact the CCP considers SOEs essential to achieving strategic objectives and this often overrides market economic logic.¹¹⁶ The top down approach to innovation through initiatives such as MIC2025 tend to favor SOEs

¹¹⁵ Kennedy, "The Fat Tech Dragon: Benchmarking China's Innovation Drive."

¹¹⁶ Lardy, *The State Strikes Back: The End of Economic Reform in China?*, 122.

because the established presence and state protection tends to attract more capital and talent, and SOEs inherently are more able to access public resources quicker due to their proximity to the government.¹¹⁷ As a result of preferential access to credit and internal mismanagement, a dual dependency arises from paternalistic bureaucrats who feel the need to protect SOEs under their purview, and a SOE that becomes addicted to its easy access to credit and resources.¹¹⁸

This state patronage phenomenon can be seen in the case of Lenovo—which has decreased its state holding from 57 percent in 2003 to 32.5 percent today.¹¹⁹ State patronage has led to two outcomes. First, state procurement has aided to preserve Lenovo’s sizable share of the Chinese domestic market, before and after its acquisition of IBM’s PC division.¹²⁰ Second, the guarantees of state favor and barriers to superior foreign competition in the 1990s have likely eliminated market pressures to innovate as Lenovo’s lack of R&D is repeatedly cited as a characteristic of its corporate culture which thus has led them to reach the technological frontier through acquisition rather than R&D.¹²¹ In conclusion, the effect of state patronage practices are that they create stagnation and block inherent market incentives to place value in R&D and S&T innovation.

Although some data shows that reforms have made some improvement to the efficiency and innovativeness of SOEs, it is evident that these reforms have not fostered the development of a S&T innovation capacity. Innovation is likely to continue to be less effective as long as the government continues to use the strategic value of SOEs to rationalize reform measures to get SOEs to act more like private firms. These factors do not motivate a shift of corporate culture from production to seeing R&D as the area in which bulk of value added is captured. Part of that is due to the latent effects of state

¹¹⁷ Appelbaum et al., *Innovation in China: Challenging the Global Science and Technology System*, 65; Xiaolan Fu, *China’s Path to Innovation* (Cambridge: Cambridge University Press, 2015), 197.

¹¹⁸ Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China’s Technological Development*, 35.

¹¹⁹ Fuller, 69.

¹²⁰ Fuller, 72–76.

¹²¹ Fuller, 71, 73, 75.

patronage which will still mitigate incentives for newly hybridized firms to place the proper amount of emphasis on R&D and instead focus on merger and acquisition.

2. Private Firm Outcomes

While private sector policy has focused on making innovation resources more accessible to private firms, the management capacity for these initiatives has remained weak, and thus much of the innovative activities seen in the private sector has been undertaken by firms themselves on their own volition. The broad theme that arises in the policy language is that innovation in the private sector is driven by “marketization.”¹²² Research is generally categorized into three groups—basic research, applied research, and product development. Because product development is the closest to furnishing technologies into commercial applications, it is heavily preferred by private enterprises in China because of the lower capital requirements. The financial constraints that arise through state patronage force innovations that likely have greater market potential, shortest time horizon based on R&D time, and/or maximize the return on asset rather than products that may have greater technological value. This shapes the range of opinions on private sector innovation in China. Optimistic business-minded observers contend that this demand-oriented environment has led to the development of a more open innovation environment which has led China to be more innovative, while bearish observers contend that though pressures exist to foster innovation, a dearth of resources results in less innovative outcomes. Overall, I find that firms are not compelled or incentivized place the necessary amount of resources toward R&D.

a. Bullish Perspectives

This perspective posits that micro-level analysis of Chinese firms demonstrates that they are, in fact, becoming more innovative. Ironically, it is the weak institutional capacity to regulate IPR and inability to manage funding towards technology-intensive firms that leads Chinese firms to focus on innovation activities that are within their capital

¹²² State Council of the People’s Republic of China, “State Council on Strengthening the Implementation of Innovation-Driven Development Strategy Opinions on Further Promoting the in-Depth Development of Mass Entrepreneurship and Innovation,” sec. 2.

constraints, low-risk, and easy to transform into commercial application.¹²³ This is demonstrated by the high degree of product development that is evidenced. There are three elements to this perspective. First, Chinese firms focus on marketability—that is a deep understanding of what customer demand is. Next, the market forces of being a late-developing nation create niches in which the Chinese consumer has unfulfilled needs arising from undeveloped institutional capacities as well as a “good enough” mindset which suggests utility and price point are the biggest considerations for Chinese consumers.¹²⁴ As a result, Chinese firms often end up modifying existing technology to suit the unique needs of domestic consumers, and this new twist on existing technologies can be interpreted to be a new product and therefore “innovative”.

Proponents of this perspective suggest that the institutional environment has created a unique innovation environment that is neither better nor worse than in the West—just different. Given constraints such as lack of skilled personnel and lack of information on technologies, start-ups and entrepreneurs have leveraged the weak IPR institutions to access a broader base of knowledge which to develop their products from.¹²⁵ It is collaborative such that an inventor’s contributions and intellectual property are part of a larger repository of knowledge that other inventors can plug and play in their products.¹²⁶ With this base of core technologies, the bulk of what consequently occurs is actually product development. This is reflected in fact that product development expenditure dominates total R&D expenditure at nearly 85 percent while basic research is only at 5 percent.¹²⁷ One place where this is evidenced is in Shenzhen where proximity to manufacturing plants in the Pearl River Delta Region allows for rapid prototyping and

¹²³ Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China’s Technological Development*, 60–61, 99.

¹²⁴ Yip and McKern, *China’s Next Strategic Advantage: From Imitation to Innovation*, 4–6.

¹²⁵ Demuth, *Shenzhen: The Silicon Valley of Hardware*; Fu, *China’s Path to Innovation*, 176.

¹²⁶ Demuth, *Shenzhen: The Silicon Valley of Hardware*; Fu, *China’s Path to Innovation*, 163.

¹²⁷ OECD, “Main Science and Technology Indicators” (OECD Science, Technology and R&D Statistics (database), 2020), <https://doi.org/10.1787/data-00182-en>; Kennedy, “The Fat Tech Dragon: Benchmarking China’s Innovation Drive,” 20.

access to intermediate components which speeds up the iteration of R&D.¹²⁸ Further evidence that open innovation is occurring is from a study conducted by Tsinghua University in 2008 which found that 37 percent of Chinese manufacturing firms were collaborating with other firms or research institutes for new product development.¹²⁹ The biggest merit of this outcome is the modularity of this approach lowers the transaction costs to innovators and increases diffusion of knowledge across sectors. Thus, what appears to be happening is the unintentional construction of an innovation ecosystem that fosters collaboration amongst researchers and product developers.

Additionally, late developing countries develop faster than the infrastructure can take root such that in China, these unfulfilled gaps create niches that only Chinese firms know to fulfill because of their broad knowledge of the Chinese consumer landscape. For example, the reason for the rise and demise of eBay in China was a failure to account for the underdevelopment of electronic payment and e-commerce infrastructure in rural parts of China. This underdeveloped capacity was seized by Alibaba's Alipay system where the key innovation was not just the introduction of an online payment/banking mechanism but an escrow mechanism baked in to prevent fraud.¹³⁰ The advent of the internet in China occurred largely in the mobile era, thus app development and the development of an ecosystem predicated on mobile technology has occurred more quickly in China.¹³¹ This is a big reason why China appears to be extremely innovative; costs in the mobile app development sphere are generally lower and innovations can occur quicker.¹³² In this manner, one could conceive the possibility that the shortened time horizon, and co-location of manufacturing elements of the supply chain, and the large population of innovators in China creates quicker and more R&D iteration which compresses the innovation cycle and makes China more innovative.

¹²⁸ Demuth, *Shenzhen: The Silicon Valley of Hardware*; Yip and McKern, *China's Next Strategic Advantage: From Imitation to Innovation*, 234.

¹²⁹ Fu, *China's Path to Innovation*, 143.

¹³⁰ Yip and McKern, *China's Next Strategic Advantage: From Imitation to Innovation*, 233; Rein, *The End of Copycat China: The Rise of Creativity, Innovation, and Individualism in Asia*, 27.

¹³¹ Rein, *The End of Copycat China: The Rise of Creativity, Innovation, and Individualism in Asia*, 78.

¹³² Rein, 78.

Two things are problematic with this perspective. First, the efficiency imposed by the market, in this case, does not drive demand for more innovative products, but rather niche products that fill gaps in state of technology in developing countries, as evidenced by the Alipay example. Thus, while the focus on efficiency of the innovation process suggests that Chinese innovation is improving, they are merely improving the processes and competitiveness of domestic firms to cater to the domestic market. Second, if China is truly becoming innovative as the optimistic data suggest, then there should be an uptick in the production of technology patents and licensing of these patents.¹³³ Instead, there has been an increase in the production of patents which is incentivized through government policies but not in the value of the patent which is more difficult to capture and requires a longer time horizon.¹³⁴ This fact furthers the argument that Chinese innovation is merely filling in the gaps in the domestic market, not producing something that is globally valuable or truly inventive. Overall, the PRC has not fostered favorable conditions for firms to compete on the frontier of S&T innovation; rather firms are left to compete in an underdeveloped market, but still well within the bounds of S&T.

b. Bearish Perspectives

I now arrive at the perspective that side with—Chinese innovation is not taking off. This argument is comprised of three findings. First, the lack of adequate financing has led to a lack of rigorous R&D that is needed to develop the S&T capacity of Chinese firms. Secondly, the development of science parks has not stimulated the proper amount of knowledge diffusion because incentive structure for local officials is in the construction of these parks rather than the upkeep and upgrades to existing parks which would give these facilities the necessary equipment for substantive S&T research, particularly in basic research, to occur. Finally, the necessary incentives are not there to force firms to place greater emphasis on R&D.

¹³³ Warner, “Patenting and Innovation in China: Incentives, Policy, and Outcomes,” 18.

¹³⁴ China Power Team, “Are Patents Indicative of Chinese Innovation?,” para. 13.

While the business sector dominates R&D expenditures now, comprising nearly 77 percent of the 1.7 trillion RMB R&D expenditure in 2017, where SOEs comprise nearly 66 percent of that, meaning that private enterprises are disadvantaged when it comes to seeking adequate financing.¹³⁵ While portions of policy have focused on the development of more focused financial incentives directed at private sector innovation, the PRC continues to have difficulty spurring innovative activities within private firms. Structurally, despite the proliferation of different funding sources, venture capital has tended to be risk-averse and has tended to focus on scaling up marketable technologies rather than gambling on untested technologies or inexperienced start-ups.¹³⁶ There are also a number of institutional weaknesses that are exacerbated by the structural factor. State-run venture capital, in particular, suffers from poor management of guidance funds which leads to investment in tech start-ups and entrepreneurs.¹³⁷ Guidance funds are often funneled into non-technological intensive firms that meet the overly-broad scoped criteria for funding.¹³⁸ Additionally, for venture capital, the state regulates which firms can do initial public offerings (IPO) and when they can be done, and state owned banks control the flow of investment which emplace additional gatekeepers on Chinese firms seeking capital.¹³⁹ Thus, from an investment standpoint, the market potential of a new technology weighs more heavily than the novelty or utility of the new technology, and this orientation toward the marketability and short R&D time horizon inherently shapes what types of firms get money.

Private sector policy also touts science parks as a way for collaboration and the diffusion of knowledge to occur through geographic proximity. The proliferation of science parks demonstrates a clear execution of the intent expressed in policy. From 2011 to 2016, China created 79 high-tech parks leading to a total of 168 high-tech parks that accounted

¹³⁵ OECD, “Main Science and Technology Indicators”; ChinaPower Team, “Is China a Global Leader in Research and Development?,” para. 14.

¹³⁶ Kennedy, “The Fat Tech Dragon: Benchmarking China’s Innovation Drive,” 23.

