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**Beyond Catch-up: Could China Become the Global Innovation Powerhouse?**  
—China's Innovation Progress and Challenges from a Holistic Innovation Perspective

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Jin CHEN<sup>1,2</sup>, Ximing YIN<sup>3\*</sup>, Xiaolan FU<sup>4</sup>, Bruce McKern<sup>5</sup>

1. School of Economics and Management, Tsinghua University, China

2. Research Center for Technological Innovation, Tsinghua University, China

3. School of Management and Economics, Beijing Institute of Technology, China

4. Technology and Management Centre for Development, University of Oxford, United Kingdom

5. Business School, University of Technology Sydney, Australia

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\* **Corresponding author:** Ximing Yin, E-mail: yxm11@tsinghua.org.cn

**ABSTRACT:**

Over the last century and a half, global technological leadership has shifted from Europe to the United States, while scholars argue that the world has seen that it is now shifting from the U.S. to China due to China's extraordinary catch-up in the past 4 decades, in which the public policy-oriented national innovation system development plays a critical role that might provide an alternative way for innovation-driven development especially for emerging markets. Even though encountering many challenges ahead, China is positioning itself to take over the global innovation leadership in the next few decades. Here in this paper, we introduce a serious yet underexplored question: could China go beyond catch-up and become the global innovation powerhouse? Specifically, drawing from the holistic innovation perspective, which is an original theoretical paradigm for the mission-oriented innovation policy change, this paper critically reviews, both qualitatively and quantitatively, China's remarkable innovation progress and main drivers in comparison with G7 countries plus South Korea and India, trying to provide a comprehensive and critical view of state-of-the-art research on China's innovation catch-up. We further explore the five major challenges that China's must take seriously when marching towards the global innovation powerhouse. Finally, we propose a mission-oriented holistic STI policy design framework for both China and other emerging economies to go beyond catch-up in a competitive dynamic world. This paper provides a new and holistic perspective to access China's innovation progress and challenges, also generates novel insights for scholars and public agencies to contribute to global innovation development, with a shared goal of achieving global sustainable development in the post COVID-19 pandemic world.

**KEYWORDS:** Catch-up; China; Innovation Development; Holistic Innovation; Mission-oriented Innovation Policy; Sustainable Development

**JEL:** B52 – Historical; Institutional; Evolutionary; F63- Economic Development; O25 - Industrial Policy; O33 - Technological Change: Choices and Consequences; Diffusion Processes; O38 - Government Policy

## 1. Introduction

Innovation has been widely regarded as the most important driving force for industrial catch-up, endogenous economic growth, sustainable competitive advantages, as well as driving global sustainable growth (J. Chen, Yin, et al., 2020; Dosi, 1982; Fu & Gong, 2011; K. Lee & Malerba, 2017; Keun Lee, 2016; Lewin et al., 2016; Mazzucato, 2018). China, as a typical latecomer in industrialization, has been continued to invest in science, technology and innovation, aiming to tackle the so-called middle-income trap(MIT) (Cai, 2012; Keun Lee, 2016; Lewin et al., 2016), move upward in the global value chain as well as build a strong national innovation system to obtain the new power of sustainable socio-economic development (Fu, 2015; D. Li et al., 2019; Yip & McKern, 2016; Yu et al., 2017). Not only does China is going to take the global leadership in economic development, but also China has been trying to move up to the innovation leaders in the global innovation map through continuous Science, Technology, and Innovation (STI) policy and effective implementation of National Innovation-Driven Strategy (Chen et al., 2018; Fu et al., 2016). Both the world and Chinese people have seen the raising of China's innovation capacity as well as the innovation capability improvement of Chinese companies after entering the 21-century (Ernst, 2011; Huang & Sharif, 2016; Keun Lee, 2016; Someren & Someren-Wang, 2014; Yip & McKern, 2016). The rise of China's innovation is receiving more and more attention from the world, even so-called "trade war" between China and U.S. lighted up by the U.S. government since the early of 2018, "is not about trade; it is about who will lead global innovation in the 21<sup>st</sup> century."<sup>1</sup> At the same time, China, like most of other emerging economies, is encountered with many critical challenges on the road of towards a strong innovative nation (Fu et al., 2016; Shang-Jin et al., 2017), as which a powerful way to overcome the middle-income trap(MIT) (Keun Lee, 2016; Kong-rae Lee et al., 2017; Lewin et al., 2016).

**China's fast catching up also attract global academic attention trying to study the dramatic rise of the Chinese economy with a goal to explain why it happened and what are left to be deal with for China's to hasten the progress** (Fu, 2015; Fu et al., 2021; Huang & Sharif, 2016; Lewin et al., 2016; Someren & Someren-Wang, 2014; Yip & McKern, 2016). For example, the classical book *China's Innovation Challenge: Overcoming the Middle-Income Trap* edited by Arie Lewin et al. (2016) discussed the complexities and challenges of transforming the Chinese economy into an innovation-driven one from a wide range of perspectives, the conclusion regarding China's innovation from buoyant optimism, with a focus on China's increasing innovative capability, which is similar as argued by Cai(2012) and Ernst (2011), to deep pessimism, with a critical concerns of China's incapacity to

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<sup>1</sup> Said by Geoffrey Garrett, former dean of Wharton Business School. See also: <http://knowledge.wharton.upenn.edu/article/u-s-china-trade-war-really-future-innovation/>

overcome the middle-income-trap in the absence of radical and political reforms from the political and sociology perspective. However, this book is more focus on “overcoming the middle-income trap (MIT)” issue which is an economic transition development perspective on innovation ignoring the reversed relationship that innovation is a critical way for overcoming the MIT (J. Chen et al., 2018; Kong-rae Lee et al., 2017; Romer, 1986). In which the chapter by Keun Lee (2016) presents a constructive view from the innovation economist perspective, pointing out that “innovation is a significant factor for economic growth in middle-income countries and particularly relevant for China” (Keun Lee, 2016, p. 109), because “the difference between the more successful Asian economies and the less successful Latin American economies can be explained by the amount of priority given to the enhancement of long term growth potentials, particularly innovation capability” (Keun Lee, 2016, p. 110). He concluding that China has already passed the “technological turning point” by increasingly moving into short-cycle technology-based sectors, as “China increasingly become innovative and thus differs from other middle-income countries, therefore is not likely to be falling into the MIT” (Keun Lee, 2016, p. 118). This is in line with the core argument of Malerba & Lee (2020) as well as the *Handbook of China Innovation*, edited by Fu, Chen and McKern (2021), that catch-up is a long-term process of closing the gap in capabilities by promoting learning and innovation in interaction with innovation system.

On the other hand, **current scholarly work, either draws from economic perspective (i.e. (Lewin et al., 2016), or from innovation system perspective (Malerba & Lee, 2020), or public policy perspective (Ernst, 2011), have either explored China's innovation with the underlying assumption of a friendly international socio-political environment which has been changed since the China-U.S. “trade war” in 2018, or only from the perspective of “catch-up”, instead of thinking about “beyond catch-up”.** Especially, since year 2019, China's GDP per capita is more than 30% (a typical upper range of “middle-income trap” area) of that of the U.S., which together denotes that China's innovation development is entering a new turning point, from only catch-up with developed economies like the U.S., to a serious competitor with these western players (Geoffrey, 2018), from a “short-cycle technology based sectors” to more difficult “long-term sectors” (Keun Lee, 2016), as well as going beyond the “catch-up” mindset to explore the alternative mode for global innovation-driven development, especially for the other emerging economies (J. Chen, Yin, et al., 2020; Fu et al., 2021; World Intellectual Property Organization, 2019).

**Regardless of the dynamic international environment, China is positioning itself to assume global leadership in cutting edge technologies and industries within the coming few decades, rather than just follow a catch-up curve and traditional approach, which calls for renewing the**

**perspective of science, technology, and innovation (STI) policy, which is a left question in Keun Lee's classical view on the innovation and technological specialization of China (Keun Lee, 2016).** To effectively implement the innovation-driven development strategy in the new stage of China's development requires a more comprehensive way of innovation with a larger scope and strategic vision to support and improve the regional innovation system (Chen et al., 2018; Lewin et al., 2011). **What we have to do ultimately is to answer the key and serious question: Could China go beyond catch-up and become the global innovation powerhouse?** More specifically, how does China deal with the innovation challenges and foster innovation by apply a better-designed mission-oriented holistic innovation approach in order to build an innovative nation, as well as contribute to the global peace and sustainable development goals (SDGs)?

Here in this paper, follow the innovation point of view (J. Chen et al., 2018; Fu, 2015; Malerba & Lee, 2020), we first briefly review China's achievements in science, technology and innovation (STI) performance by applying a method of international and historical comparison, to understand how does China perform in innovation up-to-date, which will help us predict the trend and future of China's road to an innovative nation. Then we draws from the holistic innovation perspective(J. Chen et al., 2018; J. Chen, Yin, et al., 2020), which is an original theoretical paradigm for the mission-oriented innovation policy (Mazzucato, 2018) change, providing a newly framework for scholar to understand how STI policies help China build up the competitive advantage of innovation capability (Gu & Lundvall, 2006), and identify challenges that China has to deal with for its future innovation-oriented growth. Finally, we propose a mission-oriented holistic framework of STI policy designing, aiming to contribute to China's innovation development beyond catch-up as well as other emerging economies in a competitive dynamic world. This paper not only adds comprehensive and critical thinking on understanding of China's march toward global technological and innovation leadership into research community, but also provides research and policy propositions on what need to be answered by further research and what need to be taken into consideration when designing STI policy in the future. What's more, this paper also generates novel insights for scholars and public agencies to contribute to global innovation development from the holistic innovation perspective, with a shared goal of achieving global sustainable development in the post COVID-19 pandemic world.

## **2. China's Catch-up and Reshaping Global Innovation Landscape**

### **2.1 China's Catch-up on Innovation Input and Output**

China's government launched a new national action plan<sup>2</sup> in 2017 as a sweeping vision for AI ascendancy, which aiming to attract the talents around the world to make “major breakthroughs” by 2025. As the article in MIT Technology Review entitled with *China's AI Awakening* commented that “The West shouldn't fear China's artificial-intelligence revolution. It should copy it” (Knight, 2017). This is a recent example of the remarkable action of China's STI policy and a mirror of China's becoming an innovation. In the past four decades since the reform and opening up in year 1978, the world has seen China's impressive accelerating innovation efforts and achievements in science, technology and innovation. Except the remarkable economic growth, China has also been the leading driver of global growth on patent applications, academic research publications, R&D investment, high-tech industrial product exports. As an example, China's STI policy on building a high-speed rail network since early 2000s spur technological development and improved the country's transportation system as well as accelerated the innovation in the whole manufacturing industry (Chen, 2017; Chen, Yin, et al., 2020; Chen & Mei, 2018; Knight, 2017).

Ernst (2011) examined the impact of China's innovation policy on the country's innovative capability and reviewed data on the speed of learning and catch-up that is transforming China's production and innovation system, he found that both input indicators (R&D investments, number of engineers and scientists) and output indicators (science and technology publications, patents) of China's evolving innovation capabilities show that China has become a serious competitor of the US, not only on price but also on technology. In the four decades since its opening to the world economy, China's speed of catch-up in innovation has been truly impressive. According to the report *Global Innovation Index 2019*, China ranks 14<sup>th</sup> in year 2019, which was 3 up from year 2018, becoming the first-ever middle-income economy in the top 15 innovative countries (World Intellectual Property Organization, 2019) and also the first time that surpass Japan (15<sup>th</sup>). According to the report *European Innovation Scoreboard 2018* by the European Commission, even though the EU continues to improve its position relative to the United States, Japan, and Canada. “However, China is catching up at three times the EU's innovation performance growth rate”<sup>3</sup>.

### 2.1.1 China's Cath-up on National Innovation Investment

The R&D expenditure in China has continued increase in the past decades, even during the global financial crisis of 2008 in which period most of other countries reduced R&D expenditure largely (See Figure 1). According to the Ministry of Science and Technology, China's spending on research and development (R&D) reached 2,173.7 billion RMB (about 3,080 billion USD) in 2019, with over 78

<sup>2</sup> Please see the National Action Plan of AI development: [http://www.gov.cn/zhengce/content/2017-07/20/content\\_5211996.htm](http://www.gov.cn/zhengce/content/2017-07/20/content_5211996.htm)

<sup>3</sup> See also: [http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards\\_en](http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en)

percent coming from enterprises. The gross domestic expenditure on R&D (GERD) accounted for 2.19% of GDP in 2019, 10.5% increased than that of 2018, with a 29-year continuous growing (see Figure 2).

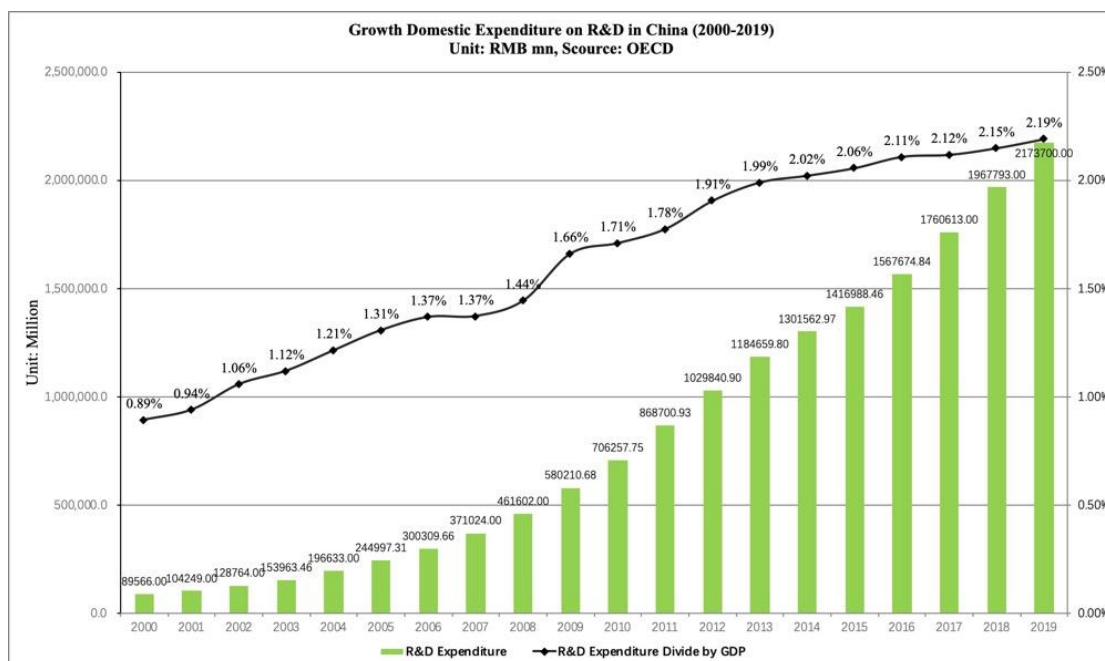


Figure 1 Growth Domestic Expenditure on R&D in China (2000-2019)

Unit: million RMB(Left); Percent (Right), Data Source: OECD

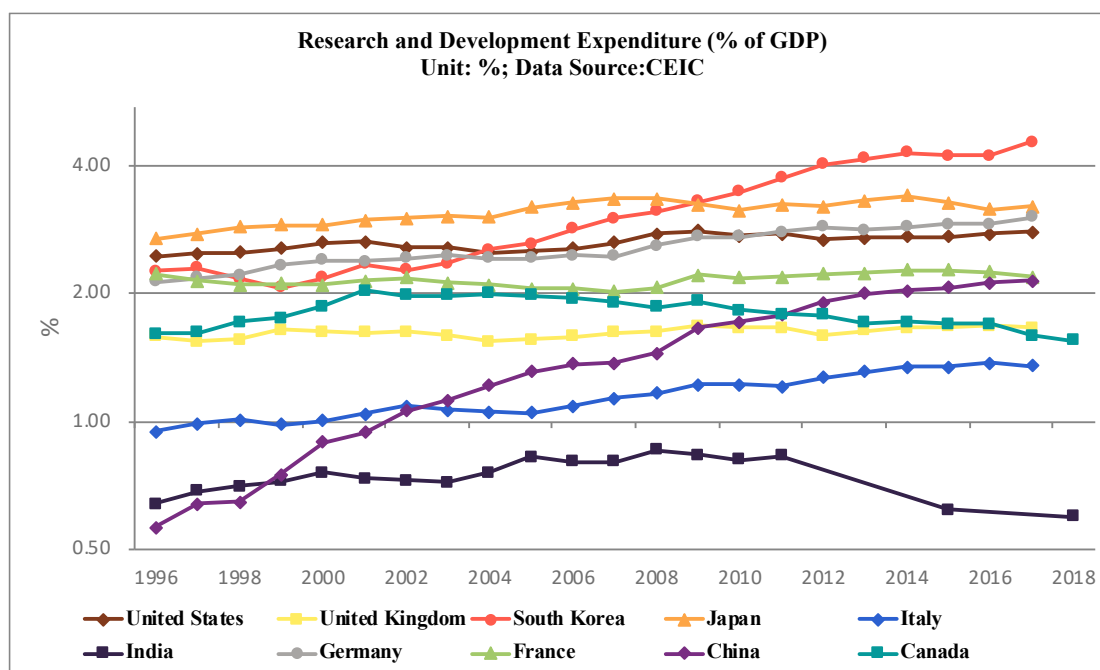


Figure 2 Growth Domestic Expenditure on R&D (1996-2018) Unit: Percent, Data Source: CEIC

In comparison with the Group 7 (G7) countries, South Korea and India (as shown in Figure 2), we could see that the gross domestic expenditure on R&D in China has already invest a bigger ratio

of GDP on R&D than that of India, UK, Canada, Italy, and France. The indicator is catching up quickly and shows a trend to catch up with that of United States soon.

According the Ministry of Science and Technology in China, the scientific and technological progress contribution increased to 59.5 percent in China's economic growth in 2019, which means that China is becoming a research-intensive and innovation-driven economy, no longer a labor-intensive economy anymore. China's R&D expenditure also championed the global innovation map. The study of global R&D data in the report *Global Innovation Index 2018* by WIPO yields that about eight years after the financial crisis in 2008, the worst-case scenario of permanently reduced R&D growth has to date been avoided, thanks to these anticyclical innovation policies and the role of R&D champions such as China, which have consistently spent large and growing sums on R&D. China's gross domestic expenditure on R&D (GERD) has increased by 276% comparing to that of 2018, ranking 1<sup>st</sup> among all the nation<sup>4</sup>.

### 2.1.2 China's Catch-up in Science and Technology Output

One main result from the continues investment in research and development and innovation system building driven by the National Innovation System, China gains ground in ranking of research nations with significant progress on scientific and technical knowledge creation. Based on the analysis conducted by Elsevier, and has garnered the second-most worldwide citations of academic research papers, just behind the United States and ahead of the United Kingdom<sup>5</sup>. And the number of papers published in most influential international journals in various disciplines written by Chinese scholars has been ranked second in the world for seventh consecutive years, which means China has also made a huge improvement in science research and innovation. According to the *Science and Engineering Indicators 2018* by the National Science Board of US, China's share of world total science and engineering publications grew from 12.1% in 2006 to 18.6% in 2016, becoming the leading country among the S&E publications, while the U.S. share declined from 24.4 to 17.8% (National Science Board, 2018).

In order to grasp the landscape of global innovation map and the dynamics between mains players in the past 20 years since new century began, we choose the G7-group countries, newly industrialized economy South Korea, and Asia second largest emerging market India to conduct an international and historical comparisons. In the Figure 3, we demonstrate the annul number of science and technical research journal articles published in the international journals by selected countries experiences significant dynamics since year 2000. While the annual S&E research publications shows incremental

<sup>4</sup> Please see: <http://www.globalinnovationindex.org/Home>

<sup>5</sup> See the newspaper: [http://www.chinadaily.com.cn/world/2017-10/17/content\\_33340948.htm](http://www.chinadaily.com.cn/world/2017-10/17/content_33340948.htm)

growth in Germany, Japan, South Korea, Italy, France and Canada, India, publications from emerging markets like India and China shows a significantly increase in the past two decades. However, the United States experiences a small but significant trend of decrease since year 2014 while most of other countries are catching up. Especially, China shows a radical increase in the total number of publications during the period, and quickly catch up with the six main players of G-7 group countries, and surpassed the U.S. for the first time in year 2016, and continue leading the global growth of new knowledge creation measured by S&E research publications.

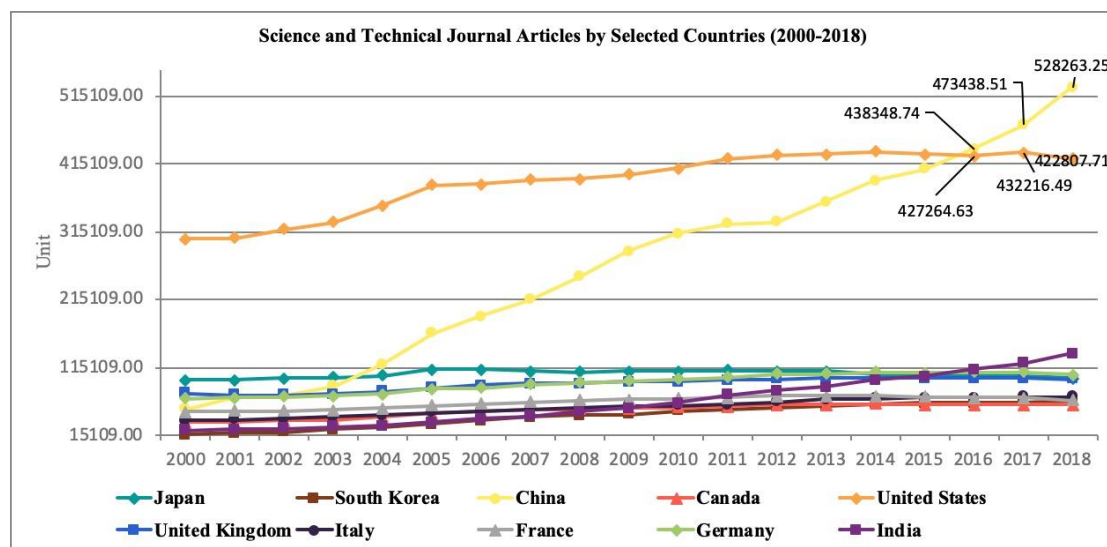


Figure 3 Science and Technical Journal Articles by Selected Countries (2000-2018) Data Source: CEIC

Patent applications, is another strong indicator that shows China continuing to lead the world growth in science and technological innovation. According to WIPO's annual World Intellectual Property Indicators 2018 (WIPI) report on worldwide filing activities for patent, trademark and industrial design applications for 2017. Worldwide filings for patents, trademarks and industrial designs reached record heights in 2017 amid soaring demand in China, which received more patent applications than the combined total for the United States of America, Japan, the Republic of Korea and the European Patent Office. Innovators around the world filed 3.17 million patent applications in 2016, up 5.8% in an eighth straight yearly increase, which mainly driven by the increasing of IP filings from China. From already high levels, patent filings in China grew by 14.2% and trademark filings by 55.2%. These high growth rates propelled China's shares of global patent filings and trademarks to reach 43.6% and 46.3%, respectively. China's office received a record total of 1.38 million patent applications in 2017, more than double the number received by that of the U.S. (606,956). If we look at the data of patent application number among the top five IP offices from year 1978 to year 2017 (see Figure 4), there is no doubt that China is build up a strong potential of technological innovation and will take the advantage of its intellectual property in a knowledge-based competitive world.



WIPO in the early 2020, China filed 58,990 applications in 2019 via PCT system, ended the U.S. (57,840) reign as the biggest user of PCT system (followed by Japan, Germany and the South Korea), one position held by the U.S. each year since the PCT system began in 1978. This is a milestone significant evidence showing that China not only continues leading global innovation growth measured by new patent, but also is going beyond the catch-up and taking its role of global leader in technology with high-quality and competitive intellectual property creation.

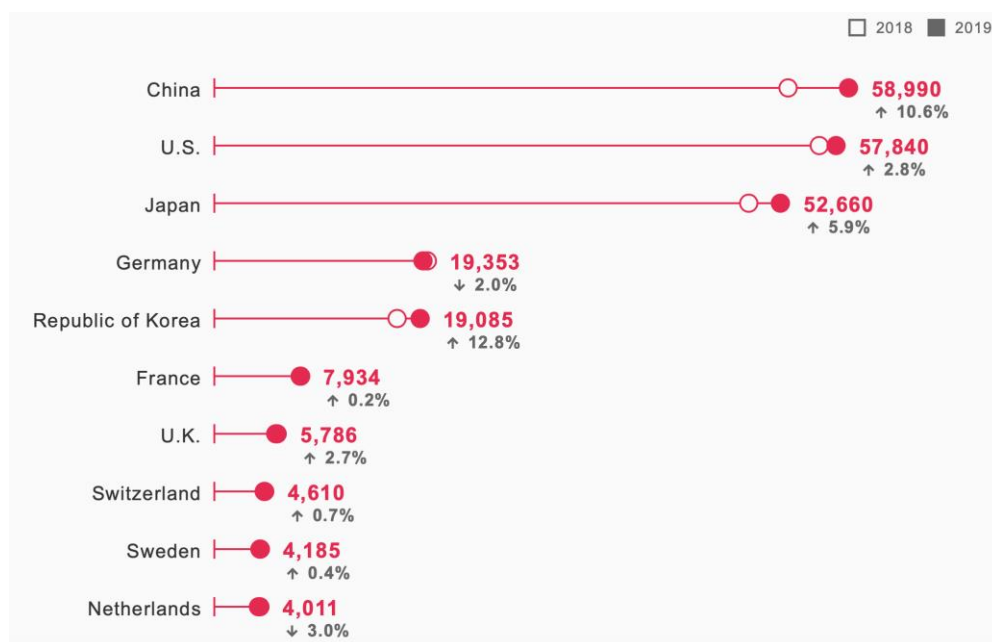


Figure 5 PCT Top 10 Countries in 2019 Comparing to 2018, Data Source: WIPO

## 2.2 Engineering Technological Innovation Catch-up in China

Even though China is a latecomer country that faces the issue of catch-up with the advanced countries, rather than the promotion of innovation through private sector R&D expenditure (M.-C. Hu & Mathews, 2005), we still observed that China has made great improvements in engineering technological innovation, including high-speed train, AI, quantum computer, new energy industry, and internet-based economy.

For example, in the highly competitive technology field of quantum computing, China has achieved the world's first quantum computer in year 2017<sup>8</sup>, and it can supposedly do calculations 24,000 times faster than its international counterparts. While other tech companies like D-Wave and IBM have already managed to build their own quantum computers, what differentiates China's quantum computer is the use of multiple photons (the visible particles of light), specifically five of

<sup>8</sup> Please also see: <http://wallstreetpit.com/113417-worlds-first-quantum-computer/>

them, which is what gives its computing speed a super boost. This remarkable breakthrough helps China set up its advantage in quantum device and will finally boost other industry.

Following the financial crisis of 2008, the main measurement of development, GDP measures, ignores social costs, environmental impacts and income inequality (Costanza et al., 2014). We have seen that economists and national leaders are increasingly talking about how to create or find new energy that is more environmentally friendly and more sustainable. Methane hydrates, also called "flammable ice", hold vast reserves of natural gas, is a new type of energy that hold high value. Many countries including the US and Japan are working on how to tap those reserves, but mining and extracting are extremely difficult. Combustible ice usually exists in seabed or tundra areas, which have the strong pressure and low temperature necessary for its stability. It can be ignited like solid ethanol, which is why it is called "combustible ice." China began research in methane hydrates almost 40 years later than US and Japan who started in the 1960s. On May 18, 2017, China for the first-time extracted gas from an ice-like substance under the South China Sea on a trial mining site. After nearly two decades of continuous efforts and indigenous innovations by China in theory, technology, engineering and equipment for natural gas hydrate exploration and exploitation, China finally mastered combustible ice mining technology, this is a major breakthrough that contributes to the global energy revolution<sup>9</sup> and also a typical example of China's catch-up in engineering technological innovation.

The third example can be the high-speed train. Owing to long-term strategic planning, continuous investment, and holistic ecosystem-driven construction, China has built more than 29,000 km of dedicated high-speed railways, which is longer than the total length of railways in the rest of world combined, and has successfully become the first middle-income country to develop a high-speed railway network and affordable service for people of all income levels (J. Chen, Yin, et al., 2020; Lawrence et al., 2019). After scrutinizing the planning and delivery mechanisms that enabled the rapid construction of the high-speed rail system in China, the World Bank published a report entitled *China's High-speed Rail Development*, pointing out the thing that other countries could learn from China's remarkable experience is the strong ecosystem, specifically, "the strong capacity development within and cooperation among China Railway Corporation, rail manufacturers, universities, research institutions, laboratories, and engineering centers that allowed for rapid technological advancement and localization of technology".