¹³⁷ Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China’s Technological Development*, 61.

¹³⁸ Fuller, 64.

¹³⁹ Fuller, 61; Kennedy, “The Fat Tech Dragon: Benchmarking China’s Innovation Drive,” 22.

for 12 percent of China's GDP and 18 percent of exports in 2016.¹⁴⁰ In spite of the focus on fostering start-ups through science parks, the firms that are widely reported to have emerged are big tech firms that did not grow as a result of using science parks such as Alibaba, Baidu, Huawei, Lenovo, Tencent, and Xiaomi.¹⁴¹ This can partly be explained by the fact that only large private enterprises have the requisite capital to conduct research and can leverage the appealing parts of science parks—human capital and proximity.

The generalized failure of science parks can also be partially explained through the evaluation system used for local officials. Local level government officials are incentivized to build new parks rather than upgrade existing facilities to promote better collaboration and diffusion.¹⁴² This is contrasted with similar tech parks in Taiwan and Singapore where officials' performance was evaluated on the basis of upgrading facilities to provide the latest equipment for high tech research.¹⁴³ Thus, science parks in China could be more accurately described as close proximity office spaces. On the other hand, other authors suggest that there are some long-term benefits that science parks bring that have not fully reached their potential yet. Part of the success that is cited in the case of Suzhou Industrial Park (SIP) is due to the attraction of multinational corporations (MNC) which can be advantageous in the long term.¹⁴⁴ In particular, Appelbaum et al. cite the potential for innovation spillover from large MNCs in SIP to create momentum that boosts the innovative capacity of domestic firms that are collocated at SIP. The prevalence of MNCs

¹⁴⁰ Appelbaum et al., *Innovation in China: Challenging the Global Science and Technology System*, 122.

¹⁴¹ Yip and McKern, *China's Next Strategic Advantage: From Imitation to Innovation*; Rein, *The End of Copycat China: The Rise of Creativity, Innovation, and Individualism in Asia*; Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China's Technological Development*; Appelbaum et al., *Innovation in China: Challenging the Global Science and Technology System*; Economy, *The Third Revolution: Xi Jinping and the New Chinese State*; Clifford, *The China Paradox: At the Front Line of Economic Transformation*.

¹⁴² Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China's Technological Development*, 52; Appelbaum et al., *Innovation in China: Challenging the Global Science and Technology System*, 157.

¹⁴³ Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China's Technological Development*, 54.

¹⁴⁴ Appelbaum et al., *Innovation in China: Challenging the Global Science and Technology System*, 156.

and domestic tech firms with pre-existing heft could explain the sizable percentage of GDP contribution cited earlier, but it overshadows the fact that small start-ups are not thriving in the manner intended in the design of these science parks. In spite of some noted successes, it appears that science parks, for the moment, seem to favor large firms rather than small start-ups because of the gravitational pull of brand recognition that fuels the conglomeration of firms such as those noted above.

Finally, the lack of in-house R&D capacity among firms means that firms are not drawing on an indigenously developed and owned base of core technology but instead rely on outside entities to develop their foundational technologies. Firms that recognize the need for a robust in-house R&D capability are, indeed, thriving, which makes them the exception rather than the norm. The prime example of the exception, Huawei, spends approximately \$15–\$20 billion on R&D, which is approximately 15 percent of total revenue, of which, 30 percent of that budget is dedicated toward basic research.¹⁴⁵ For comparison, the level prescribed by the 13th Five Year Science and Technology Plan of R&D investment as a percentage of revenue is set at a modest 1.1 percent.¹⁴⁶ The annual working hours of engineers in 2017 at Huawei is claimed to be 2,750, which is twice as much as its western counterparts.¹⁴⁷ Perhaps the best evidence that Huawei’s focus on R&D has merit is in the latest PCT application statistics. In 2018, Huawei was the largest corporate filer of patents in the world, filing 5,405 patent applications and topping U.S. companies Intel (2,812) and Qualcomm (2,404).¹⁴⁸

While there are other companies like Huawei, they tend to be big companies with enough capital to devote toward more holistic R&D. If China was truly becoming

¹⁴⁵ Reuters, “China’s Huawei to Raise Annual R&D Budget to at Least \$15 Billion,” *Reuters*, July 28, 2018, <https://www.reuters.com/article/us-huawei-r-d/chinas-huawei-to-raise-annual-rd-budget-to-at-least-15-billion-idUSKBN1KG169>; China Daily, “Huawei’s R&D Investment in 2018 Exceeds \$15 Billion,” *China Daily*, April 9, 2019, <http://www.chinadaily.com.cn/a/201904/09/WS5cac0859a3104842260b5265.html>; Kennedy, “China’s Innovation Trajectories,” 73.

¹⁴⁶ State Council of the People’s Republic of China, “‘13th Five-Year’ National Science and Technology Innovation Plan.”

¹⁴⁷ Gan and Govindarajan, “The Factors Behind China’s Growing Strength in Innovation,” para. 8.

¹⁴⁸ Xinhua, “Huawei Tops Corporate Patent Applications in 2018: WIPO,” March 19, 2019, paras. 5–6, http://www.xinhuanet.com/english/2019-03/19/c_137907828.htm.

innovative in S&T, there should be more evidence of a more comprehensive focus on R&D. While the 13th FYP does call for an increase in the production of patents filed through the Patent Cooperation Treaty (PCT),¹⁴⁹ there are no policies that outline a specific roadmap to achieve these targets. As I have highlighted earlier, resource misallocation has also prevented a lot of these firms from devoting a greater focus toward basic and applied research. China certainly has the opportunity to enact more targeted industrial policy such as incentives based on patent value captured abroad; until it does so, I remain bearish about the prospects of Chinese firms becoming innovative to the degree that is in line with its stated objectives of becoming world leaders in S&T innovation by 2030.

While open and collaborative innovation certainly provides some benefit to innovation, it must be remembered that a big driver of innovation is to move up the value chain where value is captured through the creation of technology and the licensing associated with that. From that standpoint, the failure to foster on R&D capacity in enterprises constitutes a lack of innovation. While open innovation is an adequate solution for low-cost industries such as app and software design, it is less effective in more advanced sectors requiring much more basic research such as the aerospace and advanced materials industries. This suggests that while private firms are becoming more innovative, they are not on track to become a world powerhouse in innovation by 2050 as stated. Because open innovation is a relatively new phenomenon, it is unknown whether open innovation is simply a phase in development where firms accumulate enough capital to eventually fund their own R&D in the future or if this model is an outright alternative to other established models of innovation.

E. CONCLUSION

Although there is much Chinese government interest in fostering innovation, I have illustrated that it is not necessarily a policy failure that results in the lack of development of R&D capacity, but ineffective management of investment and institutional values that

¹⁴⁹ PCT Is a Multilateral Framework for patent filing that has higher standards for originality in patent applications than current Chinese domestic standards.

do not place enough emphasis R&D are creating barriers to achieving S&T innovation. Preferential access and a lingering state interest in SOEs will always bias resources toward the public sector, in spite of efforts to make SOEs behave more like private firms. Small and medium enterprises, as a result, lack the requisite resources and the knowledge spillover to dedicate a greater focus toward R&D. Thus, absent resources, small private enterprises often leverage low IPR barriers and focus on product development rather than research. The difficulty in sourcing credible evidence of innovation in industry, writ large, suggests that Chinese industrial innovation policy is not working as well as the policy prescribes. It also suggests that the problem lies in the management of the initiatives prescribed by policy. While resources are an issue for small private firms, it does not appear that this is the case for all private firms. There does appear, though, to be a small cadre of larger tech firms that have the heft and autonomy to focus on basic and applied R&D and this suggests that it is perhaps not the policy, but the management that is lacking.

While information sources focus on the lack of innovation that has occurred since the hype surrounding Chinese innovation began, scholars have tended to evaluate the past rather than extrapolate into the future. A theme that is constantly reiterated in Chinese policy documents is the long-term target, 2050, for achieving their goals. Thus, because the time horizon is extremely long, one could take the perspective that the nascent developmental progress that China is currently exhibiting is consistent with what the timeline of their goals.

While ineffective management has impacted the effectiveness of innovation policy, there are some areas where China's scale could become the predominant factor on fostering innovation. As stated earlier, for instance, it is entirely likely that the critical point for knowledge spillover to have positive effects has not occurred yet, and thus it is possible that as the amount of STEM-trained human capital continues to flow through the halls of science parks and the ranks of large tech giants, the diffusion of knowledge and values could speed up and transform small private firms into propagators of Chinese innovation—an intended goal of Chinese industrial policy. This is also not to say that the policy management has suffered while policy has been perfect. As the PRC is on the cusp of publishing a new five-year plan, it will be interesting to see if and how the PRC tweaks

their innovation policy to foster a greater focus on R&D within industry by upping their targeted percentages for firm level R&D investments. Also, while Chinese research lags on the industry side, some evidence suggests nascent progress toward advancing the quality and output of research on the academic side of China's innovation system—a theme which I will explore in the next chapter.

III. EDUCATIONAL POLICY

A. INTRODUCTION

Education plays a crucial role in China's innovation system because it is in universities and research institutes where much of the *research* activities in R&D are taking place. Thus, as China seeks to become indigenously innovative, the prospects of whether or not China can cultivate its own core technologies will be important in assessing China's potential to accomplish its goal of self-sufficiency. China has dedicated state funded research institutes that exist alongside universities whose purpose is to research and develop core technology, and thus education plays a very important role in fostering innovation. As universities seek to foster more scientific inquiry and take on a research role, there appears to be some overlap with the roles traditionally occupied by research institutes. Because research institutes are more analogous to universities than they are to firms, they are included in the discussion of education policy and the analysis of the research environment. This chapter examines how Chinese national education policy supports the advancement of S&T innovation through curriculum reforms, develops talent through scientific inquiry and curiosity, and increases the output of STEM-related products—human capital, intellectual property, and publications. The discussion is subdivided into compulsory (primary/secondary) educational policies that seek to improve the quality of instructional methods and assessment of talent and higher education and research policies which seek to boost the volume and rigor of research. My main findings are that while Chinese policies have found some success at creating high level academic institutions, progress of educational reforms in compulsory education has been very modest comparatively. Overall, however, the improvement and development of a scientific research culture in China has shown evidence to suggest that the goals are being attained, and thus I believe Chinese educational policy has and will have a positive influence on the development of S&T innovation.

This assessment is rooted in the fact that there is evidence that suggests that the Chinese education is producing globally competitive talent in its wealthiest urban areas. On the compulsory education side, OECD sampling of test scores of Shanghai secondary

school students suggests that while educational outcomes are very unequally distributed across geographic and socioeconomic classes, there is nascent but substantive progress in fostering the kind of creativity and student engagement required to succeed at higher levels of academia. In higher education, the increased output of STEM graduates over the last twenty years has been accompanied by a shift among universities from knowledge distillation and vocational training toward a research focus. While there is no direct data to say that the quality of STEM graduates is now better, oblique evidence such as rising graduation requirements and increases in publication output do suggest that the foundational orientation toward scientific inquiry has taken root.

Yet, in spite of these recent achievements, there are glaring structural and institutional weaknesses that remain. In compulsory education, the educational outcomes vary greatly from urban areas to rural areas/western provinces. This creates issues with the efficient development of talent. Next, the college entrance examination creates pressures that reinforce the rote-memorization methods of learning, and it does a poor job of meritocratically distributing talent to higher education institutions. In higher education, while the number of scientific publications has increased, the quality of these publications lags behind OECD nations as a result of several factors—PhD graduation requirements, a short cycle evaluation system, fraud, and plagiarism. Additionally, because the burden of basic research primarily rests on state-funded research institutions, there are coordination problems with industry that arise from the utility of research findings towards commercial application. Also, because basic research is largely state funded, the scale of this funding limits the scale of core technology development. While there are substantial drag factors foisted upon the educational system, the development of human capital on the order of which China can produce as well as the fundamental shift from knowledge delivery toward research and inquiry outweigh the impact that these weaknesses pose toward fostering innovation.

This chapter is divided into three sections. The first section summarizes the main goals of Chinese government policy over the last ten years, and is divided by policy directed at primary/secondary education and higher education/research. The second section discusses the results of these policies and highlights areas in which government policies

have fostered creative and innovative behavior, while in others have failed to achieve their goals. I end with concluding remarks that offer an assessment of Chinese policy.

B. EDUCATIONAL POLICY

The main policy document that drives Chinese education policy is the *National Plan for Middle and Long-Term Education Reform and Development* and is also known as *Blueprint 2020*. *Blueprint 2020* was issued in July 2010 by the Central Government. It discusses a wide array of issues in all levels of education—compulsory and higher education. I begin the policy discussion by summarizing the main educational reforms in compulsory levels that pertain to fostering innovation. I then discuss university level educational policies meant to boost the capacity of universities to be innovative and on the cutting edge of research.

1. Primary and Secondary Education Policies

The *National Plan for Middle and Long-Term Education Reform and Development* (2010-2020) is the most authoritative national level guidance on how the development of the primary and secondary education system should occur over the last decade. The plan also makes reference to S&T being an outcome for the growth experienced thus far, and globalization and innovation being key motivators for educational reform and development.¹⁵⁰ In particular, the initiatives that pertain specifically to fostering S&T innovation can be categorized into two lines of effort—creating greater equality and overhauling the education system

Creating more equal access to compulsory education is important to S&T innovation because it increases the talent pool of eligible candidates as well as ensures more efficient assessment and distribution of talent across academic institutions. Broadly this is addressed in two ways. First, recognizing that there is a gap in educational outcomes

¹⁵⁰ Ministry of Education, “Outline of China’s National Plan for Medium and Long-Term Education Reform and Development (2010–2020).” (Central Government of People’s Republic of China, July 2010), 5, http://planipolis.iiep.unesco.org/upload/China/China_National_Long_Term_Educational_Reform_Development_2010-2020_eng.pdf.

between urban and rural areas, the plan calls for bridging the gap in rural areas. This includes setting up more schools in rural areas, allowing children of migrant workers to test in place rather than returning to their assigned place of residence, and attracting more teachers to work in rural areas through subsidized training programs and career advancement opportunities.¹⁵¹ The goal of these initiatives is to universalize the quality of compulsory education provided across the board between urban and rural localities.

A second way of tackling inequality and inefficiency is to reform the talent assessment process to ensure that talent is identified and vectored for development. The plan calls for an overhaul of academic aptitude exams for middle school students to better screen for and route scientifically inclined students toward “outstanding” senior middle schools (the analogue of an American high school) and secondary vocational schools.¹⁵² Additionally, the plan also calls for an overhaul of the *Gaokao* or college entrance exam process. Initiatives include shifting questions to focus on scientific topics, screening for innovative abilities, and allowing localities to have greater say in enrollment processes.¹⁵³ These efforts demonstrate a recognition that China has not fully harnessed the full potential of its human capital and illustrate a clear tie to fostering S&T innovation by optimizing talent assessment, development, and management.

In addition to making educational access more equitable, China has sought to modernize its education system in terms of how students are taught and assessed. This modernization is perhaps obliquely driven by the recognition that rote learning does not promote the creativity and critical thinking required to foster scientific discovery.¹⁵⁴ To rectify this weakness, the plan calls for updating teaching methods, a change in the exam oriented culture, and a shift away from excessive schoolwork for secondary school students.

¹⁵¹ Ministry of Education, 14, 44.

¹⁵² Ministry of Education, 27.

¹⁵³ Ministry of Education, 27.

¹⁵⁴ Shang-jin Wei, Zhuan Xie, and Xiaobo Zhang, “From ‘Made in China’ to ‘Innovated in China’: Necessity, Prospect, and Challenges,” NBER Working Paper Series (National Bureau of Economic Research, 2016), 8; Regina Abrami, William Kirby, and F. Warren McFarlan, “Why China Can’t Innovate,” *Harvard Business Review*, March 2014, <https://hbr.org/2014/03/why-china-cant-innovate>.

In order to move away from rote teaching methods, the plan calls for schools to diversify their teaching methods to cater to different student styles of learning, teachers to challenge their students to focus on comprehension, and students to pursue their interests rather than memorizing and studying to pass exams.¹⁵⁵ The plan also calls for changes in how teachers are trained and accredited so that they will be able to foster this shift in the classroom.¹⁵⁶ Notably, the effort to elevate teachers is also accompanied by calls to elevate the social status of teachers to help foster a learning-oriented society.¹⁵⁷ This shift in teaching methods and focus on teacher development represents a change in emphasis away from preparing students toward fostering more innate curiosity in students that is meant to spur innovation.

Accompanying the cultural shift in learning is a move away from emphasis on the college entrance exam as the sole determinant of a student's future. The plan calls for the development of differing exams assessing different competencies to better track and develop students according to their strengths.¹⁵⁸ This shift is necessary because by tracking students by vocation or interest, subsequent exams will thus be more tailored to how students are performing within their designated fields as opposed to a single examination that determines whether or not a student goes to college or not, but provides little fidelity as to what skills a student possesses. The plan also calls for the examination process to be more transparent and better regulated to ensure that there is a shift toward a more equitable process which will be key to creating a normative foundation for the educational culture to shift from exams toward fostering curiosity.¹⁵⁹

One final initiative that the plan calls for is to decrease the workload burden on students, especially during their senior middle school years. The rationale is that decreased workload allows for greater flexibility in how students are engaged and to allow students

¹⁵⁵ Ministry of Education, "Outline of China's National Plan for Medium and Long-Term Education Reform and Development (2010–2020).," 14–16.

¹⁵⁶ Ministry of Education, 36.

¹⁵⁷ Ministry of Education, 37.

¹⁵⁸ Ministry of Education, 27.

¹⁵⁹ Ministry of Education, 28.

“enough time to learn about the society, think deeply, practice more, and do exercises to amuse themselves.”¹⁶⁰ This is, perhaps, a tacit recognition that the past methodology of time consuming repetition through heavy schoolwork burden did not foster the creative thinking desired. It also suggests that the teaching methodology of the past was inefficient at cultivating curiosity and, by extension, innovative talent.

2. Higher Education Policy

In contrast to primary/secondary education policy, higher education policy focuses less on reform and on capacity development. The most authoritative policy initiatives are *Blueprint 2020*, *Double First-Class Universities*, and *Thousand Talents Program* which address most but not all reform efforts taken at the higher education level. This section proceeds thematically analyzing themes that are emphasized in this array of policies. The main themes highlighted in this section are talent recruitment and the pursuit of world recognition of Chinese institutions as world-leading innovators.

Talent recruitment in this context means filling and managing the ranks of Chinese universities with qualified experts that can then boost the productive capacities of these institutions and build them into world-leading citadels of knowledge. This move indicates a shift away from a role of education for socioeconomic mobility toward the research university model.¹⁶¹ However, because Chinese universities were shuttered during the Cultural Revolution and initiatives since the 1980s to send students abroad to be educated in the West have resulted in a brain drain, the depth of Chinese university faculties has not reached critical mass required to advance the state of Chinese S&T research.¹⁶²

The latest Chinese efforts to fill these ranks is through scholarships and talent attraction programs. *Blueprint 2020* calls for special grants to attract foreigners with to come teach in Chinese universities as well as importing foreign scientific textbooks and

¹⁶⁰ Ministry of Education, 15.

¹⁶¹ John Douglass, “China Futurisms: Research Universities as Leaders or Followers?,” *Social Research: An International Quarterly* 79, no. 3 (Fall 2012): 648.

¹⁶² Kim Hanna, “Glocalizing Cures for China’s Brain Drain Ills: The Thousand Talents Plan in Shanghai, Tianjin, and Guangdong,” ed. Allen Ryan Michael, *International Journal of Comparative Education and Development* 20, no. 1 (January 1, 2018): 16, <https://doi.org/10.1108/IJCED-10-2017-0028>.

increasing the percentage of foreign faculty members in universities.¹⁶³ The Thousand Talents Plan is the latest effort to attract world-class talent to China. While a major thrust of the effort is to attract overseas Chinese back to China, it also seeks to transplant foreigners as well to fill equivalent roles in Chinese universities and or enterprises as professors, researchers, and executives.¹⁶⁴ Enticements include stipends and grants for foreign talent to move their families and live in China, as well as expediting visas for these personnel and their families.¹⁶⁵ The 5–10 year shelf life of this program likely indicates the aspirations and foundational role that overseas and foreign talent has at spurring a scientific renaissance in China.

As China is attempting to fill its growing list of universities with world-class talent, it is also seeking to boost the credibility, rankings, and competitiveness of its universities. There are several ways of doing accomplishing. First, China has sought to increase international exchange to better integrate Chinese institutions into the latest academic discussions. This will occur through student exchanges, easing of credit transfer requirements, and qualification recognition of other foreign universities.¹⁶⁶ Another way that China is seeking to boost the reputations of its universities is to delegate the administration of universities and allow for greater autonomy in how universities are

¹⁶³ Ministry of Education, “Outline of China’s National Plan for Medium and Long-Term Education Reform and Development (2010–2020).,” 34–37.

¹⁶⁴ 1000 Plan Recruitment, “History and Background,” Government, 1000 Talents Recruitment Program, n.d., <http://www.1000plan.org.cn/en/history.html>.

¹⁶⁵ Baike, “Overseas Talent Recruitment Plan,” Reference, Baidu Baike, December 29, 2019, https://baike.baidu.com/item/%E6%B5%B7%E5%A4%96%E9%AB%98%E5%B1%82%E6%AC%A1%E4%BA%BA%E6%89%8D%E5%BC%95%E8%BF%9B%E8%AE%A1%E5%88%92#5_1; Ministry of Natural Resources, “Interim Measures for Attracting High-Level Talent,” Government, Ministry of Natural Resources of the People’s Republic of China, October 14, 2013, http://www.mnr.gov.cn/zt/kj/kjfz/kjrc/gjkjrcjh/201811/t20181129_2370185.html.

¹⁶⁶ Ministry of Education, “Outline of China’s National Plan for Medium and Long-Term Education Reform and Development (2010–2020).,” para. 11; Australian Government, “Implementation Measures Released for China’s New World-Class University Policy,” Government, Department of Education | Australian Government, February 28, 2017, para. 8, <https://internationaleducation.gov.au/International-network/china/PolicyUpdates-China/Pages/Implementation-measures-released-for-Chinas-new-world-class-university-policy.aspx>.

run.¹⁶⁷ One final initiative is to emphasize scientific research as a core function and updating the facilities of these universities to cultivate the thinking required to continue to attract talented academics and boost the global competitiveness of Chinese universities.¹⁶⁸ Overall, these developments shape Chinese education in the sense that it improves the capacity of its universities while further linking them to their counterparts outside of China, and if successful, it will serve as a key indicator of China's progress in not just S&T innovation but also in its socioeconomic development.

C. POLICY RESULTS

Has Chinese educational policy met its goals thus far? Overall, substantive evidence that China is overtaking the U.S. is lacking, but the qualitative trends suggest that China is beginning to build a sustainable base and foundational orientation toward scientific inquiry. However, while universities and research institutes appear to have made some progress, the development of a more modern and meritocratic compulsory education system appears to be fairly modest. Educational outcomes are still very much based on socioeconomic situations and geographic access to the external cultural exchange, and in spite of efforts to provide more qualitative assessments of students and interactive teaching pedagogy, the high stakes college entrance exam reinforces lecture style teaching. Thus, while I generally believe Chinese educational development is succeeding at fostering innovation activities, the weaknesses of the compulsory Chinese education system could create bottleneck that could stifle the continued growth of Chinese research at the higher education level. I proceed by first discussing the outcomes at the compulsory education level and then discussing outcomes at the higher education level.