### 2.3 China's Catch-up Regarding the Firm Innovation Capability

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<sup>9</sup> Please see also: [http://www.xinhuanet.com/english/2017-05/18/c\\_136295598.htm](http://www.xinhuanet.com/english/2017-05/18/c_136295598.htm)

As for the most innovative company among the world, there are more and more top50 most innovative or smartest companies are born and developing in China. According the annual list of the World's 50 Smartest Companies ranking by MIT Technology Review, there are 9 companies from China, including iFlytek (6<sup>th</sup>), Tencent (8<sup>th</sup>), Face++ (11<sup>th</sup>), DJI (25<sup>th</sup>), Foxconn(33<sup>rd</sup>), Alibaba (41<sup>st</sup>), HTC (42<sup>nd</sup>), Ant Financial (49<sup>th</sup>), and Baidu (50<sup>th</sup>)<sup>10</sup>. There are 7 companies from China that list on the Forbes the World's Top100 Most Innovative Companies 2018<sup>11</sup>, and there are 5 companies from China that list on the BCG's 50 Most Innovative Companies 2020. Where more than half of the most innovative companies from China is internet-based, which also stands for a new trend of Chinese company's innovation. Alibaba is a typical example of innovative companies in China. Alibaba is the world largest e-commerce company presiding over a collection of online platforms—including Tmall, Taobao, similar to eBay; and the payment service Alipay (operated by Ant Group)—that together create one of the most sophisticated and lucrative online retail ecosystems in the world. Based on the business ecosystem and science and technology ecosystem as the dual innovation ecosystem, Alibaba gradually build a "city brain" system based on the digital economy and data technology throughout China and achieved a huge economic scale and local-community improvement (Chen, 2017; Chen et al., 2018). During the 2020 Singles' Day (Nov.11), shoppers spend \$74.1 billion within 24 hours on Alibaba's e-commerce platform, a 26% increase from last year, ten times than that of Black Friday in the U.S. (7.4 \$billion)<sup>12</sup>.

### 3. Holistic Innovation: New Perspective on National Innovation Progress

Scholars argues that for the purpose of global sustainable development, China's emergence and progress among the global innovation map should not be perceived as a threat to the western world (Ernst, 2011; Li-Hua, 2014; Richard, 2017; World Intellectual Property Organization, 2019) but a useful model or promising potential choice for global innovation, especially for emerging markets (Chen et al., 2018; Fu & Gong, 2011; Kong-rae Lee et al., 2017; X. Li, 2009; WIPO et al., 2018). The *Global Innovation Index 2018* report that "China's rapid rise in innovation shows the way for other middle-income economies"(2018). Geoffrey Garrett, American economist and the former dean at the Wharton School also noted that "It does not matter 'who wins' in innovation, because the whole world will benefit from more innovation no matter where it comes from."<sup>13</sup> Therefore, critically reviewing China's innovation in the past decades from a new and holistic perspective will generate important insights for international scholars as well as public agencies to promote global science, technology and

<sup>10</sup> See also: <https://www.technologyreview.com/lists/companies/2017/>

<sup>11</sup> See also: <https://www.forbes.com/innovative-companies/list/>

<sup>12</sup> See also: <https://www.cnbc.com/2020/11/12/singles-day-2020-alibaba-and-jd-rack-up-record-115-billion-of-sales.html>

<sup>13</sup> See also: <http://knowledge.wharton.upenn.edu/article/u-s-china-trade-war-really-future-innovation/>

innovation development, contributing to global sustainable development goals in the post COVID-19 pandemic world.

The international community has for a long time been pre-occupied with China's innovation model (Li-Hua, 2014). Reviewing the remarkable achievements in science, technology and innovation, it is more important to figure out a further question: How does China make it happen to transit from a labor-intensive towards an innovation-driven and knowledge-based economy? What is behind China's innovation legacy? Richard Li-Hua proposed a strategic model named "China's embracing innovation" (Li-Hua, 2014) to refer the strategic model of the wise who are seeking common development, sharing resources and win-win solution. Embracing innovation is a novel and innovative solution to a complicated social problem, which defines the concept of embracing innovation as a social innovation with Chinese characteristics (Li-Hua, 2014), rather a comprehensive perspective to reflect China's STI performance in the past decades. On the other hand, Huang & Sharif (2016) identified three resources of competitive advantage for China's ascent in the global technology stakes: its massive domestic market, its centralized power and willingness to employ state-sponsored industrial policy and government support, and the process of globalization that continues to transform markets worldwide. While they did not see the effect of environmental change and institutional innovation on STI policy and supported by entrepreneurship.

### **3.1 Holistic Innovation: An Emerging Paradigm of Nudging National Innovation**

Traditionally, innovation has been considered as a one-way and gradual linear process, while both the practice and research have shown that innovation is a diverse process embedded with multilevel integrated complex mechanisms among diversified factors and actors (Carayannis & Campbell, 2009; Chen, Yin, et al., 2020; Edquist, 2019; Lundvall, 2010). Chen, Yin & Mei (2018) who are from Tsinghua University, reviewed the deficiency of current innovation paradigm in the context of China as well as today's highly competitive business world, they introduce a new paradigm of innovation, holistic innovation (HI) based on eastern wisdom and global best innovation practices. Holistic innovation is a total and collaborative innovation driven by strategic vision in today's open innovation era. This new innovation paradigm is a helix of strategic innovation, collaborative innovation, total innovation and open innovation, which reflects both the innovation practice in Chinese context and the wisdom from eastern culture (Chen, Yin, et al., 2020; Chen & Yin, 2019b; M.-J. Chen & Miller, 2010). Holistic innovation is an original theoretical paradigm to understand the national innovation system trend that driven by the central and national government's strategic actions for catching up as well as keep national advantages (Chen et al., 2018; Edquist, 2019). It also provides theoretical foundations for mission-oriented innovation policy change (Mazzucato, 2018) that conforms to the

needs of technological innovation management of enterprises and supports the implementation of the national innovation-driven development strategy, as well as helps enterprises to build global innovation leadership, improves national innovation capability. Finally, it optimizes the innovation policy design and action mindset to achieve a holistic goal of global peace and sustainable development.

Holistic innovation is not only just an emerging innovation paradigm or theoretical perspective, but also a promising innovation policy trend. For example, Charles Edquist, a Swedish scholar from Lund University, further puts forward holistic innovation policy (Edquist, 2019) by introducing and discussing the Swedish National Innovation Council(NIC) and its characteristics. Holistic innovation policy, defined by Edquist, is a kind of policy that integrates all public actions that influence or may influence innovation processes (Edquist, 2019). Edquist argues that most innovation councils in the western countries tend to focus predominantly on research and development policy, which often treated innovation policy as an “appendix” to research policy. This typical policy model is currently lagging behind innovation research. While the Swedish NIC is a new model of innovation policy that was created and chaired by the Swedish Prime Minister since 2015 with a clear focus on innovation policy. The Swedish NIC represents a totally new policy practice that “make it possible for Sweden to gradually leave the linear model in innovation policy and move towards the development of a holistic innovation policy” (Edquist, 2019, p. 869). He finally argues that the Swedish NIC is a new way of nudging innovation because it gives innovation policy issues a much higher political status and practical priority that previously within the government itself and in government agencies, thus creates a more efficient and holistic way which can serve as a role model for other countries and regions in attempts to initiate and govern a holistic innovation policy.

### **3.2 Mission-Oriented Innovation Policy Design**

Similar to the holistic innovation perspective that emphasizes the role of strategic vision and national government's strategic actions driven holistic instead of linear innovation mindset. European scholars, represented by Mazzucato (2018) also argues that mission-oriented innovation policy is an emerging but promising approach for nations to improve the innovation policies and development tool kit in order deal with so-called “grand challenges” such as climate change, health and well-being concerns and difficulties in achieving sustainable development or inclusive growth (Mazzucato, 2018). This kind of mission-oriented policy mindset has been adopted by not only advanced economies (including the Europe Union, the United States) but by emerging economies represented by China. The common characteristic among these multinational practices in mission-oriented innovation policy is these mission-oriented innovation policies share a holistic innovation mindset, aim at achieving an investment-led sustainable and inclusive growth. The way to achieve this goal is setting a clear and

well-defined innovation mission, and then transform single-factor innovation projects to a portfolio of such projects by reforming the institutional framework(Chen et al., 2018; Mazzucato, 2018), only in this way, the coordination between institutional innovation and policy portfolios could drive the investment across different sectors and involve multiple types of actors.

Taken together, holistic innovation paradigm provides a new STI policy design perspective based on the global view (Chen & Yin, 2019b; Edquist, 2019). Innovation policy should not be limited to science and technology. Science and technology, education, social and political norms, culture, people's livelihood and ecology should be combined to create a system of synergy to promote total and collaborative innovation that driven by clear mission and strategic design (Fu et al., 2021; Lewin et al., 2016; Mazzucato, 2018). Only in this way can China as well as other emerging economics implement national innovation strategy, industrial innovation strategy and enterprise innovation strategy. Then not only scholars and public agencies could have a new and holistic way to understand China's fact catch-up in STI, but also both the nation and firms could systematically upgrade the national and regional innovation system and technology transfer system so as to provide the nation with technical assistance in major technological fields, strategic industries and enterprises to win the advantages of global innovation and leadership. Finally, the holistic innovation paradigm has the potential to lead the nation to ultimately achieve the mission and goal of contributing global sustainable development.

#### **4. Five Main Impetus for China's Fast-growing in Technological Innovation**

Here in this section, drawing from the holistic innovation theory and mission-oriented innovation policy, combined with current literature by international scholars, more than thirty-years interviews and cases studies the authors conducted both inside and outside China regarding on China's innovation-driven, we identify five main drivers for China's growth in technological innovation (as shown in Table 1). Most important, China's innovation are fostered by national STI policy and implementation (J. Chen, Yin, et al., 2020; J. Chen & Mei, 2018; Ernst, 2011; Fu, 2015; Fu et al., 2016; Gu & Lundvall, 2006; X. Liu & White, 2001). Second, the massive infrastructure and urbanization initiate the technological innovation (Andersson et al., 2009; J. Chen & Mei, 2018; Lawrence et al., 2019; Sha et al., 2006). What's more, informatization as well as internet-based digital transformation is a powerful strategic tool for China's industrial upgrading, economic transition as well as firm innovation(Chen et al., 2018; Chen, Yin, et al., 2020; Economist, 2018; Gary & Michele, 2018; F. Li, 2019). Fourth is that globalization drives China's into a new era that both government and firm can take the advantage of global innovation resources to catch up with developed economies (Fu & Gong, 2011; Kong-rae Lee et al., 2017; M. Liu et al., 2020; Phan et al., 2010; Yang & Li, 2008). Last and

recent is that China's mass innovation and mass entrepreneurship lights up the future of an innovative nation (Chen, Yu-shan, et al., 2020; T.-J. Chen & Ku, 2014; Gwyne, 2010; Kong-rae Lee et al., 2017; Phelps, 2015).

Five Main Drivers for China's Growth in Technological Innovation	
1	National STI policy and efficient implementation
2	Initiated by infrastructure and urbanization
3	Led by informatization and digitalization
4	Driven by globalization
5	Supported by entrepreneurship

*Table 1 Five Main Drivers for China's Growth in Technological Innovation*

#### 4.1 National STI Policy and Efficient Implementation

As Martin(2016) pointed out in his research, before the great depression in the middle of 20<sup>th</sup> century, the government role in liberal market economics such as the US and UK is viewed as largely confined to fixing “market failures”, such as those encountered in the area of defense, health, education and research (and more recently banks). While if government do not take risks in their policies, they may not have failures as well as not have any great success either. The western governments believe that markets should drive innovation (Ernst, 2011), the role of government has been underplayed for a long time for political or ideological reasons, especially in the USA (Martin, 2016). While at the same time, China's government emphasizes the critical role of public policy in fostering indigenous innovation, including its effort to accelerate innovation and participate in the globalization and compete in global value chain(Ernst, 2011; Fu et al., 2016; Someren & Someren-Wang, 2014).

The most recent and impressive STI policy is that China's central government released a new national action plan and put up with a “Three Steps to Global Innovation Leadership”<sup>14</sup>. In 2016, China's government came up with an *Outline of the National Strategy of Innovation-Driven Development (hereafter called the Outline)*, in which the government claimed that scientific and technological is a strategic pillar for boosting social productivity and comprehensive national strength and therefore must be placed at the heart of the country's development. The Outline is a strong simple of the STI policy motivation, which means that the central government put innovation at the top of the five development principles and identified innovation as the number one factor of driving development.

<sup>14</sup> Please see the original version of the *Outline of the 13th Five-Year Plan for the National Economic and Social Development of the People's Republic of China*: [http://www.xinhuanet.com/politics/2016-05/19/c\\_1118898033.htm](http://www.xinhuanet.com/politics/2016-05/19/c_1118898033.htm)

The **Outline** identified the three for implementing the strategy of innovation-driven development, which are consistent and mutually reinforcing with the strategic goal of achieving China's modernization in "three steps" --

Step 1, China should become an innovative country by 2020 to give strong support for building a moderately prosperous society in all respects; Step 2, China should move to the forefront of innovative countries by 2030 to lay a solid foundation for building China into a major economic power and a society of common prosperity; Step 3, China should become an innovation power by 2050 to support the building of a prosperous, strong, democratic, culturally advanced, harmonious, modern socialist country and the realization of the Chinese dream of national renewal.

One example is DJI-Innovations, a company that successfully position himself as the global innovative company based in the south China city of Shenzhen --- a city that has been growing up to a global technological innovation center after the China's reform and opening up policy. Chinese drone manufacturer DJI-Innovations (DJI) has pioneered the development of drones with its products gaining 80 percent of the global market share. With the addition of innovative enterprises like DJI, the production value of the seven "strategic emerging industries," such as biology and the internet, has enjoyed an average annual increase of 17.4 percent in Shenzhen, according to the ministry of science and technology in China.

Following by the Outline, China has identified several strategic industries in order to build its competitive advantages. One recent example is *AI Action Plan*<sup>15</sup>, which calls for homegrown AI to match that developed in the West within three years, for China's researchers to be making "major breakthroughs" by 2025, and for Chinese AI to be the envy of the world by 2030. As Knight(2017) emphasized, "the government's call to action will accelerate what has already begun to happen. The country's tech companies, led by the Internet giants Baidu, Alibaba, and Tencent, are hiring scores of AI experts, building new research centers, and investing in data centers that rival anything operated by Amazon, Google, or Microsoft. Money is also pouring into countless startups as Chinese entrepreneurs and investors spy a huge opportunity to harness AI in different industries".

## 4.2 Initiated by Infrastructure and Urbanization

Cities and urbanization is playing an important role in knowledge spillovers that generate economic growth, technological innovation as well as productivity (Andersson et al., 2009; Chua et al., 2019). The characters of cities are propitious to innovation and provide appropriate conditions for innovation diffusion. During the past two decades, China has witnessed a rapid rate of urbanization

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<sup>15</sup> Please see the *AI Action Plan*: [http://www.gov.cn/zhengce/content/2017-07/20/content\\_5211996.htm](http://www.gov.cn/zhengce/content/2017-07/20/content_5211996.htm)

and is faced with unique problems due to the country's natural resources, history, society, economy and culture (Sha et al., 2006). Continuing significant economic growth represents a daunting challenge for China, as the portfolio of highly effective policies that created surplus labor in the rural economy that made China the manufacturing hub of the world and created the resources for building infrastructure (roads, railroads, ports, airports, electric power, telecommunications, etc.), new cities and massive residential housing projects, runs its course. From the Figure 6 and Figure 7, we can see that both the total person and percentage of population living in urban area continue growing in the past decades, while China experiences the most significant growth comparing other 9 economies. Also, the urbanization rate in China has increased from 17.9% in year 1978 to more than 59.15% at the end of year 2018, and the total urban population is more than the total of other 8 advanced economies (except India as emerging economy), which provide both talents and huge market that drives technology innovation in China.

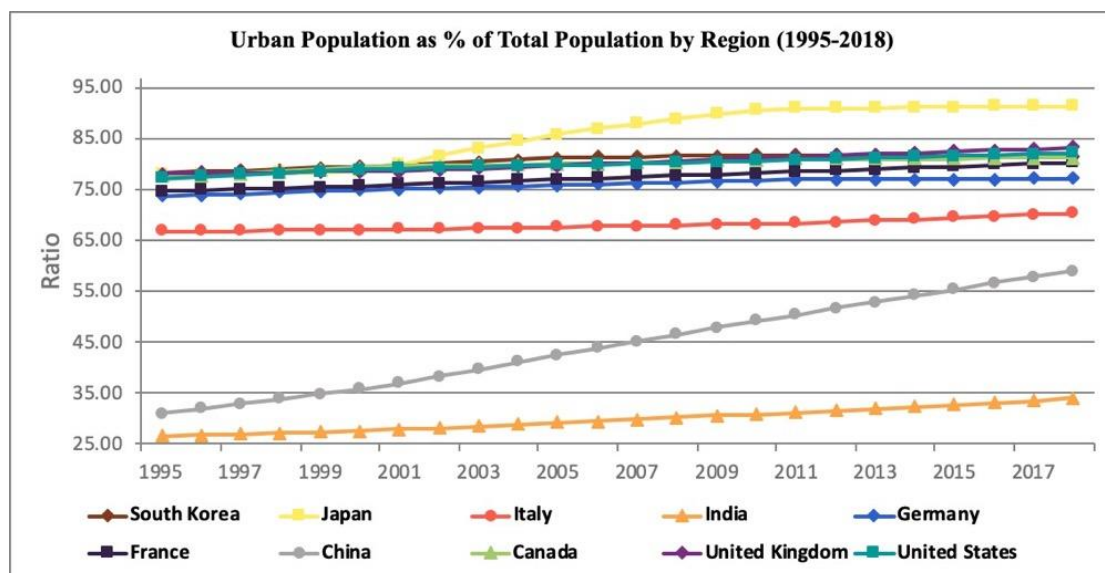


Figure 6 Urban Population as % of Total Population by Region (1995-2018), Data Source: CEIC

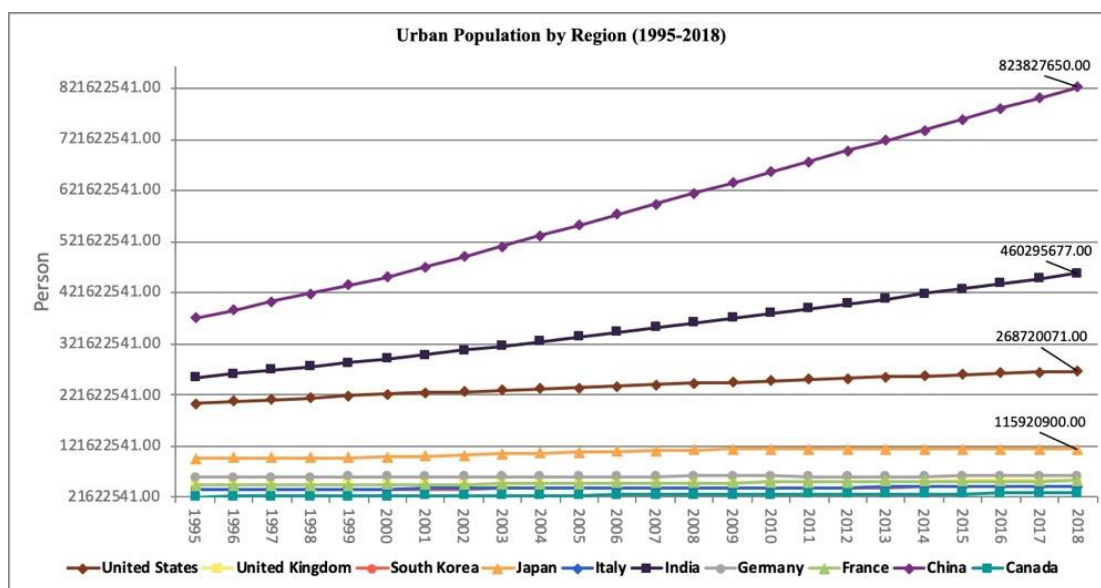


Figure 7 Urban Population by Region (1995-2018), Data Source: CEIC

### 4.3 Led by Informatization and Digitalization

Learning and information accumulation has been proofed to play a major role in innovation and innovation diffusion (Feder & O'Mara, 1982; S. Li et al., 2015; Rogers & Shoemaker, 1971; Swanson, 1994), especially in the current global transition of digitalization (Ferreira et al., 2019; Gobble, 2018; Nambisan et al., 2019). In an era of revolutionary new developments in basic information technology, innovation in its employment among organizations is increasingly crucial to competitive survival and success not only for firms (Swanson, 1994), but also for national competitive advantage (J. Chen, 2017; Leamer & Storper, 2014; J. Lee et al., 2014). In recent years, the internet of Things (IoT) has drawn significant research attention and has a promising impact on the future of internet, which will empower the connected things with new capabilities (Leamer & Storper, 2014; S. Li et al., 2015).

As is shown in Figure 8, the total number of internet users in China has grows from 253million in 2018 to 903.59 million at the end of year 2019, with a 112.27% annual growth rate. As a result, the internet users as percentage of total population grows from 14.31% to 64.53% by the end of year 2019. At the same time, as show in Figure 9, the mobile phone user number per 100 people in China grows from almost zero in 1995 to more than 115 at the end of 2018, even higher than that of France and Canada. At the end of year 2018, 81.4 million people in China uses more than 1.6 billion mobile phones in China (with annual growth rate higher than 100%), which is higher than the total of G7 countries, making China as the largest mobile phone market in the world. Because of the great improvement of informatization in China, both the traditional industries and new industries that based on internet have obtain a great advantage of digital transformation and market demand to increase

productivity as well as technological innovation. China has an ambitious high-tech development strategy, but high-tech development does not automatically bring about innovation. In recent decades, the Chinese government has launched high-tech development plan every five years, and issued from time to time some national strategies, such as *Made in China 2025* and action plan to promote the combination of informatization, digital transformation and industrialization<sup>16</sup>.

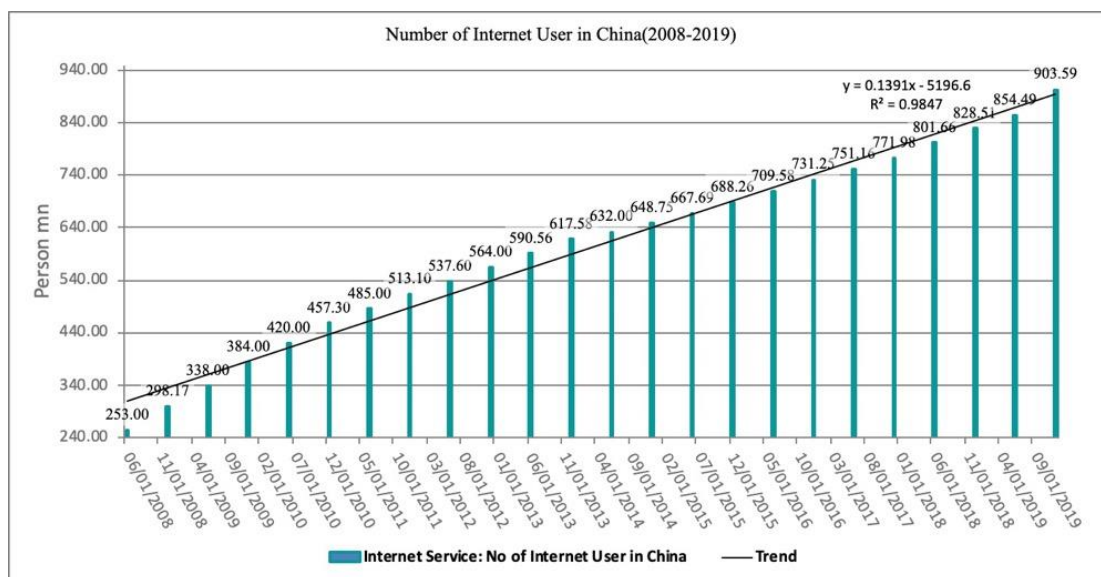


Figure 8 Number of Internet User in China (2008-2019), Data Source: CEIC, NBSC

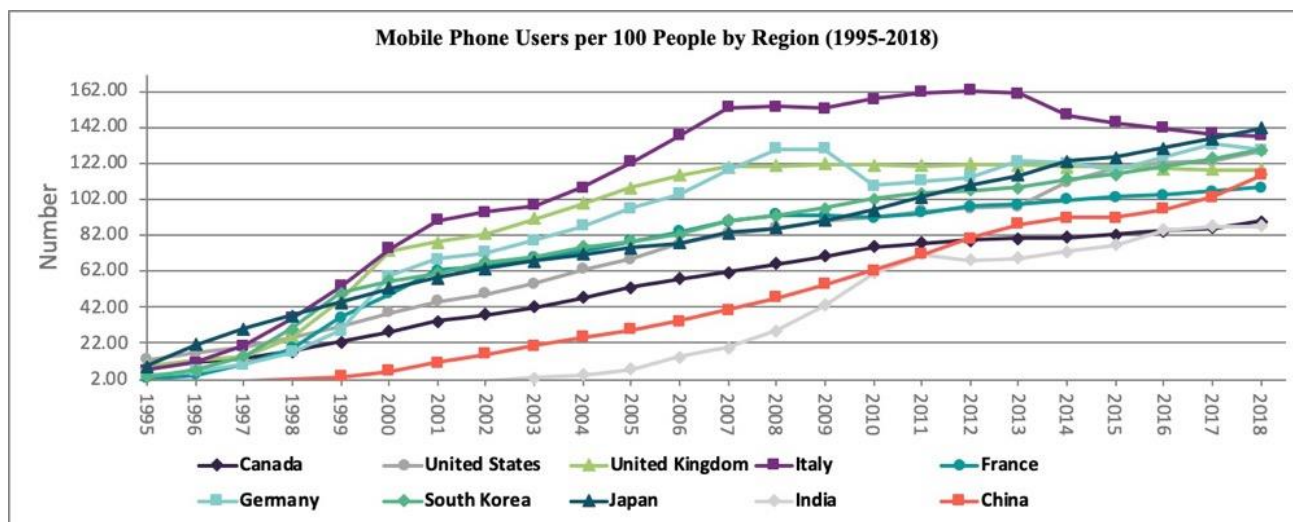


Figure 9 Mobile Phone Users per 100 People by Region (1995-2018), Data Source: World Bank, NBSC

On the other hand, the depth of integration of information technology and national economy and society, which provide a sustainable power for economic growth. At present, the penetration rate of digital design tools in machinery, shipbuilding, automobile, rail transit and other fields has exceeded

<sup>16</sup> Please see also: [http://www.gov.cn/gongbao/content/2017/content\\_5241931.htm](http://www.gov.cn/gongbao/content/2017/content_5241931.htm)

85%, and the numerical control rate of key process such as petrochemical, non-ferrous metal, coal, textile and pharmaceutical exceeds 65%. Large and medium-sized enterprises ERP equipment utilization rate of 70%. China has grown into the largest electronic information product manufacturing base in the world. In 2015, there were 60,800 electronic information industry enterprises above designated size in China, including 19,900 electronic information manufacturing enterprises and 40,900 software and information technology service enterprises. The total annual sales revenue reached 15.4 trillion yuan, an increase of 10.4%.

#### 4.4 Driven by Globalization

As foreign direct investment (FDI) can benefit innovation activity in the host country via spillover channels such as reverse engineering, skilled labor turnovers, demonstration effects, and supplier-customer relationship, globalization provide huge advantages for emerging markets to make the best of global market and especially investment and technologies (Fu & Gong, 2011; Soete, 2011; Tassey, 2008). Under its “market for technology” policy, China has been the largest recipient of FDI among the developing countries in the 1990s. What’s more, China has already become the global center for many different stages of production, since China gained entry to the World Trade Organization (WTO) in 2001. Intensified globalization will continue to benefit Chinese companies in the coming decades, providing a third advantage in its drive to become a worldwide force in technology. On the other hand, Chinese firms need not develop every advanced technology on their own in a globalized world. Backed by the government’s “go global” strategy, they can acquire such technologies through mergers and acquisitions abroad (X. Hu et al., 2020; M. Liu et al., 2020).

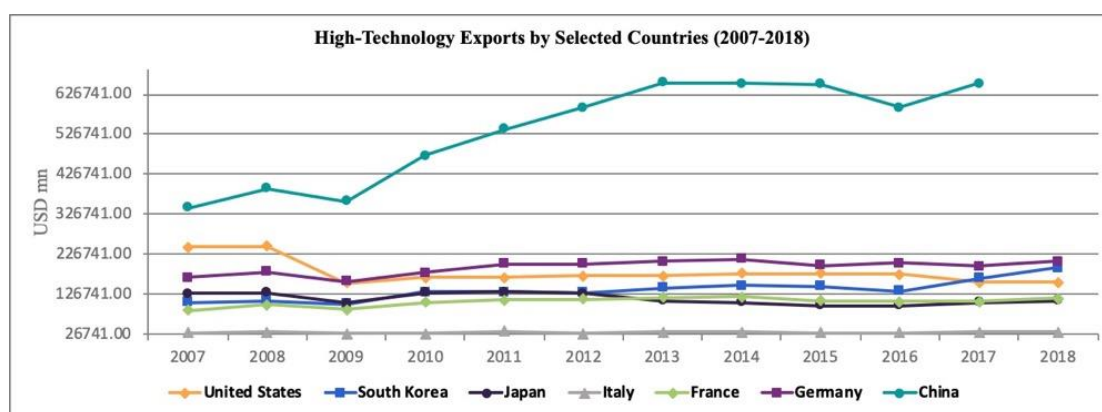


Figure 10 High-Technology Exports by Selected Countries (2007-2018), Data Source: CEIC

On the other hand, as the economy grows and indigenous companies move up the technological ladder, foreign multinational corporations will be increasingly tempted, or perhaps feel compelled, to bring their advanced products to China, eventually even patenting their cutting-edge technologies there.