¹⁶⁷ Ministry of Education, "Outline of China's National Plan for Medium and Long-Term Education Reform and Development (2010–2020).," 29; Ministry of Education, "Guiding Opinions on Accelerating the Construction of 'Double First Class' in Colleges and Universities," Government, Ministry of Education of the People's Republic of China, August 20, 2018, para. 13, http://www.moe.gov.cn/srcsite/A22/moe_843/201808/t20180823_345987.html.

¹⁶⁸ Ministry of Education, "Guiding Opinions on Accelerating the Construction of 'Double First Class' in Colleges and Universities," paras. 7–10; Ministry of Education, "Outline of China's National Plan for Medium and Long-Term Education Reform and Development (2010–2020).," 29–30.

1. Compulsory Outcomes

The following discussion shows that Chinese progress at fostering scientific inquiry among students and overhauling teaching methods are highly socioeconomically and geographically dependent and are localized to large urban areas that are easily accessible to the outside world. One limitation of this research is the lack of available quantitative data that characterizes some of the temporal trends of the policy execution. Given that the education policy I am examining is nearing the end of its lifecycle, I examined the evidence from the perspective of *are the outcomes consistent with the policy goals?* Although the fostering scientific thought is the core of this discussion, the limiting factors of Chinese socioeconomic development quickly become a significant factor in explaining why progress in the development of scientific education in China is relatively modest. On the one hand, cities such as Shanghai have demonstrated the fruits of progressive education reform by increasing test scores, improving the aggregate quality of its schools, and bridging the gap in inequality within education. On the other hand, in spite of ongoing efforts to reduce the importance of the *Gaokao* as the determinant of students' futures, its institutional inertia continues to reinforce system-wide practices that hinder the development of creative thinking and scientific inquiry.

a. Early Successes

The most concrete evidence that China has been able to improve its scientific education is in Shanghai. Shanghai's educational success is significant because it is not merely a single data point that suggests educational progress, but a few factors that suggest that, qualitatively, Shanghai's education system is truly progressive. First, test scores on the OECD administered Programme for International Student Assessment (PISA) in 2009 placed Shanghai ahead of not just the rest of China, but ahead of other advanced countries.¹⁶⁹ Secondly, investment in teachers and schools leadership has helped to ensure that the improvements in schools are not localized to a few elite schools but spread

¹⁶⁹ "How Shanghai Schools Beat Them All," *The Diplomat*, August 1, 2011, para. 2, <https://thediplomat.com/2011/08/how-shanghai-schools-beat-them-all>.

throughout the city. Finally, some data suggests that even migrant children are performing better in Shanghai schools.

Shanghai attracted international interest because its 2009 and 2012 PISA scores showed that Shanghai students scored significantly higher than both the rest of China as well as OECD countries such as Korea, Finland, and Singapore.¹⁷⁰ The difference in score outcomes between Shanghai and other big cities in China suggests that socioeconomic wealth do not fully explain educational outcomes, and there must be something else that is unique to the Shanghai education system. Most significantly, the 2009 PISA found that “twenty-six percent of Shanghai 15 year-olds could demonstrate advanced problem-solving skills, whereas the OECD average is 3 percent.”¹⁷¹ This provides some fairly compelling evidence to suggest that Shanghai has succeeded in fostering creativity and critical thinking in its students through its education system and could be indicative of what is on the horizon for the rest of China.

Why has Shanghai been able to score so well? Some data suggests that Shanghai has been able to rise to the top is because of its focus on cultivating a broad base of skilled teachers and school administrators. This results in two important outcomes. First, teachers are trained to teach in a more student-centric manner that emphasizes student participation rather than teacher centric which emphasizes lecture.¹⁷² Secondly, Shanghai’s local government has been keen to focus on improving weak schools by moving high performing teachers and principals to weaker performing schools.¹⁷³ In this manner, the aggregate quality of the educational supply side (educators) has increased which helps explain why the educational outcomes even for migrants.

¹⁷⁰ Nicholas Sun-Keung Pang and Zhuang Miao, “The Roles of Teacher Leadership in Shanghai Education Success,” *BCES Conference Books* 15 (2017): 95.

¹⁷¹ “How Shanghai Schools Beat Them All,” para. 3.

¹⁷² “How Shanghai Schools Beat Them All,” para. 9.

¹⁷³ OECD, “Chapter 4: Shanghai and Hong Kong: Two Distinct Examples of Education Reform in China,” in *Strong Performers and Successful Reformers in Education: Lessons from PISA for the United States* (OECD, 2011), 96–98, <http://www.oecd.org/education/school/programme-for-international-student-assessment-pisa/strong-performers-and-successful-reformers-in-education-lessons-from-pisa-for-the-united-states.htm>; “How Shanghai Schools Beat Them All,” para. 7.

The plight of migrant children in Shanghai's education system gives greater reason for optimism in China's education system writ large. One reason to take interest in the 2009 PISA results is because it is estimated that migrant children comprise 20 percent of the total primary/secondary student population in Shanghai.¹⁷⁴ The outcomes of the PISA test further corroborate the arguments made that Shanghai's educational success is largely attributed to its focus on pedagogy and educator depth. Nonetheless, hukou restrictions, which prevents Chinese citizens from legally changing their place of domicile, may still have kept an untold number of migrant students from taking the PISA which could have skewed the results more favorably. More importantly, though, this highlights that there are still very significant institutional barriers to educational equality which may be placing a drag on producing the innovative research culture China is seeking to build.¹⁷⁵

Overall, the case of Shanghai demonstrates the limits of national level policy. Shanghai's financial resources and wealth of human capital make it possible for it to craft local level policy to leverage these resources in pursuit of fostering scientific education. However, the fact that Shanghai's outcomes are better than the outcomes in Beijing, Tianjin, and Guangzhou further demonstrates that local level policy making matters more than socioeconomic development as an indicator of where and why Chinese educational development is succeeding.

b. *Much Progress Still to be Made*

While I have highlighted that a commitment to education has succeeded in building Shanghai's education system into a world-class institution, the results do not appear to be as replicated in the rest of China. At the national level, there is still a correlation between wealthier regions of China and educational outcomes. Figure 4 illustrates the primary student-teacher ratio. To illustrate the skew of resources toward wealthier localities, Figure 4 shows that wealthier localities such as Beijing and Shanghai have better student-teacher

¹⁷⁴ OECD, "Chapter 4: Shanghai and Hong Kong: Two Distinct Examples of Education Reform in China," 96.

¹⁷⁵ Duoduo Xu and Jaap Dronkers, "Migrant Children in Shanghai: A Research Note on the PISA-Shanghai Controversy," *Chinese Sociological Review* 48, no. 3 (2016): 291, <https://doi.org/10.1080/21620555.2016.1165605>.

ratios in spite of being more densely populated. Contrastingly, Figure 5 shows the tertiary (college and vocational) enrollment. Note that similarly, the wealthiest provinces or directly administrated cities in this case—Shanghai, Beijing, and Tianjin—show the most favorable statistics and demonstrate the highest tertiary institution enrollment rates. On the other hand, less urbanized and/or poorer provinces—Yunnan and Guangxi—display the least favorable trends of having the largest student-teacher ratios and lowest tertiary enrollment.¹⁷⁶

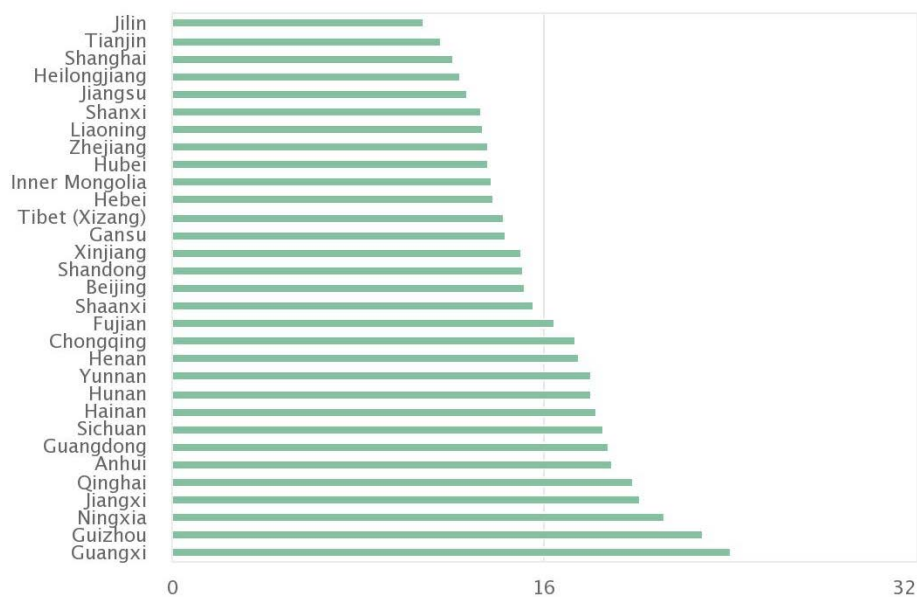


Figure 4. Secondary Student-Teacher Ratio by Province¹⁷⁷

¹⁷⁶ ChinaPower Team, “How Does Education in China Compare with Other Countries? | ChinaPower Project,” Reference, ChinaPower Project, November 15, 2016, <https://chinapower.csis.org/education-in-china>.

¹⁷⁷ Source: ChinaPower Team.

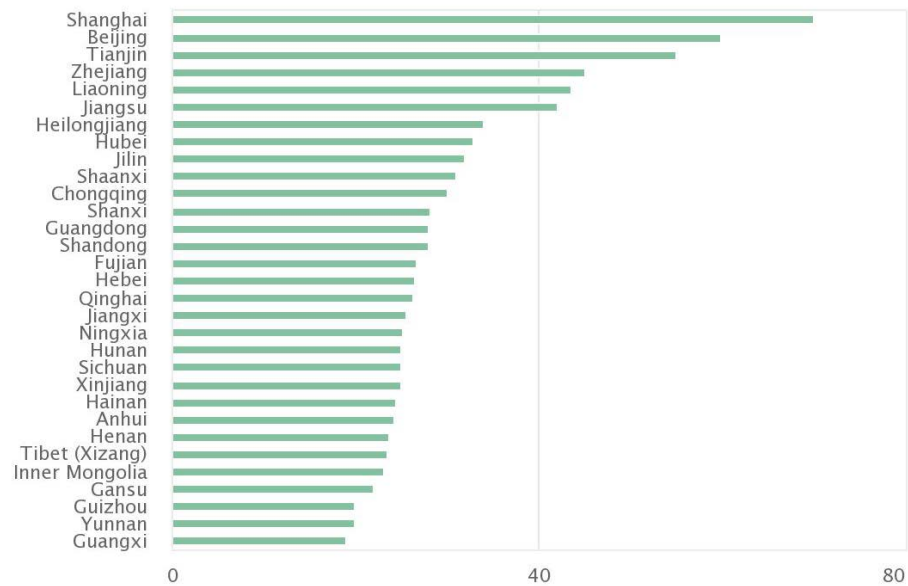


Figure 5. Tertiary Enrollment by Province¹⁷⁸

These two charts illustrate two facts that demonstrate how the Chinese education system creates structural barriers to social mobility. First, in spite of the larger population density in China's urban centers, the student-teacher ratios indicate that educational resources are inequitably distributed throughout China. Indeed, Blueprint 2020 calls for initiatives and funding to incentivize and subsidize the relocation of educators to rural and/or western parts of China, but inferences from these two figures suggest that these measures have yet to deliver on equalizing educational access across the China. Second, it hints at greater disparity in socioeconomic situations of the top performing localities and the rest of the pack. The power of personal wealth allows for a greater investment in education in richer areas, such as Shanghai, versus places where discretionary income is less. Parents in Shanghai spend an average of nearly 50,000 RMB (roughly \$7,000) a year on tutoring and extracurricular activities to prime their children for the college admission process, which exceeds the national average income of a Chinese worker of 42,000 RMB.¹⁷⁹ Furthermore, competition to get children into the best secondary schools has led

¹⁷⁸ Source: ChinaPower Team.