This will in turn generate demonstration, labor mobility, and competition effects—or ‘spillovers’—to benefit local firms.

In Recent years, through administrative action, institutional innovation, and IP protection as well as encouragement on firm R&D investment, China has been actively developing a new technology policy based on the promotion of its own technical standards. Through actively participating in the globalization, China will not only benefit from the global value chain collaboration, but also will contribute to the innovation around the world.

#### **4.5 Supported by Entrepreneurship**

Entrepreneurship is a multilevel phenomenon that begins with the combination of human creativity, financial resources, and technological capital; fostering the discovery and establishment of new ways to organize production processes and new institutional forms; and leading to such outcomes as venture growth and new ventures. New venture growth is a defining characteristic of developing economies (Phan et al., 2010). As the largest transition economy in the world, on the way towards a market-based economic system, entrepreneurship as an economic activity has been an important engine of Chinese economy. Domestic entrepreneurial organizations, including private start-ups, township and collective enterprises and transformed state-owned enterprises (SOEs), have emerged as one of the most important driving forces behind China's rapid economic development (Yang & Li, 2008).

“China's biggest strength for development lies in its rich human resources”, noted by Premier Li Keqiang, “The 1.3 billion Chinese people, of which over 900 million are in the labor force and over 170 million have received higher education or acquired specialized skills, represent an infinite source of entrepreneurship and innovation”<sup>17</sup>. In order to make the best of Chinese human recourse as well as the power of entrepreneurship, China launched the mass entrepreneurship and innovation initiative across the country, which greatly unleashed market vitality and social creativity.

The number of market entities in China increased by a daily average of 40,000 in the past three years. 14,000 enterprises were registered every day on average, with about 70 percent of them active in business, and the number of new enterprises rose to 8,000 a day in year 2017, giving a strong boost to job creation and new wealth<sup>18</sup>. Meanwhile, mass entrepreneurship and innovation also helped transform the country's traditional sectors and accelerate the upgrading of the economy. Mass

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<sup>17</sup> Please see also: [http://www.xinhuanet.com/english/2017-09/12/c\\_136603727.htm](http://www.xinhuanet.com/english/2017-09/12/c_136603727.htm)

<sup>18</sup> According to the speech by Premier Li Keqiang at the opening ceremony of the Annual Meeting of the New Champions 2017, also known as the Summer Davos, held in northeast China's coastal city Dalian.

entrepreneurship and innovation as an effective way to achieve inclusive growth in China and will continually promote the national innovation capability.

## 5. Five Major Challenges on the Way Towards the Innovation Powerhouse

Looking forward, China is entering a new historical *Great Transformation* period, which is from catch-up to competing for and maintaining the global innovation leadership. As soon as China joins the “club of innovators”, the co-evolutionary processes, as well as the institutional design and industrial policies, are bound to profoundly change. Catch-up is quite different from maintaining and exploiting technological leadership. Institutions and relations among them are bound to change, too, for example, among social and institutional norms, science, technology and industry; or the mechanisms governing income distribution.

Even many scholarly work find that China had already started moving away from a reliance on imported technology and equipment, and using indigenous R&D efforts to innovate for the coming market economy in the past decades (Clarke et al., 2018; Guan et al., 2009; Someren & Someren-Wang, 2014), it is clear that China faces policy challenges at every level when implementing the National Innovation-Driven Strategy and trying to push the industrial upgrading. According to the report by Clarivate, *The State of Innovation Report 2017*, “Although still on an upward trajectory, global innovation activity as a whole slowed down this year ... That slowdown was driven largely by China”. Challenges that faced by China on the way towards the most innovative nation vary from macroeconomics to micro and individual level. Challenges that are often mentioned by public agencies, Chinese academics and social media include: How to improve the balance and mix between public guidance and market forces? How to find new sources of innovation and growth? How to accelerate technological upgrading of existing industrial and service sectors? How to exploring and entering new industrial and service sectors? How to nourish a culture of grassroots dynamism and mass entrepreneurship? How to create world-class universities and research institutes? How to cultivate and attract more innovation talents? How to improve the quality of life and continue the mission of anti-poverty as well as contribute to the peace and global sustainable development goals? (Cai, 2012; J. Chen et al., 2018; Gu & Lundvall, 2006; Lewin et al., 2016; Phelps, 2015).

As Thomas Clarke et. al (2018) point out, “while Asian economies have achieved rapid industrial progress, as they reach the global technological frontier they need to develop new institutional capabilities for sustaining international competitiveness. Foundational institutions including education, research, law and finance require coordination around coherent national innovation systems to sustain commitment to innovative products and processes.” Drawing from China’s current socioeconomic

situation, global trend and academic insights, here we identified five major challenges that China has to deal with when building a most innovative nation (See Table 2).

Five Major Challenges on the Way Towards Global Innovation Powerhouse	
1	Nursing world-changing basic research and original innovations
2	Cultivating & attracting best talents and resources from all over the world
3	Balancing the paradox of open innovation and indigenous innovation
4	Building a core-competence based innovation ecosystem
5	Contributing to global peace and sustainable development

*Table 2 Five Major Challenges on the Way Towards Global Innovation Powerhouse*

### 5.1 Nursing World-class Basic Research and Original innovations

Basic research is seen as the basis for all other technological developments, while contrarily, most Chinese enterprises are involved in applied research (Sabir & Sabir, 2010). Thanks to the development of national innovation system and five drivers as discussed above, China's original innovation capability has markedly improved, and produced a number of influential research outcomes in basic, frontier and strategic high technologies, such as major breakthroughs have been made in high-temperature superconductor, quantum theory, stem cell research and other subjects of basic research. Proud achievements have been scored in key technologies like manned space and lunar exploration.

However, comparing the innovation strategy and practices in other leading innovative countries, especially the U.S., what China need to pay more attention is that China is in lack of original innovations and have competitive weakness in the basic research. China still lacks a reliable reserve of science and technologies as well as sufficient high-end professionals. The problem that key and core technologies (so-called the *bottleneck technologies*) are still mainly controlled by other countries which remains to be resolved.

For example, even though the R&D intensity as well as total R&D investment in China have experienced a radical increase in the past four decades and becomes the driving power for global innovation investment and output (National Science Board, 2018; World Intellectual Property Organization, 2019), China is still far behind the G7 countries and especially South Korea in terms of researchers in R&D per million people (as shown in Figure 11). As show in Figure 12, even though China has invested more percentage of GDP in innovation than Canada, UK and India, but still far behind from most of the advanced economies.

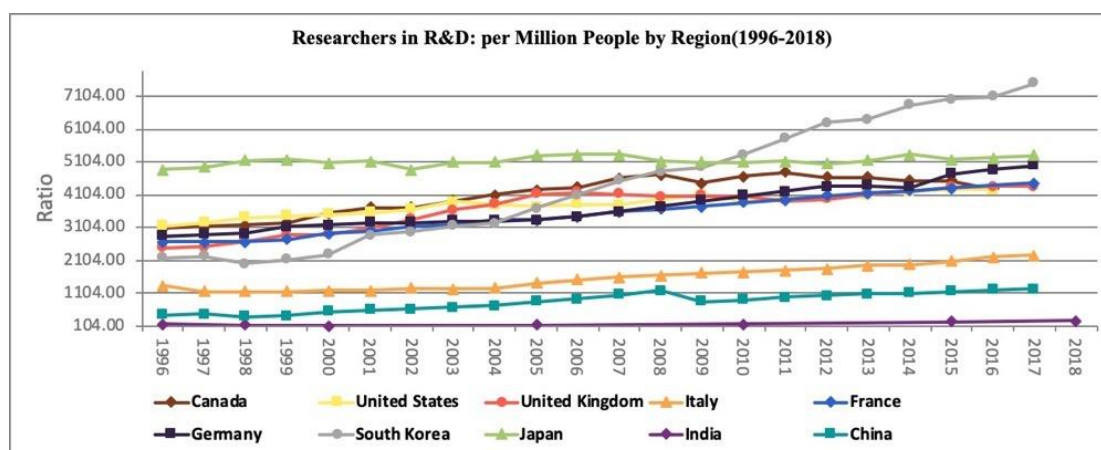


Figure 11 Researchers in R&D: per Million People by Region (1996-2018), Data Source: CEIC

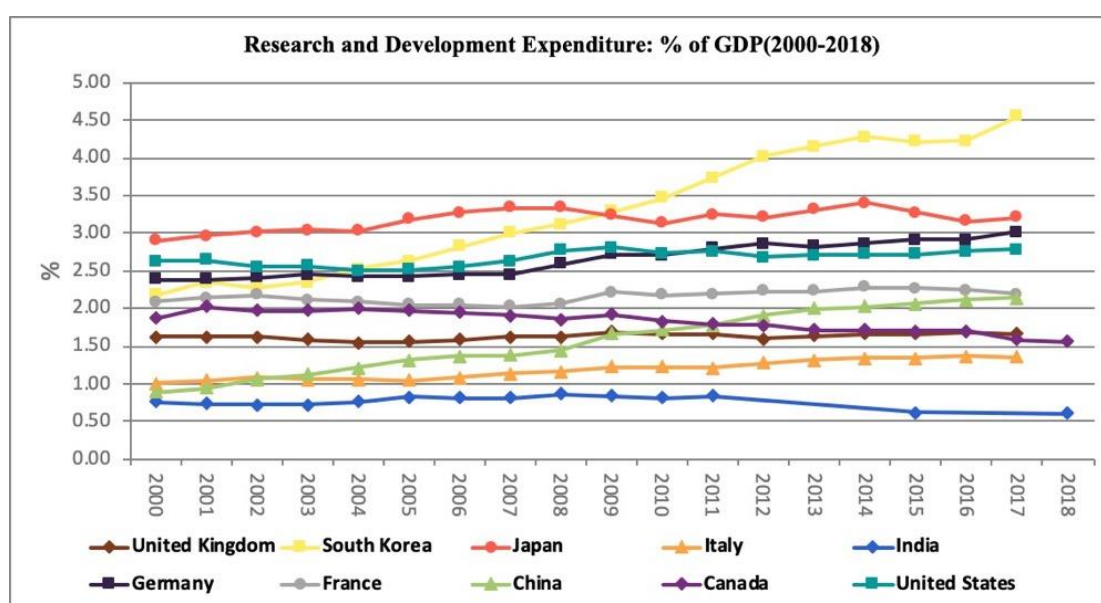


Figure 12 Research and Development Expenditure: % of GDP (2000-2018), Data Source: CEIC

In order to move to a growth model that is based more on innovation and productivity increase in the past and break the “Middle-income Trap”, China has to find a way to encourage world-class basic research and create more original innovations by conducting indigenous innovation (J. Chen, Yin, et al., 2020; Shang-Jin et al., 2017).

Most importantly, as the data shows in Figure 11 and 12, both Japan and South Korea shows significant and impressive in terms of researcher intensity and R&D intensity, even they already make it to break the “Middle-income Trap” and become the strong innovation players both in Asia and the world (Freeman, 1987; Kim, 1997; Keun Lee & Lim, 2001), they are still continue investing heavily in innovation, especially basic and long-term projects to maintain their national innovation competitive advantage around the world. This is an excellent example for China to go beyond the catch-up, otherwise it is hard to say China would make it for global innovation leadership without world-class original innovations.

## 5.2 Cultivating and Attracting the Best Talents and Resources from All Over the World

While the government's call for "indigenous innovation" has led to significant development in China's science, technology innovation policy (such as Spark 863, 211 Project, Torch Projects, and 973 Project) and building collaborative relations between research institutions and industry in China (Lu & Etzkowitz, 2008), China is still in lack of high-quality human resources, especially small and middle enterprises (SMEs) who are struggling for the transition from labor-intensive growth pattern to innovation-driven growth pattern need more skilled labors (Sabir & Sabir, 2010). The original sources of national innovation capability are talents and skilled labors, which could be cultivated by the country itself or by attracting the best talents around the world. Without talents, all R&D investment and innovation policy will make no sense for obtain global innovation leadership.

Regarding to these two aspects, China not only has a long way to go in improving domestic education, but also faces grand challenges of brain drain issues, which are the two critical issues for a developing country to go beyond the catch-up cycle.

High-quality education, especially world-class universities is the critical way to cultivate and make the best of high-quality creative talents in China. Yet this could not be achieved without continuous education investment. As for education expenditure comparisons among the selected regions, we could see from the Figure 13, even though China's government expenditure on education as total of GDP has the biggest increase in the past years, while the expenditure rate is only 3.78%, far behind from the U.S. and U.K, even lower than that of India. And the rate has decreased to 3.19% in year 2018, a phenomenon must be paid careful attention in China's future development.

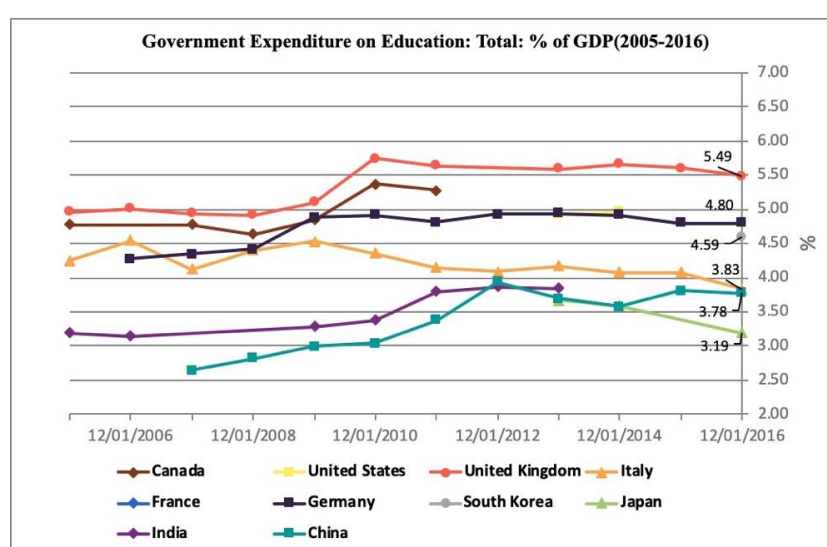


Figure 13 Government Expenditure on Education: Total: % of GDP (2005-2016),

Data Source: NBSC, CEIC

Also, as one of the typical developing countries, China is facing with a serious problem of brain drain, which is defined as the migration of health personnel in search of the better standard of living and quality of life, higher salaries, access to advanced technology and more stable political conditions in different places worldwide. In Figure 14 and Figure 15, we demonstrate the international comparisons among selected regions in total international migrant stock and the number of net migrants. One critical information that we could get is that leading innovation players represented by the United States continues their global advantage in attracting international talents for their own innovation development, while China not only have least international migrant stock than other competitors (even lower than India), but also continue suffers from brain drain with huge negative net migrants. This indicates that China must take seriously action on both reform international talents programs but also create better and diversify innovation environments to embrace more international innovation talents as well as other followed-by resources to make the best from cross-culture knowledge and knowledge spillover (Fu, 2015; M. Liu et al., 2020; Yip & McKern, 2016).

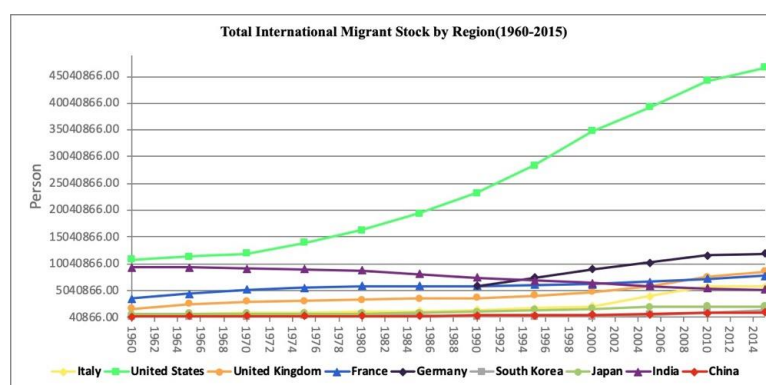


Figure 14 Total International Migrant Stock by Region (1960-2015), Data Source: CEIC

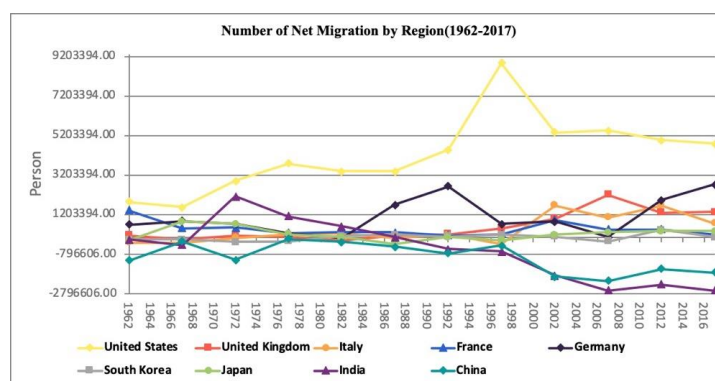


Figure 15 , Number of Net Migration by Region (1962-2017), Data Source: NBSC, CEIC

China has gone through a dynamic process in which foreign sources of knowledge has played a critical role in particular at the initial stage, and in which the channel used for foreign technology transfer also evolved with the rapid development of China's technological base (Fu et al., 2016). In

2006, China declared indigenous innovation to be a strategic priority and started shifting its innovation focus from external acquisition of knowledge to internal creation of knowledge. However, the core element of indigenous innovation is human resources and talent, both from inside the country or outside the country. So, the main challenge of make breakthroughs in basic research and original innovations fall into the need for creating and attracting talents and resources from all over the world.

At the same time, good news is that China has the world's largest number of graduates and postgraduates, mainly are in STEM majors and the world's largest number of students who are studying abroad and return back to China after graduations. As shown in Figure 16, the annual number of graduates in China has reached to more than 758.5 million at the end of year 2019, and the postgraduates in China has reached to more than 64 million at the end of year 2019. This is a huge potential for China to leverage under the support of education system reform in the future for its goal of become the most innovative country in the world. As shown in Figure 17, total number of Chinese students who are studying abroad and then return back to China after graduation every year continues growth at a sharp rate after China enter the WTO at the beginning of the century. Specifically, there are more than 66.2 million Chinese students studying abroad, mostly in the U.S. and Europe Union, with an annual growth rate at higher than 117%. At the same time, there are more than 51.9 million Chinese students who choose to go back to work in China after finishing study abroad, with an annual growth rate at 125%, higher than that of students going abroad. This means that there are more and more Chinese young generation talents who have international experience and education background choose to work and create in China, this will become one stream of the strategic innovation resources for China in the future.

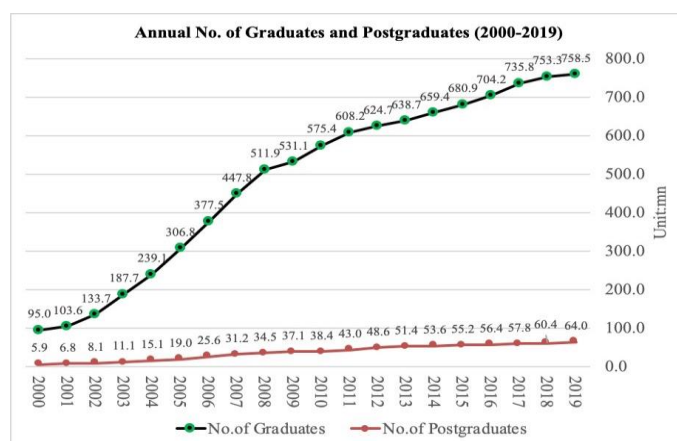


Figure 16 Annual No. of Graduates and Postgraduates (2000-2019), Data Source: NBSC



Figure 17 Annual No. of International Talents (2000-2018), Data Source: NBSC

As it is argued by Fu (2015), Edquist (2019) and Mazzucato (2018), innovation itself is not the goal of a national holistic innovation policy, the ultimate goal should be innovation-driven sustainable development, for China's to overcome so-called "middle-income trap" (Cai, 2012; Lewin et al., 2016) and contributes the world's sustainable and inclusive development (Chen et al., 2018). To achieve this long-term economic development goal, China's not only need a holistic innovation path, but also need leverage the power of mass innovation and entrepreneurship that mainly are conducted by creative citizens (Sauermann et al., 2020). One powerful way is to continue social and political reform as an important way to encourage and cultivate more responsible social and civil organizations that play an important role to bridge government's innovation mission and the social and market demand (Lewin et al., 2016). This is also in line with the global trend of open innovation (Kankanhalli et al., 2017) and citizen science (Sauermann et al., 2020), in which the civil and social organizations such as NGOs and NPOs work as informal institutional intermediaries (Armanios et al., 2017) in both local communities and specific sectors to leverage the power of citizens and decentralized social resources for sustainable innovation and development.

### 5.3 Balancing the Paradox of Open Innovation and Indigenous Innovation

Standing on the new stage of China's reform and opening up, China have to produce more indigenous innovation instead of buying from outside or just copying the western countries, and improve the dual model of combining its own capability building with acquiring knowledge from all over the world. The nation has to balance the paradox of open innovation and indigenous innovation (Chen, Yin, et al., 2020; Chen & Yin, 2019b; T.-J. Chen & Ku, 2014). The concept of open innovation has recently gained widespread attention (Chesbrough, 2003; Kankanhalli et al., 2017; Lichtenthaler, 2011). It is particularly relevant now because many firms are required to implement open innovation, despite the difficulties associated with managing these activities (Lichtenthaler, 2011). It is clear that both firm and nation often need to draw from and collaborate with a larger number of actors from

outside their organization in order to obtain ideas and resources for innovation, while at the same time, they need also to be focused on capturing the returns from their innovative ideas as well as indigenous research and development.

Chinese government, as well as companies, have to learn to manage the paradox of open innovation -- the creation of innovations often requires openness, but the commercialization of innovations requires protection (Laursen & Salter, 2014). On the other hand, too much openness may have the risk of losing control of power and lack the motivation to invest on core technology, which in turn might be taken over by the outside partners or competitors. In the future, both Chinese government and firms has to learn how to balance the paradox of open innovation and indigenous innovation so as to continue the reform and opening up policy.

#### **5.4 Building a Core-competence Based Innovation Ecosystem**

Both academics and practitioners hold the common thought that in recent highly competitive world, neither a country nor a firm can survive or obtain competitive advantage without a portfolio of core technology that can build core competence (J. Chen, 2017; Fu, 2015; Gu & Lundvall, 2006; Prahalad & Hamel, 1990). In order to render efforts made by innovation searching effective, firms and government need to align their internal processes to the external environment: they need to configure their firms to enable successful absorption of knowledge from external sources (Cohen & Levinthal, 1990; Gkypali et al., 2018; Martinkenaite & Breunig, 2016; Todorova & Durisin, 2007; Zahra & George, 2002). From the perspective of innovation ecosystem, the best way to build up a sustainable approach of innovation and obtain the advantage of ecosystem is to have a comprehensive strategic of innovation (J. Chen et al., 2018; J. Chen & Yin, 2019b), and build a core-competence based innovation ecosystem to make the best of player inside and outside of the ecosystem, at the same time to protect the rights and position of focal players -- firm or country (Adner, 2017; Euchner, 2014). So, the challenge following by this approach is how does China continue its effort by applying a better STI policy to build up national and regional innovation systems, as well as accelerate the process of national technology transfer system, in order to promote the knowledge creating and knowledge commercialization (See Figure 18).

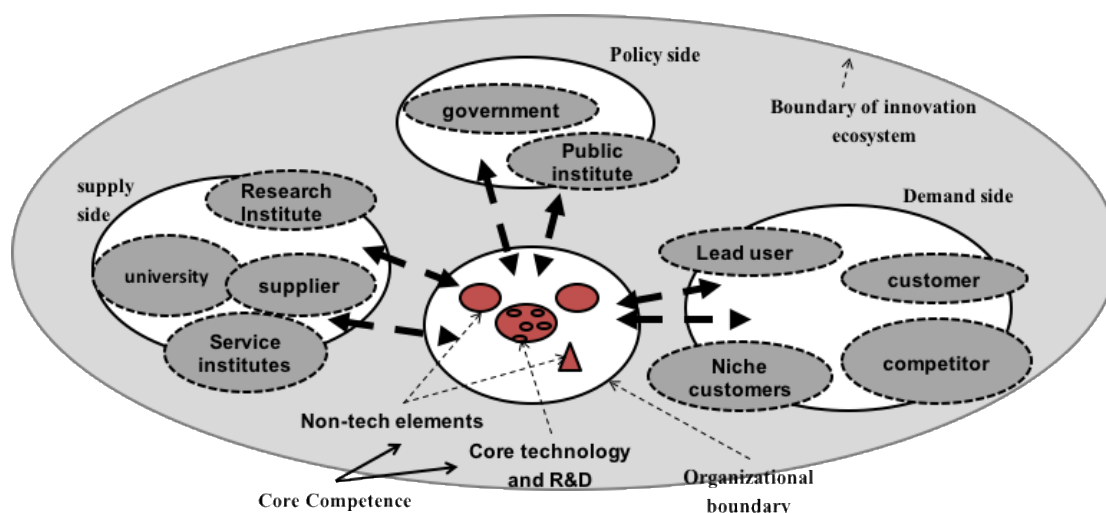


Figure 18 Core Competence Based Innovation Ecosystem Framework, Sources: Chen (2017)

## 5.5 Contributing to Global Peace and Sustainable Development via Inclusive Innovation Development

Improving the incomes of the large numbers of the Chinese population who are not yet participating in the middle class is an important priority for China, which is also emphasized by the President, Xi Jinping.

During the 1980s and 1990s, the political and economic agenda was dominated by concerns with economic competition, growth, wealth creation, productivity and efficiency, in which the key measurement is a country's gross domestic product (GDP). While the GDP measures "everything except that which makes life worthwhile" (McGregor & Pouw, 2017). GDP measures mainly market transactions, which ignores social costs, environmental impacts and income inequality (Costanza et al., 2014). China, is not an exception, or even have more serious challenges ahead, including air pollution, environmental damage as well as the ignoring of well-being of the poverty. The world has observed that China made great achievements of the last four decades in removing millions of people from poverty (see Figure 19), and the total percent of people who live in the poverty decreased from 43.6% in 1990 to 0.6% in 2019, and the total population or the poverty decreased from 770 million in year 1978 to 5.51 million till the end of year 2019. With such an extraordinary achievement in anti-poverty, China still face a serious challenge of anti-poverty before the end of year 2020, when is the deadline that Chinese government aims to move all the poverty out of absolute poverty and promote to a better life. At the same time, China has to shift the growth pattern from wealth creation to innovation for wellbeing and embrace the socially responsible and inclusive innovation, so as to contribute to global sustainable goals (SDGs).

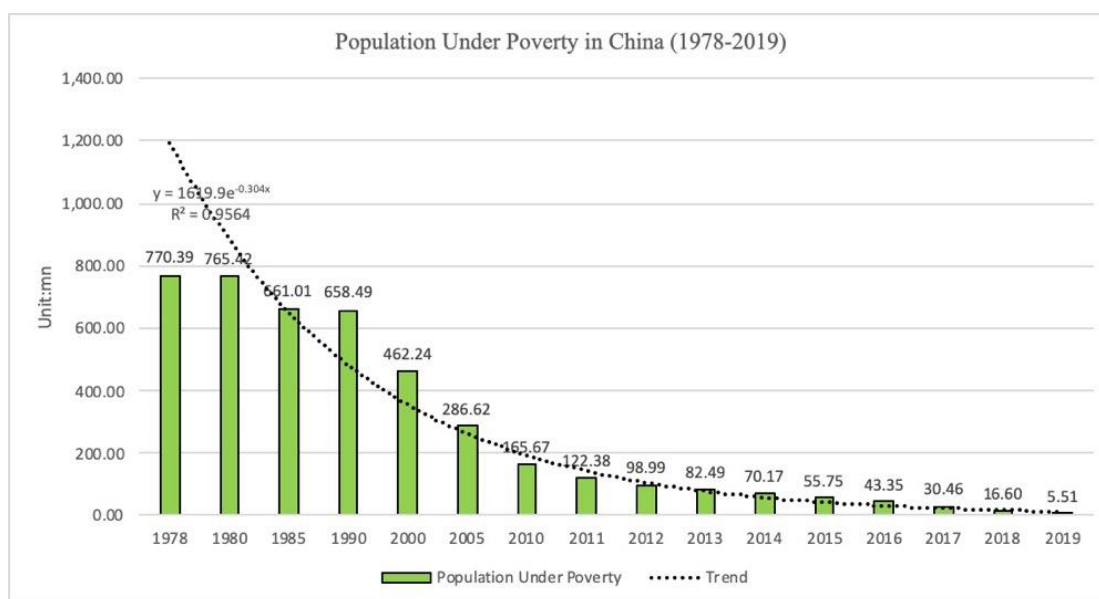


Figure 19 Total population under poverty in China continue decreasing; Source: World Bank

## 6. Holistic Innovation Path Leads Towards China's Global Innovation Leadership

### 6.1 Mission of China's Mission-oriented STI policy

China is determined to apply the holistic innovation path with similar kind of mission-oriented innovation policy as these leading innovation players do in the past years. At the same time, China has its own special institutional advantage on applying this approach. Because in the past four decades of reforming and opening up since 1978, China has accumulated lessons and practical cases in balancing the role of government and market, which is the key to implement mission-oriented innovation policies -- not only fixed the market failure but also further construct an institutional-innovation driven national innovation ecosystem (J. Chen et al., 2018; Fu et al., 2016, 2021; Lawrence et al., 2019; Lewin et al., 2016; Mazzucato, 2018; Schmid & Wang, 2017).