¹⁷⁹ Tom Loveless, "PISA's China Problem," Think Tank, Brookings Institute, October 9, 2013, para. 4, <https://www.brookings.edu/research/pisas-china-problem>.

to documented cases of bribery which also advantages parents with more financial means to ensure their children get into the best high schools.¹⁸⁰ All this suggests that institutional weakness and structural factors favoring richer areas of China will only reinforce the educational and socioeconomic disparities in China for years to come.

As compulsory education system broadly highlights the inequity of the Chinese education system in cultivating talent, a couple of issues with the college entrance exam, the *Gaokao*, are worth having their own discussion. First, the emphasis placed on the test as the primary determinant of a college applicant's merit makes the stakes for the test extremely high. Secondly, decentralized execution of the test means that, again, there is latent favoritism toward applicants living in urban areas. Overall, this means that the screening process for future talent is not entirely meritocratic but rather a function of some merit, socioeconomic means, and hereditary luck.

Consider that the *Gaokao* is the primary measure of differentiating college applicants from each other in a bid to get into the best universities. Because there is a finite amount of universities with finite capacity, competition to get into the best universities is cutthroat because of the implications on social mobility. Thus, the pressure to perform on the *Gaokao* is immense. This emphasis on the *Gaokao* through a student's academic career perhaps creates pressure to resort to rote learning, repetition, and memorization to digest the vast array of topic areas that are assessed in the *Gaokao*.¹⁸¹ Recent efforts to move beyond rote learning toward student-centered, ability focused techniques have been tempered by the exam driven culture.¹⁸² In an effort to change the cultural norms of total emphasis of test taking, some Chinese universities are beginning to move beyond the *Gaokao* by conducting face-to-face interviews to assess the attributes of an applicant that

¹⁸⁰ Dexter Roberts, "Chinese Education: The Truth Behind the Boasts," *Bloomberg Businessweek*, 2013, 12.

¹⁸¹ Zhang Gaoming, "Between a Rock and a Hard Place: Higher Education Reform and Innovation in China," ed. Zhao Yong et al., *On the Horizon* 20, no. 4 (January 1, 2012): 269, <https://doi.org/10.1108/10748121211272489>.

¹⁸² Cuidian Feng and Lingbiao Gao, "Assessing Science Learning in Schools: Current Policy and Practices," in *Chinese Science Education in the 21st Century: Policy, Practice, and Research*, ed. Ling Liang, Xiufeng Liu, and Gavin Fulmer, Contemporary Trends and Issues in Science Education (Dordrecht: Springer Nature, 2017), 229.

a standardized test cannot.¹⁸³ Recent initiatives have pushed for changes in the subjects tested in the *Gaokao* to allow for greater flexibility in what a student chooses to test in, but this initiative has only been rolled out in several provinces, not nationwide.¹⁸⁴ The bottom line, however, is that in spite of efforts to blunt the importance of the *Gaokao*, there has been very little substantive change because it is broadly considered by many parents to be the fairest, most meritocratic and least corruptible way to access students for college admissions.

By contrast, the bigger and more contentious debate about the *Gaokao* is the inequity created by the decentralization of the exam. Broadly speaking, it is a nationally standardized test, but there are variances in how it is conducted and subsequently how students are stratified. First, variance exists amongst provinces in the exam format as highlighted earlier. This decentralization to the provinces means that the exam could be easier to take in one province while being more difficult in another province. The result is a differing standard in cutoff score for university admission among different provinces.¹⁸⁵ Admission statistics for applicants from Anhui Province versus Beijing showing that applicants from the former are 40 times less likely to be admitted into Peking University than Beijing residents, which corroborates the disparity highlighted by differential cutoff scores.¹⁸⁶

This has caused parents to move their children to areas with more favorable *Gaokao* policies in the hopes that they will have a marginally better chance at admission to an elite

¹⁸³ Adam Tyner, “Can Test-Obsessed China Change?,” *The Diplomat*, September 8, 2017, para. 4, <https://thediplomat.com/2017/09/can-test-obsessed-china-change>.

¹⁸⁴ Sina Education, “Beijing Launches New Round of College Entrance Examinations,” *Sina Mobile*, September 18, 2018, <https://edu.sina.cn/gaokao/bkzn/2018-09-18/detail-ihkhfqns6010502.d.html>; Sina Education, “Summary of the Third Batch of New College Entrance Examination Requirements for 2021 Majors in 8 Provinces,” *Sina Mobile*, August 23, 2019, <https://edu.sina.cn/gaokao/gkrx/2019-08-23/detail-ihytcitn1354811.d.html>.

¹⁸⁵ Heidi Ross and Yimin Wang, “Reforming The College Entrance Examination: Epicenter of Tension, Change, and Resistance,” *International Perspectives on Education and Society*, Impact and Transformation of Education Policy in China, 15 (2011): 218, [https://doi.org/10.1108/S1479-3679\(2011\)0000015012](https://doi.org/10.1108/S1479-3679(2011)0000015012).

¹⁸⁶ Zhang Gaoming, “Between a Rock and a Hard Place: Higher Education Reform and Innovation in China,” 271.

university.¹⁸⁷ Additionally, children of migrant workers have sought to forge their *hukou* or residential registration in better areas than their home location in an attempt to reap the benefits of a lower cutoff score and not have to pay the cost of a journey back to their home province just to take the *Gaokao*.¹⁸⁸ Because *hukou* registration is extremely difficult for any Chinese citizen to change, it is often considered a hereditary attribute due to the fact that a child is legally and ancestrally bound to the land that their parents grew up in.

The *Gaokao* generates two negative externalities that stifle innovation. First, as previously highlighted, the stakes of the test drive the mode of learning to focused on memorization rather than application which stifles the cultivation of creativity and curiosity. Secondly, the differential cutoff is not truly meritocratic and inefficiently assesses and admits talent to higher echelons of academia. Therefore, because China has not fully realized the potential of its human capital, it is likely that this, too, creates a drag on S&T innovation.

Overall, while there are indicators that China has improved the quality of its education in pursuit of becoming more innovative, these successes appear to be localized and do not confront the larger issues of how the exam-oriented culture forces less comprehensive learning and bottlenecks the production process. Nonetheless, it is possible to see how the downstream effects of an educated population from successful schools will be incrementally transformative over the next few generations to building larger and larger cadres of educators throughout the education system who are committed toward STEM education. As policy suggests, the goals are long-term (2030-2050) and thus the nascent amount of progress that one sees through conversations on what the college entrance exam should look like or how to improve weak performing schools may be the appropriate amount of progress for now.

¹⁸⁷ Ross and Wang, “Reforming The College Entrance Examination: Epicenter of Tension, Change, and Resistance,” 217.

¹⁸⁸ Zhang Gaoming, “Between a Rock and a Hard Place: Higher Education Reform and Innovation in China,” 269; Roberts, “Chinese Education: The Truth Behind the Boasts,” 212; Ross and Wang, “Reforming The College Entrance Examination: Epicenter of Tension, Change, and Resistance,” 217.

2. Higher Education Outcomes

Outcomes at the university-research institute level are less about educational outcomes of students, and more about the effectiveness that its research apparatus has on fostering inventiveness and innovation. As the burden of universities shifts from knowledge inculcation toward research, their indispensable role as the supplier of core technology and basic research will only grow in China's national innovation system. This section discusses both evidence that suggests Chinese efforts to foster innovation through university research is showing returns and evidence that suggests that weaknesses in policy design have and will impose drag on Chinese efforts to foster innovation. Notably, I discuss how the ongoing investment in universities through programs such as Double First-Class University and Project 985 have produced increases in scientific publications doctoral graduates, and the research capacity of these universities have been able to be leveraged by large multinational companies in adjoining research parks. In contrast, I also discuss the limitations of Chinese efforts to increase its research throughput through its lack of funding of basic research, lower quality scientific publications, and fast paced evaluation cycle which continues to incentivize production quantity over quality. Overall, I find that while these weaknesses matter, the nascent progress of Chinese research system shows more signs of optimism rather than pessimism.

a. Evidence of Growth

The increased production of PhDs and scientific publications over the last twenty years suggests that China is increasing its scientific base which will prime its ability to become more innovative in the future. The fact that the growth of Chinese research output and institutions is in orders of magnitude rather than percentages is significant in the sense that demonstrates the capacity of the Chinese government to mobilize the necessary resources to motivate a massive shift toward innovation. This is evident through the production of increased PhD production and the increased scientific journal publications. Ultimately, this growth is important for two reasons. First, it provides the basis for pivoting the rest of education system away from knowledge inculcation and social mobility and toward scientific inquiry and innovation. Secondly, it builds the foundation for the

continued production of STEM graduates through the period in which China claims its goals will be met.

To evaluate the efficacy of national policy in fostering a more inquisitive research environment, one must look at Project 985. Because the fruits of the Double-First Class University Plan have yet to show, its predecessor, Project 985, is perhaps a better gauge of progress in Chinese universities. The purpose of this initiative was to transform key Chinese universities into globally acclaimed institutions.¹⁸⁹ The fact that the compound annual growth rate (CAGR) of R&D expenditures during the early 2000s outpaced GDP growth demonstrates both the potential that targeted investment could play in educational development as well as the seriousness of Chinese efforts to create globally competitive institutions.¹⁹⁰

Accompanying this growth in R&D expenditures is a payoff in the form of doctoral graduates. In 2014, 34,000 STEM doctoral degrees were awarded—nearly eight times the amount from nearly 20 years before.¹⁹¹ Put another way, 60 percent of all Chinese PhDs awarded in 2015 were in STEM fields.¹⁹² This is significant for two reasons. First, the incredible growth in the output of STEM graduates at the highest echelons of higher education demonstrate a commitment toward furthering the emphasis on science and correspondingly, innovation. Secondly, this growth occurred in an era in which the Chinese focus has been on developing its research capacity, rather than a social transformation project. The implication is thus that while the quality of these institutions, admittedly, may not be world-class currently, the commitment toward improving research quality will lead

¹⁸⁹ Han Zhang, Donald Patton, and Martin Kenney, “Building Global-Class Universities: Assessing the Impact of the 985 Project,” *Research Policy* 42 (2013): 765–75, <http://dx.doi.org/10.1016/j.respol.2012.10.003>.

¹⁹⁰ Zhang, Patton, and Kenney, 765.

¹⁹¹ Ling Liang, Xiufeng Liu, and Gavin Fulmer, eds., *Chinese Science Education in the 21st Century: Policy, Practice, and Research*, 1st ed., vol. 45, Contemporary Trends and Issues in Science Education (Dordrecht: Springer Nature, 2017), xix; National Science Board, “2018 Science and Engineering Indicators” (Arlington, VA: National Science Foundation, 2018), O7, <https://nsf.gov/statistics/2018/nsb20181/assets/nsb20181.pdf>.

¹⁹² Appelbaum et al., *Innovation in China: Challenging the Global Science and Technology System*, 22.

to generational improvements in line with its long-term goals of being world leader in innovation by 2050.

Another way to capture the progress is through the increased output of scientific publications. Figure 6 illustrates the trends of scientific publications between 2003–2016 by country. Much like the extraordinary growth rate of R&D expenditure, the publication growth rate has also increased at nearly 19 percent, growing from less than 200,000 publications in 2003 to over 426,000 publications in 2016.¹⁹³

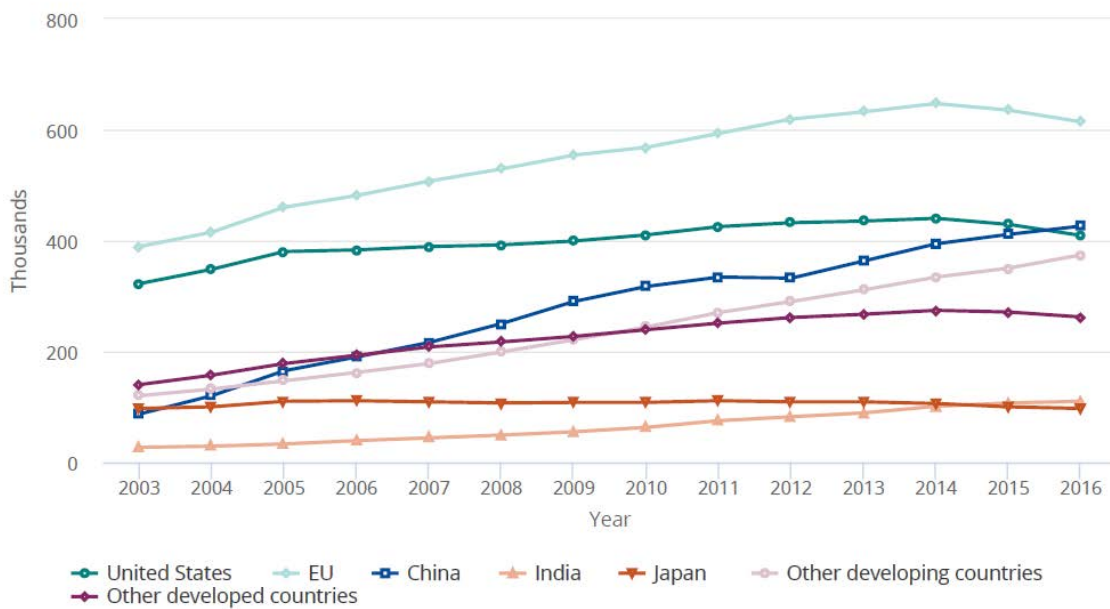


Figure 6. S&E Articles, by Selected Region, Country, or Economy: 2003–2016¹⁹⁴

Because much of the preceding data demonstrates quantitative upticks, the worry is that the focus of Chinese science is on quantity over quality. One reason for optimism in the quality of Chinese science is that this current generation of doctoral students and recent

¹⁹³ National Science Board, “2018 Science and Engineering Indicators,” O18; Han and Appelbaum, “China’s Science, Technology, Engineering, and Mathematics (STEM) Research Environment: A Snapshot,” 2.

¹⁹⁴ Source: National Science Board, “2018 Science and Engineering Indicators.”

graduates has grown up being educated in a transitional era where student-centric teaching methods meant to foster scientific inquiry and critical thinking are new developments in Chinese education. One should therefore expect that subsequent generations of doctoral students and researchers, more soundly educated in their compulsory education to foster scientific inquiry and critical thinking, would be more educationally prepared and cultivated to produce higher quality research. Thus, while the initial impression of China's increased output of doctoral graduates and research publications do not appear to be substantial, the increased cultivation of a research culture combined with the integration of these individuals into the various levels of academia could create more inertia to move away from inculcating knowledge toward fostering creativity and curiosity amongst Chinese students. If China succeeds in institutionalizing the role of these universities, this may become the best evidence of China's education system becoming innovative.

b. Weaknesses in China's Research System

In spite of the noted successes above, there are still several factors that drag down the advancement of China's research culture. In order for Chinese research to flourish, the PRC must still refine its policy to allow for future development. There are three weaknesses that I foresee as hindering future development. First, Chinese scientific publications, by some measures, have less impact toward science than outside publications. Second, the incentives of the Chinese research system emphasize a focus on production volume of research rather than the quality of research. Finally, China has underinvested in basic research and has coordination issues in aligning university basic research priorities with industry goals.

One of the debates about the development of Chinese research is whether or not this uptick has led to substantive improvements. A couple of ways to gauge the impact is through the level of collaboration of Chinese researchers with the outside and ultimately the number of citations that Chinese publications receive. Overall, the data in these categories suggests that Chinese publications are not really improving China's impact on science.

To begin, one way to garner acclaim and credibility within the scientific community is through the visibility of scientific publications. Because of this, collaboration with the outside is seen as a way to facilitate knowledge diffusion and produce scientific research. One observation is that overseas Chinese scholars brought back to faculties in Chinese universities through the Chang Jiang Scholars Program appear to collaborate more internationally than domestically educated peers likely due to the social network established while abroad.¹⁹⁵ For this reason, overseas educated scholars tend to publish in higher impact journals than their domestically educated peers.¹⁹⁶ However, overseas educated scholars are a low density high demand commodity, having only recruited a little over 7,000 people through 2018 through the 1000 Talents umbrella.¹⁹⁷ Thus the weakness in the research system is not only that the Chinese supply of overseas educated scholars is limited, but the data also appears to suggest that domestically cultivated scholars are producing less impactful research than their foreign educated peers.

A second way to gauge the impact of journal publications is through citations. An increase in citations suggests that Chinese science is becoming more impactful, and therefore reflects China's status as a global innovation leader. From 2000 to 2013, the citations of solely Chinese produced (no international collaboration) articles as a percentage of the global average went from 29 percent to 70 percent.¹⁹⁸ One factor that is seen as a significant contributor to the increase is the accompanying growth in Chinese publications in which other Chinese researchers have helped to boost the number of citations of Chinese publications.¹⁹⁹ One way of explaining the growth in citations is that

¹⁹⁵ Feng Li, Yajun Miao, and Chenchen Yang, "How Do Alumni Faculty Behave in Research Collaboration? An Analysis of Chang Jiang Scholars in China," *Research Policy* 44 (2015): 448, <https://doi.org/10.1016/j.respol.2014.09.002>.

¹⁹⁶ Li, Miao, and Yang, 448.

¹⁹⁷ Permanent Subcommittee on Investigations, "Threats to the U.S. Research Enterprise: China's Talent Recruitment Plans," Staff Report (Washington DC: Senate Committee on Homeland Security and Governmental Affairs, 2019), 2, <https://www.hsgac.senate.gov/imo/media/doc/2019-11-18%20PSI%20Staff%20Report%20-%20China's%20Talent%20Recruitment%20Plans.pdf>.

¹⁹⁸ Qingnan Xie and Richard Freeman, "Bigger Than You Thought: China's Contribution to Scientific Publications and Its Impact on the Global Economy," *China & World Economy* 27, no. 1 (2019): 16, <https://doi.org/10.1111/cwe.12265>.

¹⁹⁹ Xie and Freeman, 16.

Chinese researchers are making a deliberate effort to cite more Chinese research to boost credibility and impact. Another way of interpreting this statistic is that the increase in citations over time accompanied an increase in the graduation of scientists and engineers over time, so this uptick should be expected as there are nominally more Chinese researchers. This is perhaps more suggestive of China expanding the scale of its scientific development, but it does provide some evidence that China is becoming more innovative.

Just how innovative is China becoming? The temporal increase of citations suggests that as a baseline, Chinese science is improving. However, the increase of top Chinese science appears to be slower. The percentage of Chinese scientific publications cited by the top one percent of all scientific publications worldwide increased from 0.5 percent in 2002 to 1.0 percent in 2014 which is still below the U.S. percentages of 1.76 percent and 1.94 percent, respectively.²⁰⁰ In essence, while Chinese science is expanding, this suggests that China is still far from being the global leader it aspires to be.

Part of this slow growth is explained in part by the fact that a large proportion of Chinese publications (42 percent from 1996–2011, 24 percent from 2013–2017) were written in Chinese rather than English, which is generally considered to be the language of international literature, and this therefore limits the reach of Chinese research outside of China.²⁰¹ Additionally, because the standards to be indexed in the Chinese National Knowledge Infrastructure (CNKI) database of journals require less references and are generally shorter, CNKI publications are therefore considered to be less impactful.²⁰² While there does appear to be a decrease in the production of Chinese language publications, the qualitative development of Chinese research, currently, does not appear to be as impressive as the quantitative growth in publications and citations.

²⁰⁰ Han and Appelbaum, “China’s Science, Technology, Engineering, and Mathematics (STEM) Research Environment: A Snapshot,” 2; National Science Board, “2018 Science and Engineering Indicators,” O19.

²⁰¹ Hugo Horta and Wenqin Shen, “Current and Future Challenges of the Chinese Research System,” *Journal of Higher Education Policy and Management*, 2019, 13, <https://doi.org/10.1080/1360080X.2019.1632162>.

²⁰² Qingnan Xie and Richard Freeman, “Bigger Than You Thought: China’s Contribution to Scientific Publications,” *NBER Working Paper Series*, 2018, 8, <https://doi.org/10.3386/w24829>.

In addition to the impacts that collaboration and citations have on the quality of science, the “research for the sake of national prestige” rather than “research for the sake of knowledge pursuit” hampers the advancement of innovation in China. Some of the practices of China’s research system suggest that what matters in China is not the substance of the science achieved, but the volume of science attained. While there are many ways this culture is perpetuated, here are two examples. First, the massive increase in production of scientific publications is partially due to the compulsion of doctoral students to publish as a part of their doctoral programs. Although not explicitly dictated by policy language, a de facto requirement exists for doctoral candidates to publish multiple papers and possibly receive a certain amount of citations before being allowed to defend their dissertations.²⁰³ Such requirements drive other negative externalities such as increasing the retraction rates due to practices such as falsifying peer reviews and ghost authoring.²⁰⁴

Second, the publish or perish dynamic in China’s research culture incentivizes the production of publications, not the impact of research. In particular, researchers are incentivized to publish frequently in their respective fields, and publication count factors into the cash prizes as well as recruitment, tenure, and promotion of university faculty.²⁰⁵ Goals of boosting the international standing of its universities has created a culture where the production of research publications is more valued rather than the quality and impact of the knowledge that is produced. The perils of not publishing in line with the evaluation cycle include further financial support and punitive sanctions which thus incentivize

²⁰³ Cao et al., “Reforming China’s S&T System,” 461; Zhang, Patton, and Kenney, “Building Global-Class Universities: Assessing the Impact of the 985 Project,” 773.

²⁰⁴ Horacio Rivera, “Fake Peer Review and Inappropriate Authorship Are Evils,” *Journal of Korean Medical Science* 34, no. 2 (2019): 3, <https://doi.org/10.3346/jkms.2019.34.e6>; Han and Appelbaum, “China’s Science, Technology, Engineering, and Mathematics (STEM) Research Environment: A Snapshot,” 2.

²⁰⁵ Mei Tian, Yan Su, and Xin Ru, “Perish or Publish in China: Pressures on Young Chinese Scholars to Publish in Internationally Indexed Journals,” *Publications* 4, no. 2 (2016): 3, <https://doi.org/doi:10.3390/publications4020009>.

problematic behavior such as fraud and plagiarism in order to pass evaluations.²⁰⁶ While there may be exceptions to this norm in highly reputable journals, the structure of the research system, which is centered around plan driven targets as well as an evaluation system to distribute rewards, values the production volume of research rather than the production quality of research, and this further dilutes Chinese research.

A final weakness worth highlighting is the lack of basic research in China's National Innovation System (NIS). This weakness is driven by the fact that because most private enterprises in China lack the requisite capital to devote toward basic research, the main source of basic research is thus universities and research institutes. This bifurcated system leads to research that is interesting in academia but not useful in marketable applications. Furthermore, while the government has sought to foster R&D in industry, it continues to underfund basic research, in general. Because of these issues, China lacks a core technology base and China tends to rely on technology transfers either through policy, theft, or acquisition.