Facing the major challenges on the way of going beyond catch-up for the global innovation leadership, China must need new clear mission for the nation to further develop the new innovation policy tool kit and strategies. In 2017, General Secretary Xi Jinping declared that China is going into a new era at the 19<sup>th</sup> National Congress of the Communist Party of China, in which the principal contradiction facing Chinese society has evolved into one "between unbalanced and inadequate development and the people's ever-growing needs for a better life." The mission of China's STI policy is falling into the goal of a "better life" and the goal of a "better world" --- by building the world's most innovative nation, China's shall have the potential sustainable capability to continue its economic growth as well as provide a social and environmental-friendly development model as an alternative

and meaningful option for the world to achieve peaceful and inclusive development in the post COVID-19 pandemic world.

## 6.2 Key Strategies that Enlighten China's Innovation Future

### 6.2.1 Grasping the Turning Point of Innovation Development Path

After reviewing the paths towards most innovative nation, we find a dual-path of improving national innovation capability (See Figure 20). The first path is basic research and core technology supply path, such as the growth patterns of Germany, UK, Japan and USA, the second path is demand generated science, technology innovation path, which is a traditional catch-up pattern of emerging economies such as South Korea, India and China (K. Lee & Malerba, 2017; Keun Lee & Lim, 2001). Nowadays, China is reaching the turning point that leap from traditional path toward new mode of innovation development.

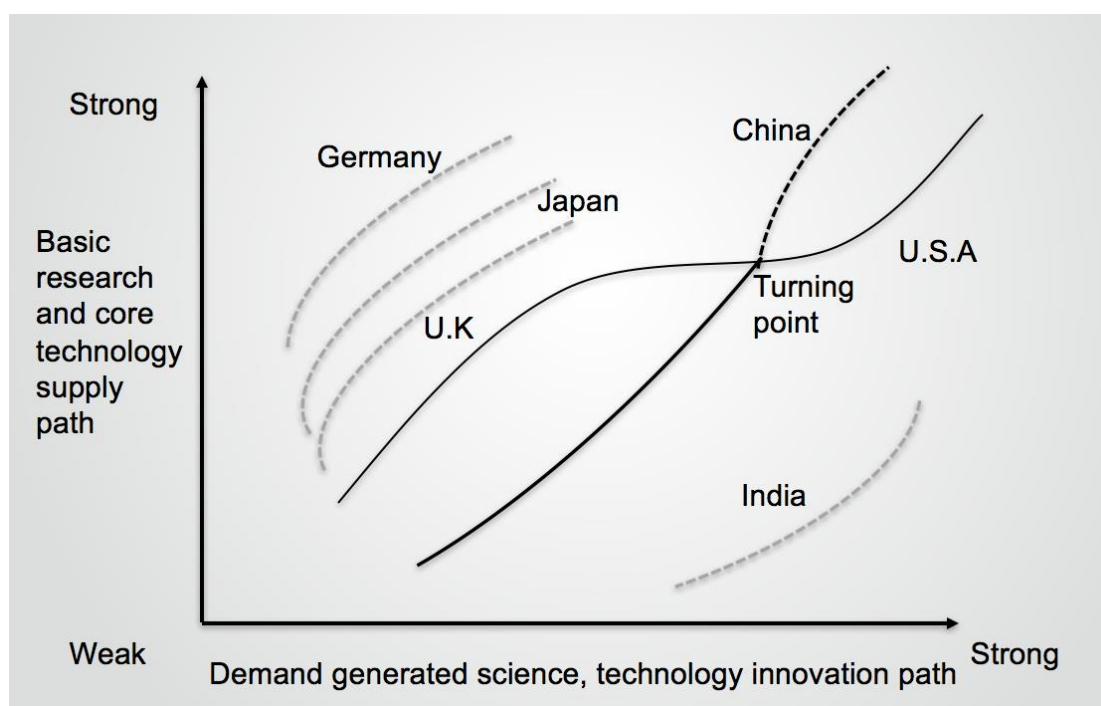


Figure 20 The Paths Towards Most Innovative Nation

During the turning point period from 2020 to 2035, the construction of most innovative country is not only facing fierce competition and even blockade from the first group of innovative countries, mainly Europe, United States, Japan and South Korea, but also facing the rapid catch-up and direct competition from emerging economies, represented by India.

Looking forward to the future of China's innovation road, China has two choices to go, one is continuing the demand-driven path, another better, and maybe also faster, way, is to combine the two paths together by strengthen its advantages as well as building up its new powerful tools of innovation.

China holds the possibility to leap from catch-up with western advanced innovation countries to compete for global innovation leadership by applying the holistic innovation model that combines the traditional demand generated path with original innovation supply path.

Looking into 2035 and 2050, the construction of most powerful innovation nation needs to be guided by the thought of sustainable growth-oriented innovation development in the new era, move from innovation driven to innovation leading development, from indigenous innovation to holistic innovation (Chen et al., 2018; Edquist, 2019). China needs to continue institutional and policy innovation as well as social reform (Lewin et al., 2016) so as to avoid system failure, strengthen policy dynamics and institutional resilience (Malerba & Lee, 2020), accelerate the fundamental transformation of the path or paradigm, as soon as possible, towards the innovative country--from demand and market driven innovation path to strong basic research and core technology supply path.

### **6.2.2 Four Strategic Goals of China's Institutional and STI Policy Improvement**

There is no doubt that China's innovation performance has improved significantly, especially after 2000, after the vigorous implementation of its proactive institutional change and innovation policy. It's a great idea that China should continue use the five sources of STI as we have discussed above to push the road towards an innovative nation. However, in order to build up the global innovation leadership, China need employ holistic innovation perspective and a mission-oriented holistic innovation policy followed by a set of new strategies that can enlighten China's innovation future and achieve the mission of institution and STI policy change.

As Fu, Woo, & Hou (2016) noted, there are two bottlenecks in China's innovation capabilities. One is creativity because the Chinese education system emphasizes respect for and attention to existing knowledge and doctrine, rather than fostering critical thinking and challenging existing limits. Another one is the inequality in access to innovation resources and the need for greater support of SMEs as well as cultivating world-class companies. What's more, as for Chinese high-tech clusters, there are too much excessive competition and lack of soft environment, including the lack of trust and cooperation which leads to high transaction cost, majority of companies do not focus on development a soft environment or couldn't collaborate with research institutes (Sabir & Sabir, 2010).

Therefore, there should be at least four strategic goals of China's STI policy to deal with the five major challenges of China's future innovation growth and achieve the mission of national innovation policies. First one is to further perfect the helix of science, technology and innovation. Second is to further enhance science, technology and economy integration. Third is to further enhance STI and education integration. Finally, China should further enhance STI and traditional culture renaissance.

### 6.2.3 From TI strategy to STI strategy

Based on the challenges and strategic goals of China's STI policy, the key strategy for China is that it needs to apply the holistic innovation perspective and mission-oriented policy approach (Mazzucato, 2018) and transit the focus of innovation policy from technological innovation to a more hybrid and holistic one that combines science, technology and innovation. The former one is a type of technological innovation system with a focus on enterprises and university-industry cooperation, while the later one is a new multi-dimension holistic system to build a science, technology innovation system with leading enterprises, universities and research institutes (Carayannis & Campbell, 2009; Edquist, 2019; K. Lee & Malerba, 2017; Schmid & Wang, 2017).

Firm is the most dynamic and powerful dimension of national innovation system (Clarke et al., 2018). In order to cultivate world-class innovative firms, government should encourage industry-leading enterprises to formulate high level research institutes, to build organizational R&D systems that collaborated with universities, to aggregate top innovation talents (Audretsch, 2014; J. Li et al., 2018; Wapner, 2016). What's more, government need to motivate leading enterprises collaborate with small and medium enterprises and research institutes to systematically layout the innovation chain, offering overall solutions to industry and regional science and technological innovation (Audretsch et al., 2012; Brown, 2016; Cooke, 2004). The third one is to cultivate a batch of innovation-oriented enterprises with outstanding capabilities in core technology and holistic innovation that can lead major industrial development (Fu & Gong, 2011; J. McGregor, 2010). Meanwhile, more Chinese firms need to strive into the top 100 innovation-oriented enterprises in the world so as to create more socioeconomic impact as well as contribute the global sustainable innovation development with leading technologies and products (J. Chen, Yin, et al., 2020; J. Chen & Yin, 2019a).

At the industry level, China's institutional and STI policy change has two parallel curves to further promote economic transformation and industrial upgrading. First curve is exploitation-oriented, that helps to deep cultivation of traditional industries through lean innovation and craftsmanship with adaptive R&D. The second curve is more exploration-oriented that focus on exploration of emerging industries (i.e. AI, IoT) and tries to achieve original and disruptive innovation by combining the basic and applied research (See Table 3).

Two Curves of Promoting Economic Transformation and Industrial Upgrading		
Attributes	First Curve	Second Curve
1	Exploitation	Exploration

2	Deep cultivation of traditional industries	Exploration of emerging industries
3	Lean innovation, craftsmanship	Original and disruptive innovation
4	Adaptive R&D	Basic and Applied Research

*Table 3 Two Curves of Promoting Economic Transformation and Industrial Upgrading*

As for the education dimension, STI policy should provide incentives to build world-class universities and first-class disciplines as well as world-class research institutes, to create more original and radical knowledge for innovation as well as creative human resources. More specifically, STI policy need to guide universities to strengthen basic research and pursue academic excellence, build comprehensive cross-disciplinary teams, form a batch of advantage subject clusters and high-level science, technology and innovation bases, enhance abilities of original innovation and innovation in socio-economical services, promote a batch of high-level universities and disciplines to become first-tier in the world. There can be four different types of universities in the future, teaching-oriented university, teaching and research university, research-oriented university, and entrepreneurial university. But all of these universities should aim to become innovative universities. The ultimate purpose of this dimension is to actively cultivate all kinds of innovative talents that can be use as sources of innovation, including strategic scientists, innovative engineers, technical workers and entrepreneurs (SEWEs). Cultivating innovators, or in other word, innovative talents, should be the common goal for both the science and technology system and the education system. Excellent innovation and entrepreneurial talents have at least four attributes: global citizenship and responsibility, critical and holistic thinking, risk-taking and risk management, persistency and leadership.

Besides the firm innovation system, education system and research system, it is more important (at least with same importance) to build the national system of technology transfer (Barr et al., 2009; Lu & Etzkowitz, 2008; OECD, 2016). A more productive helix ecosystem should not only include university, industry and government, but also need include a linkage system of knowledge transfer that helps to improve the efficiency and efficacy of knowledge flow and knowledge commercialization. Under the guise of a Triple Helix “ecosystem”, university, industry, and government interactions were purported to be core elements of regional economic growth, within a knowledge-based economy (Hair Awang et al., 2013; Leydesdorff, 2012). However, if there is in lack of financial services and business running (such as branding, IP operation, technology transfer platform), the knowledge cannot be effectively transfer between universities, industry and regional innovation system. Therefore, the STI policy should not only emphasize the creation of intellectual property, but also on the business running

and commercializing intellectual property, which means the STI policy should help to build up the closed circle from papers and patents to products and products sales.

## References

- Adner, R. (2017). Ecosystem as Structure: An Actionable Construct for Strategy. *Journal of Management*, 43(1), 39–58. <https://doi.org/10.1177/0149206316678451>
- Andersson, R., Quigley, J. M., & Wilhelmsson, M. (2009). Urbanization, productivity, and innovation: Evidence from investment in higher education. *Journal of Urban Economics*, 66(1), 2–15.
- Armanios, D. E., Eesley, C. E., Li, J., & Eisenhardt, K. M. (2017). How entrepreneurs leverage institutional intermediaries in emerging economies to acquire public resources: How Entrepreneurs Leverage Institutional Intermediaries in Emerging Economies. *Strategic Management Journal*, 38(7), 1373–1390. <https://doi.org/10.1002/smj.2575>
- Audretsch, D. B. (2014). From the entrepreneurial university to the university for the entrepreneurial society. *The Journal of Technology Transfer*, 39(3), 313–321. <https://doi.org/10.1007/s10961-012-9288-1>
- Audretsch, D. B., Hülsbeck, M., & Lehmann, E. E. (2012). Regional competitiveness, university spillovers, and entrepreneurial activity. *Small Business Economics*, 39(3), 587–601.
- Barr, S. H., Baker, T., Markham, S. K., & Kingon, A. I. (2009). Bridging the valley of death: Lessons learned from 14 years of commercialization of technology education. *Academy of Management Learning & Education*, 8(3), 370–388. <http://dx.doi.org/10.5465/AMLE.2009.44287937>
- Brown, R. (2016). Mission impossible? Entrepreneurial universities and peripheral regional innovation systems. *Industry and Innovation*, 23(2), 189–205.
- Cai, F. (2012). Is There a “Middle-income Trap”? Theories, Experiences and Relevance to China. *China & World Economy*, 20(1), 49–61. <https://doi.org/10.1111/j.1749-124X.2012.01272.x>
- Carayannis, E. G., & Campbell, D. F. J. (2009). “Mode 3” and “Quadruple Helix”: Toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management*, 46(3/4), 201. <https://doi.org/10.1504/IJTM.2009.023374>
- Chen, J. (2017). *Theory of Firm Innovation System (in Chinese)* (1st ed.). Science Publisher.
- Chen, J., & Mei, L. (2018). Innovation evolution of China's high-speed rail industry. *Frontiers of Engineering Management*, 5(4), 548–552. <https://doi.org/10.15302/J-FEM-2018208>
- Chen, J., & Yin, X. (2019a). Operation and Management Models Among the World-Class Enterprises. *Enterprise Management*, 07, 12–16.
- Chen, J., & Yin, X. (2019b). Connotation and Types of Innovation. In J. Chen, A. Brem, V. Eric, & W. P. Kam, *The Routledge Companion to Innovation Management* (1st ed., pp. 26–54). Routledge. <https://www.routledgehandbooks.com/doi/10.4324/9781315276670-3>