China's institutional arrangement for state-led innovation likely resulted from its Soviet ties in the 1950s. As discussed earlier, the shift of universities from purely knowledge and vocational training toward scientific inquiry and research is a fairly recent development. However, the presence of an adjacent established publicly funded research institutions suggests Soviet influence and further hints at why Chinese enterprises do not conduct much basic research or R&D writ large.²⁰⁷ Because the burden of R&D and providing core technology fell on research institutes rather than enterprises themselves, China's innovation system has developed into two tracks with basic research being

²⁰⁶ Han and Appelbaum, "China's Science, Technology, Engineering, and Mathematics (STEM) Research Environment: A Snapshot," 13; Tian, Su, and Ru, "Perish or Publish in China: Pressures on Young Chinese Scholars to Publish in Internationally Indexed Journals," 3; Silohenda Amuthenu, "Current Trends and the Consequences of Research Activities among Chinese Universities," *Open Access Library Journal* 6, no. e5847 (2019): 2, <https://doi.org/10.4236/oalib.1105847>; Jon Schmid and Fei-Ling Wang, "Beyond National Innovation Systems: Incentives and China's Innovation Performance," *Journal of Contemporary China* 26, no. 104 (March 4, 2017): 291, <https://doi.org/10.1080/10670564.2016.1223108>.

²⁰⁷ Immanuel C. Y Hsu, "The Reorganisation of Higher Education in Communist China, 1949-61," *The China Quarterly*, no. 19 (1964): 136-39; Futao Huang, "From the Former Soviet Patterns towards the US Model? Changes in Chinese Doctoral Education," Centre for Global Higher Education Working Paper Series (London: Centre for Global Higher Education, January 2017), 5-6, <https://www.researchcghe.org/perch/resources/publications/wp12.pdf>.

concentrated in the university/research institute (URI) side of the house rather than the industrial/enterprise side.

Further evidence of this institutional arrangement can be found in the fact that only 0.03 percent of domestic enterprises own their own intellectual property, which is consistent with the claim that most basic research is conducted on the university/research institute side.²⁰⁸ Yet, in spite of the fact that China is mostly reliant on state-funded institutions for basic research, there is little indigenous core technology to provide to the industrial sector. Part of the reason is that because there is a disconnect between research institutes and enterprises in what is researched and what technologies are needed. Research institutes and academics conduct research that is relevant to their disciplines and state goals, but enterprises are looking for core technologies that are relevant to products they are trying to develop and market.²⁰⁹

Another outcome of primarily state-led basic research is that funding is primarily supplied by the state, and the state has underfunded basic research. Figure 7 compares the R&D spending profiles of the US, China, and Japan from 2000–2016. While the United States and Japan has devoted approximately 18 percent and 12 percent of its R&D expenditure toward basic research, respectively, China has maintained a consistent 5 percent investment on basic research.²¹⁰

²⁰⁸ Liu, He, and Cheng, *Basic Research and Industrial Innovation in China*, 2:219.

²⁰⁹ Liu, He, and Cheng, 2:261, 315.

²¹⁰ ChinaPower Team, “Is China a Global Leader in Research and Development?”; Liu, He, and Cheng, *Basic Research and Industrial Innovation in China*, 2:220; Wei Yang, “Boost Basic Research in China: Improving the Quality, Integrity, and Applicability of Scientific Research Will Underpin Long-Term Economic Growth” *Nature* 534, no. 7608 (June 23, 2016): 467.

Expenditure by Research Type (%)

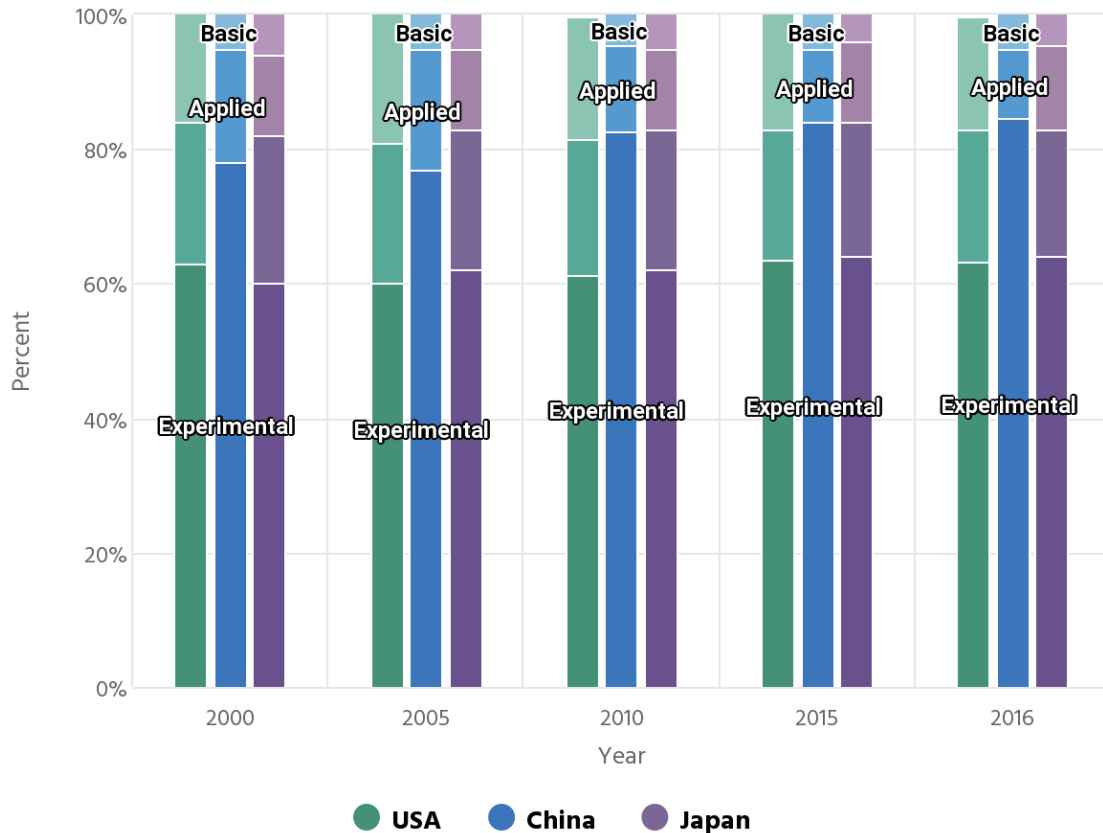


Figure 7. Expenditure by Research Type (%)²¹¹

This is problematic because China, as a result of its industrial catch-up efforts, has not created its own base of indigenous core technology. Thus, the applied research and product development that takes place in enterprise is reliant on core technologies that are exogenous to China. Evidence of this was illustrated in 2018 when Chinese telecom manufacturer, ZTE, was briefly banned from buying U.S. semiconductors.²¹² This is not to say that all companies underinvest in R&D, but as the last chapter highlighted, SOEs have comprised the bulk of R&D resources and expenditures (nearly 66 percent in 2016),

²¹¹ Source: ChinaPower Team, “Is China a Global Leader in Research and Development?”

²¹² Lewis, “Learning the Superior Techniques of the Barbarians: China’s Pursuit of Semiconductor Independence,” 23; Andrew Kennedy, “Technology: Rapid Ascent and Global Backlash,” in *Power*, ed. Jane Golley, Linda Jaivin, and Paul Farrelly, n.d., 74.

and thus greater competition for resources in the private sector has made private enterprise devotion to R&D the exception rather than the norm.²¹³ The bottom line is that while China produces publications and patents at a rate that is comparable to other, more innovative countries, its funding streams toward R&D need to be brought more in line with the levels of its peers, with greater emphasis being placed on basic research.

D. CONCLUSION

Have China's education policies fostered the necessary foundation for innovation? While China appears to be having some level of success producing researchers and volumes of research, issues with the cultivation of talent in primary and secondary education temper the efficacy of Chinese educational policy. Yet, the growing lineup of Chinese STEM graduates who have grown up in a research-focused educational system means that incremental generational gains are likely to occur. However, the fairly recent reform toward a research-based, creativity-driven culture in academia combined with the long time horizon required to educate a generation means that this era is likely at least twenty to thirty years away.

This confidence is based on the conditionality that a few issues, acknowledged by the CCP, will be addressed. First, institutional incentives that emphasize quantity over quality will be changed relatively soon. Evidence that the CCP has caught on to this already is seen in the 13th FYP which calls for a set number of patents to be in compliance with the Patent Cooperation Treaty (PCT). Secondly, a number of scholars within China, as well as Xi Jinping himself, have recognized that basic research funding and coordination is deficient and one should therefore expect there to be an increase in basic research funding in the near future. Finally, the trajectory of Chinese STEM graduate production will continue to grow as well as patents and journal publications.

However, one factor that may alter this growth trajectory is the developmental process that the primary/secondary education side plays. The development, selection, and cultivation of talent seems less meritocratic and the broader social problems that must be

²¹³ ChinaPower Team, "Is China a Global Leader in Research and Development?," paras. 14–15.

dealt with suggest that creating an efficient and meritocratic process of building its talent base to feed into universities may create a bottleneck in knowledge production in which the demand for qualified candidates exceeds the output of STEM graduates.

While China's achievements in fostering innovation in through their education system is not an unabashed adjudication of success, the weaknesses in the Chinese education system, particularly in higher education, have not prevented the transition from primarily knowledge delivery focus to research focus thus far. If China STEM education production continues to grow in trajectories consistent with current trends, the numerical output will create substantive innovation improvements for China and possibly present a competitive challenge to U.S. S&T innovation.

IV. CONCLUSION

This thesis sought to assess the impact of Chinese national policy on the development of Chinese S&T innovation. It explored two major sources of innovation—industry and the education system. Overall, the effectiveness of Chinese innovation policy is fairly mixed at this time with more optimistic signs coming from the educational side of China's national innovation system. While it is still too early to predict whether or not China will achieve its stated goals of becoming an innovation powerhouse by the middle of this century, there are several notable strengths and equally as many weaknesses.

In industry, the Chinese have shown some capacity to foster innovation in both SOEs and more significantly, private enterprises. There appears to be some appetite toward further scaling down SOEs and increasing their efficiency. Yet, SOEs still have a lower innovation efficiency (return on investment) than private firms do which can be attributed to the state interest and subsidization of risk which has led to a preponderance of R&D investment going toward the state sector, as hypothesized by Hypothesis 2. Additionally, the weaknesses of Chinese IPR have driven the development of an open innovation system, which is consistent with Hypothesis 1 in the sense that the lack of core technology has kept Chinese firms at the product development stages which are reliant on others core technology, rather than intellectual property that is endogenous to Chinese firms. This may be China's own unique path to innovating and advancing S&T. However, the most promising development in Chinese industry is the rise of big tech. This is significant because as I highlighted in Chapter II, companies like Huawei are adequately capitalized and properly oriented toward placing value in building substantive research capacity in addition to their product development abilities.

However, private companies that place emphasis on R&D are the exception rather than the norm, and this is, in part, a product of underinvestment in the private sector. Attempts to achieve spillover effect may have some effect, but it has not spurred a corporate change in small and medium enterprises to develop impactful research capabilities required for S&T innovation. Additionally, Chinese firms, writ large, are fairly inefficient at converting R&D investment into high value-captured products. In other words, Chinese

firms are not very innovative as measured by return on asset, and in pursuit of these innovations, Chinese firms are rather inefficient at spending their R&D investments. This can partially be explained by the fact that the incentives and directives are not in place to drive the kind of necessary investments in industrial research capacity. From this standpoint, I find that the problems posited by Hypothesis 3—inefficiency created through quantitative production targets—are less explained by misallocation and overcapacity, but misplaced incentives.

On the educational side, the second and third order effects of producing more STEM graduates and higher output of research are perhaps the greatest reasons for optimism. This is because while the quality of output may not be world-leading at this time, generational improvements are likely as future students will be better equipped, through their compulsory and undergraduate educations, to think critically and have an inclination toward scientific inquiry. While the shift toward critical thinking and scientific inquiry has yet to happen throughout China, the fact that it is happening and succeeding in some of China's largest and most densely populated areas on the east coast suggests that there are sustainable and substantive changes occurring in China's education system.

On the other hand, the Chinese education system also faces some barriers to fostering innovation. For primary and secondary students, educational outcomes are still a function of socioeconomic status and highly geographically dependent. These social inequities add to the inefficient distribution and development of STEM talent and reinforces an outdated role that education is status symbol rather than an engine that drives S&T progress. In higher education, China's researchers are incentivized to produce more rather than create impact. This incentive structure drives Chinese researchers to plagiarize, commit fraud, and produce unimpactful research, which is also consistent with Hypothesis 3 in the sense that publication output targets are driving inefficiencies in fostering S&T innovation. Finally, because research is highly concentrated in academia and is largely funded by the state, basic research in China is underfunded compared to OECD nations. This provides some explanatory power for why China has a shallow base of its own core technologies.

The quality of Chinese research and government funding are helpful in describing China's developments in frontier sectors such as AI and genetics. On the one hand, China has led the world in journal production in AI since 2005 and is quickly catching up to the U.S. in the production of articles on CRISPR gene editing.²¹⁴ On the other hand, the broad trends associated with lower quality and impact as described in chapter 3 are found to be applicable in these emerging sectors as well.²¹⁵ Ultimately, however, the government's role in facilitating development in these areas may be most telling of Chinese progress in AI and genetics. In AI, the production of government sponsored research papers grew 400 percent between 2007 and 2017 and the government-affiliated contribution toward AI paper production (research institutes) is roughly three times of that produced by industrial production—a trend that is consistent with the findings of chapter three.²¹⁶ In genetics, the government serves a more passive role through not creating the same institutional barriers that hold back progress in genetics research in the US.²¹⁷ These findings appear to be partially consistent with hypothesis 4 which posits that the timing which these sectors have emerged have predisposed China to being on the technological frontier of these sectors. Indeed, this is true in some ways due to Chinese interest in S&T innovation just as these fields were emerging as frontiers of science, but it misses the broader illustration of the role that the government plays in driving and sustaining innovation as opposed to the U.S. where industry plays a larger role in driving and sustaining innovation.

²¹⁴ John Cohen and Nirja Desai, "With Its CRISPR Revolution, China Becomes a World Leader in Genome Editing," *Science | AAAS*, August 2, 2019, <https://doi.org/10.1126/science.aay9689>; Saurabh Mishra et al., "Artificial Intelligence Index Report 2019," AI Index Steering Committee, Human-Centered AI Institute (Stanford, CA: Stanford University, December 2019), 16, https://hai.stanford.edu/sites/g/files/sbiybj10986/f/ai_index_2019_report.pdf; Tom Simonite, "China Is Catching Up to the US in AI Research—Fast," *Wired*, March 13, 2019, <https://www.wired.com/story/china-catching-up-us-in-ai-research>.

²¹⁵ Mishra et al., "Artificial Intelligence Index Report 2019," 18; Simonite, "China Is Catching Up to the US in AI Research—Fast," paras. 5–7.

²¹⁶ Mishra et al., "Artificial Intelligence Index Report 2019," 16; Simonite, "China Is Catching Up to the US in AI Research—Fast," para. 10.

²¹⁷ Preetika Rana, Amy Marcus, and Wenxin Fan, "China, Unhampered by Rules, Races Ahead in Gene-Editing Trials," *Dow Jones Institutional News*, January 21, 2018, para. 6, <http://search.proquest.com/docview/1989469385/>.

Although these emerging sectors offer a glimpse at areas where China could be a leader in S&T innovation, the big picture is still that industry remains deeply focused on marketization and product development rather than on advanced technology research. This largely explains the notion that Chinese firms produce new products that improve on existing technology or processes, but do not constitute invention. But, because some experts have pointed to this fact as evidence that China is becoming innovative, it has spurred an underlying debate that has appeared throughout my research: *what constitutes innovation?* For some scholars, efficiency gains in production processes and/or efficiency gains for the end user constitute innovation. For others, however, innovation encompasses invention as well as the development and reliance on indigenously developed core technologies. Because the significance of this thesis is, in part, derived from concern over China's rise as a technological and economic power relative to the US, the latter definition serves as a more appropriate standard to assess Chinese policy in fostering S&T innovation. Chinese firms underinvest and underproduce in basic research which is where core technologies are sourced. As long as this is the case, China will continue to be reliant on external technology which will continue keep China from becoming indigenously innovative, as posited by Hypotheses 1 and 2. It is, therefore, the main argument of this thesis that China is not yet becoming innovative in the realm of S&T. However, simple policy tweaks could go a long way towards becoming innovative.

A. POLICY RECOMMENDATIONS

In both sectors, there are policies that could be easily tweaked to facilitate greater efficiency in fostering innovation.

- Reward firms based on impact rather than output

Patent and publication goals set through the five-year plans currently focus on the quantitative output which, as this thesis has posited, contributes to a shallow innovation culture that is highly focused on development rather than substantive research. A change from quantitative toward rewarding firms for their value captured through licensing fees and citations in the first 5–10 years after patent granting/journal publication would help to motivate firms to focus on becoming globally competitive.

- Overhaul the research evaluation system to focus on quality

China needs to find a way to curb the publish or perish culture. Publications in high impact journals and international journals should weigh more heavily in evaluations over the quantity of publications during an evaluation period. Because the scale of output is now globally competitive, China should now shift toward making this depth in research capacity produce at a higher level. Eliminating the pressures to publish constantly will also help foster a devotion toward deeper, longer term research that likely result in more impactful publications.

- Increase the prescription for R&D investment

As pointed out in chapter two, the 13th Five-Year Plan only prescribes firms to invest 1.1 percent of revenue toward R&D. For context, the gold standard of Chinese firms, Huawei, spends approximately 15 percent of revenue on R&D. Directing and rewarding firms who spend a more optimal amount on R&D will help foster the development of the research capability that has been missing in industry. Furthermore, this will help to balance out and alleviate the burden on the government in funding research over the long term.

- Increase funding for Basic Research

This recommendation may be the most difficult to implement. In comparison to OECD nations, China spends relatively little on basic research. Because basic research is a big source of core technology, China needs to either reprogram some of its existing funding from development to basic research or better manage its funding to ensure that it is going to basic research. The greatest difficulty with this recommendation is that this thesis has presented evidence that China lacks the institutional capacity to direct investment to the appropriate sectors to foster R&D.

- Change the incentive structure for Teachers

Create better incentives for outstanding teachers and school administrators to be teaching in poorer areas and underperforming schools to lift up the aggregate standard of Chinese schools rather than focus on building “super-schools” meant to cater to the most talented students. Increasing the aggregate quality of Chinese compulsory education will

also help to more efficiently use educational investments intended to develop a more lasting and permanent scientific inquiry-based education system. This will also create a broader base of STEM graduates that will be needed to help move China towards becoming a scientific-oriented society and consequently an innovation powerhouse by 2050.

While it may be years before data will show that China is becoming innovative, seeing decisive policy action that is similar and/or consistent with the recommendations above could be predictive of a coming scientific renaissance in China.

B. IMPLICATIONS FOR THE UNITED STATES

If China manages to successfully carry out the necessary reforms toward becoming innovative, there are a couple of things that the U.S. should do in light of the development of Chinese innovation. In general, these efforts should involve bolstering the US's lead to stay ahead of Chinese innovation.

First the U.S. should seek cooperation with China in the development of ethics in frontier areas such as AI, 5G, and genetics in which it is conceivable that normative and ethical barriers that restrain the U.S. but China is unbound by could have effects on the future of the innovation balance. In these frontiers of S&T, the U.S. could temper Chinese development where the U.S. does not have a decisive lead and/or is bound by ethical concerns. Having both countries lead the development of norms could also be a gateway to further cooperation with a China that has designs on becoming more self-reliant and increasingly closed off to the West.²¹⁸

Second and most significantly, the U.S. should reinforce the development of its human capital to ensure that it is and will continue to be a world leader in producing researchers and STEM graduates who can and will contribute to America's S&T lead. This includes devoting a greater focus on STEM education during compulsory education and programs to either subsidize the postgraduate education and education of American scientists and engineers, as recommended in a House Foreign Affairs Committee

²¹⁸ FP Analytics, "Mining the Future: How China Is Set to Dominate the Next Industrial Revolution.," pt. 3; Randolph, Bishop, and Hamirani, "Chinese Innovation: China's Technology Future and What It Means for Silicon Valley," 29.

testimony.²¹⁹ As China looks to move up the global supply chain from being a low-value added segment of the supply chain toward being the supplier of technology where a large amount of value is added, the U.S. will have to contend with an increasingly competitive Chinese innovation system that will challenge American scientists and engineers for both jobs and supplying intellectual property. In this regard, the U.S. needs to protect and elevate its human capital.

In the past year, the US has stepped up efforts to prevent Chinese FDI from buying access to American technology.²²⁰ Through the US Treasury Department's Committee on Foreign Investment in the United States (CFIUS), the US has stepped up efforts to scrutinize potential Chinese investment, merger, and acquisition of American technology and firms.²²¹ In addition to these efforts, there are a couple of other actions that I posit would help the US to meet a rising Chinese challenge. The first measure is to better protect digitally stored intellectual property from being stolen by Chinese hackers. This will require greater cooperation between American firms as well as the American government. The government could set forth standards for cyber security for firms and follow up with subsidies to help smaller, more vulnerable firms establish a more vigilant level of cyber security.

Second, the US could incentivize American educated Chinese students to stay and work for the US rather than China.²²² This is advantageous for a couple of reasons. First, the successful retention of US educated Chinese STEM graduates would help to ameliorate security concerns over Chinese researchers returning to China with the knowledge of American core technologies. Secondly, as China's efforts to attract greater numbers of overseas Chinese back to work in China, US efforts to stem the outflow of Chinese

²¹⁹ Elizabeth Economy et al., "Smart Competition: Adapting U.S. Strategy Towards China at 40 Years," § Foreign Affairs (2019), <https://foreignaffairs.house.gov/2019/5/smart-competition-adapting-u-s-strategy-toward-china-at-40-years>.

²²⁰ Mira R. Ricardel, "These New Rules Might End Tech's Reliance on Chinese Investors," *Fortune*, January 20, 2020, <https://fortune.com/2020/01/20/cfius-rules-regulations-china-investment>; "Trump's Trade War."

²²¹ Ricardel, "These New Rules Might End Tech's Reliance on Chinese Investors."

²²² Economy et al., Smart Competition: Adapting U.S. Strategy Towards China at 40 Years.

researchers back to China could help to suppress China's innovation development. While security and allegiance concerns will always pose risks for international students and researchers from China in American universities, the benefits of retaining Chinese talent in the US to contribute to US technology in a technological competition could outweigh these risks.

Overall, if the US perceives China's growing technological prowess as a threat, then it should not necessarily rely solely on defensive measures to keep China out, but rather invest internally to grow the US's technological advantage. Using more selective criteria for identifying key technologies to protect, upgrading the US public's vigilance towards cyber threats, and competing better to keep foreign talent are some more active defensive measures that the US can take. However, fencing off Chinese access will only deepen the competitive dynamic of US-Sino relations, and it will do nothing to ensure that the US stays ahead of China technologically. Because there are reasons to be bullish on Chinese innovation, it should not be assumed that the US can and/or will maintain a technological edge simply based on the fact that it has a more vibrant S&T innovation system at the current moment. Cooperating with the Chinese will ensure that technology adoption will be less binary and zero-sum as the worldwide 5G adoption example illustrates. Focusing on the development of American S&T talent will help to better facilitate the expansion of America's technological lead.

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