- Chen, J., Yin, X., & Li, J. (2020). Firm Innovation System: Paths for Enhancing Corporate Indigenous Innovation Capability. *Frontiers of Engineering Management*, 7(3), 404–412. [journal.hep.com.cn. https://doi.org/10.1007/s42524-020-0116-2](https://doi.org/10.1007/s42524-020-0116-2)
- Chen, J., Yin, X., & Mei, L. (2018). Holistic Innovation: An Emerging Innovation Paradigm. *International Journal of Innovation Studies*, 2(1), 1–13.
- Chen, J., Yu-shan, S., Jeroen P.J. de, J., & von Hippel, E. (2020). Household sector innovation in China\_ Impacts of income and motivation. *Research Policy*, 49, 103931.
- Chen, M.-J., & Miller, D. (2010). West Meets East: Toward an Ambicultural Approach to Management. *Academy of Management Perspectives*, 24(4), 17–24.
- Chen, T.-J., & Ku, Y.-H. (2014). Indigenous innovation vs. teng-long huan-niao: Policy conflicts in the development of China's flat panel industry. *Industrial and Corporate Change*, 23(6), 1445–1467. <https://doi.org/10.1093/icc/dtu004>
- Chesbrough, H. W. (2003). The era of open innovation. *MIT Sloan Management Review; Cambridge*, 44(3), 35–41.
- Chua, R. Y. J., Huang, K. G., & Jin, M. (2019). Mapping cultural tightness and its links to innovation, urbanization, and happiness across 31 provinces in China. *Proceedings of the National Academy of Sciences*, 116(14), 6720–6725. <https://doi.org/10.1073/pnas.1815723116>
- Clarke, T., Chelliah, J., & Pattinson, E. (2018). National Innovation Systems in the Asia Pacific: A Comparative Analysis. In *Innovation in the Asia Pacific* (pp. 119–143). Springer, Singapore.
- Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35(1), 128–152.
- Cooke, P. (2004). The role of research in regional innovation systems: New models meeting knowledge economy demands. *International Journal of Technology Management*, 28(3–6), 507–533.
- Costanza, R., Kubiszewski, I., Giovannini, E., Lovins, H., McGlade, J., Pickett, K. E., Ragnarsdóttir, K. V., Roberts, D., De Vogli, R., & Wilkinson, R. (2014). Development: Time to leave GDP behind. *Nature News*, 505(7483), 283. <https://doi.org/10.1038/505283a>
- Dosi, G. (1982). Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy*, 11(3), 147–162.
- Economist. (2018, March 15). The battle for digital supremacy: America's technological hegemony is under threat from China. *The Economist*. <https://www.economist.com/news/leaders/21738883-americas-technological-hegemony-under-threat-china-battle-digital-supremacy>

- Edquist, C. (2019). Towards a holistic innovation policy: Can the Swedish National Innovation Council (NIC) be a role model? *Research Policy*, 48(4), 869–879.
- Ernst, D. (2011). *China's Innovation Policy is a Wake-Up Call for America* (SSRN Scholarly Paper ID 2770063). Social Science Research Network. <https://papers.ssrn.com/abstract=2770063>
- Euchner, J. (2014). Innovation Ecosystems: An Interview with Ron Adner. *Research Technology Management*, 57(6), 10–14. <http://dx.doi.org/10.5437/08956308X5706003>
- Feder, G., & O'Mara, G. T. (1982). On Information and Innovation Diffusion: A Bayesian Approach. *American Journal of Agricultural Economics*, 64(1), 145–147.
- Ferreira, J. J. M., Fernandes, C. I., & Ferreira, F. A. F. (2019). To be or not to be digital, that is the question: Firm innovation and performance. *Journal of Business Research*, 101, 583–590.
- Freeman, C. (1987). *Technology, policy, and economic performance: Lessons from Japan*. Pinter Publishers.
- Fu, X. (2015). *China's Path to Innovation*. Cambridge University Press.
- Fu, X., Chen, J., & McKern, B. (2021). *Oxford Handbook of China Innovation*. Cambridge University Press.
- Fu, X., & Gong, Y. (2011). Indigenous and Foreign Innovation Efforts and Drivers of Technological Upgrading: Evidence from China. *World Development*, 39(7), 1213–1225.
- Fu, X., Woo, W. T., & Hou, J. (2016). Technological innovation policy in China: The lessons, and the necessary changes ahead. *Economic Change and Restructuring; Dordrecht*, 49(2–3), 139–157. <http://dx.doi.org.proxy.library.cornell.edu/10.1007/s10644-016-9186-x>
- Gary, H., & Michele, Z. (2018). The End of Bureaucracy-How a Chinese appliance maker is reinventing management for the digital age. *Harvard Business Review*, 11–12, 51–59.
- Geoffrey, G. (2018, April 9). *Why the U.S.-China 'Trade War' Is Really About the Future of Innovation*. Knowledge@Wharton. <https://knowledge.wharton.upenn.edu/article/u-s-china-trade-war-really-future-innovation/>
- Gkypali, A., Arvanitis, S., & Tsekouras, K. (2018). Absorptive capacity, exporting activities, innovation openness and innovation performance: A SEM approach towards a unifying framework. *Technological Forecasting and Social Change*, 132:143-155.
- Gobble, M. M. (2018). Digitalization, Digitization, and Innovation. *Research-Technology Management*, 61(4), 56–59. <https://doi.org/10.1080/08956308.2018.1471280>
- Gu, S., & Lundvall, B.-Å. (2006). Introduction: China's innovation system and the move towards harmonious growth and endogenous innovation. *Innovation*, 8(1–2), 1–26.

- Guan, J. C., Yam, R. C. M., Tang, E. P. Y., & Lau, A. K. W. (2009). Innovation strategy and performance during economic transition: Evidences in Beijing, China. *Research Policy*, 38(5), 802–812. <https://doi.org/10.1016/j.respol.2008.12.009>
- Gwyne, P. (2010). Building R&D Capability: China's Cultural Evolution. *Research Technology Management*, 53(6), 2–3.
- Hair Awang, A., Yusof Hussain, M., & Abdul Malek, J. (2013). Knowledge transfer and the role of local absorptive capability at science and technology parks. *The Learning Organization*, 20(4/5), 291–307. <https://doi.org/10.1108/TLO-12-2011-0059>
- Hu, M.-C., & Mathews, J. A. (2005). National innovative capacity in East Asia. *Research Policy*, 34(9), 1322–1349. <https://doi.org/10.1016/j.respol.2005.04.009>
- Hu, X., Yin, X., Jin, Z., & Li, J. (2020). How Do International M&As Affect Rival Firm's Sustainable Performance? —Empirical Evidence from an Emerging Market. *Sustainability*, 12(4), 1318. <https://doi.org/10.3390/su12041318>
- Huang, C., & Sharif, N. (2016). Global technology leadership: The case of China. *Science and Public Policy*, 43(1), 62–73. <https://doi.org/10.1093/scipol/scv019>
- Kankanhalli, A., Zuiderwijk, A., & Tayi, G. K. (2017). Open innovation in the public sector: A research agenda. *Government Information Quarterly*, 34(1), 84–89.
- Kim, L. (1997). *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Harvard Business Review Press.
- Knight, W. (2017). China's AI Awakening: The West should stop worrying about China's AI revolution. It should copy it. *MIT Technology Review*. <https://www.technologyreview.com/s/609038/chinas-ai-awakening/>
- Laursen, K., & Salter, A. J. (2014). The paradox of openness: Appropriability, external search and collaboration. *Research Policy*, 43(5), 867–878. <https://doi.org/10.1016/j.respol.2013.10.004>
- Lawrence, M. B., Bullock, R. G., & Liu, Z. (2019). *China's High-Speed Rail Development* (No. 137512; pp. 1–101). The World Bank. <http://documents.worldbank.org/curated/en/933411559841476316/Chinas-High-Speed-Rail-Development>
- Leamer, E. E., & Storper, M. (2014). The Economic Geography of the Internet Age. In C. J. (Ed.), *Location of International Business Activities* (pp. 63–93). Palgrave Macmillan, London.
- Lee, J., Kao, H.-A., & Yang, S. (2014). Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment. *Procedia CIRP*, 16, 3–8. <https://doi.org/10.1016/j.procir.2014.02.001>

- Lee, K., & Malerba, F. (2017). Theory and empirical evidence of catch-up cycles and changes in industrial leadership. *Research Policy*, 46(2), 337. Scopus.
- Lee, Keun. (2016). Innovation and technological specialization of Chinese industry. In A. Y. Lewin, J. P. Murmann, & M. Kenney (Eds.), *China's Innovation Challenge: Overcoming the Middle-Income Trap* (pp. 108–120). Cambridge University Press.
- Lee, Keun, & Lim, C. (2001). Technological regimes, catching-up and leapfrogging: Findings from the Korean industries. *Research Policy*, 30(3), 459–483.
- Lee, Kong-rae, Chen, J., Li, J., & Kim, J. H. (2017). Better innovation, better future: Working together for innovating Asia. *Asian Journal of Technology Innovation*, 25(1), 1–4.
- Lewin, A. Y., Kenney, M., & Murmann, J. P. (2016). *China's Innovation Challenge: Overcoming the Middle-Income Trap*. Cambridge University Press.
- Lewin, A. Y., Massini, S., & Peeters, C. (2011). Microfoundations of Internal and External Absorptive Capacity Routines. *Organization Science*, 22(1), 81–98.
- Leydesdorff, L. (2012). The Triple Helix, Quadruple Helix, ..., and an N-Tuple of Helices: Explanatory Models for Analyzing the Knowledge-Based Economy? *Journal of the Knowledge Economy*, 3(1), 25–35. <https://doi.org/10.1007/s13132-011-0049-4>
- Li, D., Capone, G., & Malerba, F. (2019). The long march to catch-up: A history-friendly model of China's mobile communications industry. *Research Policy*, 48(3), 649–664.
- Li, F. (2019). Why Have All Western Internet Firms Failed in China? A Phenomenon-Based Study. *Academy of Management Discoveries*, 5(1), 13–37. <https://doi.org/10.5465/amd.2017.0102>
- Li, J., Yin, X., Shen, S. X., Sine, W., & Chen, J. (2018). *CHINA'S INNOVATION & TECHNOLOGY TRANSFER IN THE GLOBAL CONTEXT* (p. 74). ENRICH(EUROPEAN NETWORK OF RESEARCH AND INNOVATION CENTRES AND HUBS, CHINA). <http://china.enrichcentres.eu/sharedResources/users/4807/ENRICH%20China%20report%20THU.pdf>
- Li, S., Xu, L. D., & Zhao, S. (2015). The internet of things: A survey. *Information Systems Frontiers*, 17(2), 243–259. <https://doi.org/10.1007/s10796-014-9492-7>
- Li, X. (2009). China's regional innovation capacity in transition: An empirical approach. *Research Policy*, 38(2), 338–357. <https://doi.org/10.1016/j.respol.2008.12.002>
- Lichtenthaler, U. (2011). Open Innovation: Past Research, Current Debates, and Future Directions. *Academy of Management Perspectives*, 25(1), 75–93.
- Li-Hua, R. (2014). Embracing Contradiction. In R. Li-Hua (Ed.), *Competitiveness of Chinese Firms* (pp. 87–104). Palgrave Macmillan, London. [https://doi.org/10.1057/9781137309303\\_5](https://doi.org/10.1057/9781137309303_5)

- Liu, M., Su, C., Wang, F., & Huang, L. (2020). Chinese cross-border M&As in the “One Belt One Road” countries: The impact of Confucius Institutes. *China Economic Review*, 61, 101432.
- Liu, X., & White, S. (2001). Comparing innovation systems: A framework and application to China's transitional context. *Research Policy*, 30(7), 1091–1114.
- Lu, L., & Etzkowitz, H. (2008). Strategic challenges for creating knowledge-based innovation in China: Transforming triple helix university-government-industry relations. *Journal of Technology Management in China; Bradford*, 3(1), 5–11.
- Lundvall, B.-Å. (Ed.). (2010). *National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning*. Anthem Press. <http://www.jstor.org/stable/j.ctt1gxp7cs>
- Malerba, F., & Lee, K. (2020). An evolutionary perspective on economic catch-up by latecomers. *Industrial and Corporate Change*, In-press.
- Martin, B. R. (2016). Twenty challenges for innovation studies. *Science and Public Policy*, 43(3), 432–450. <https://doi.org/10.1093/scipol/scv077>
- Martinkenaite, I., & Breunig, K. J. (2016). The emergence of absorptive capacity through micro–macro level interactions. *Journal of Business Research*, 69(2), 700–708.
- Mazzucato, M. (2018). Mission-oriented innovation policies: Challenges and opportunities. *Industrial and Corporate Change*, 27(5), 803–815. <https://doi.org/10.1093/icc/dty034>
- McGregor, J. (2010). China's drive for ‘indigenous innovation.’ *Global Regulatory Cooperation Project and US Chamber of Commerce* < [Http://Www. Uschamber. Com/Sites/Default/Files/Reports/100728chinareport\\_0. Pdf](Http://Www.Uschamber.Com/Sites/Default/Files/Reports/100728chinareport_0.Pdf)> (Accessed 04.10. 13).
- McGregor, J. A., & Pouw, N. (2017). Towards an economics of well-being. *Cambridge Journal of Economics*, 41(4), 1123–1142.
- Nambisan, S., Wright, M., & Feldman, M. (2019). The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes. *Research Policy*, 48(8), 103773.
- National Science Board. (2018). *Science and Engineering Indicators 2018* (NSB-2018-1). National Science Foundation. <https://www.nsf.gov/statistics/2018/nsb20181/digest/sections/global-r-d-one-measure-of-commitment-to-innovation>
- OECD. (2016). *The Knowledge Triangle: Enhancing the contributions of Higher Education and Research Institutions to Innovation*. OECD. <http://www.oecd.org/sti/inno/knowledge-triangle.htm>
- Phan, P., Zhou, J., & Abrahamson, E. (2010). Creativity, Innovation, and Entrepreneurship in China. *Management and Organization Review*, 6(02), 175–194.

- Phelps, E. S. (2015). *Mass Flourishing: How Grassroots Innovation Created Jobs, Challenge, and Change* (Reprint edition). Princeton University Press.
- Prahalad, C. K., & Hamel, G. (1990). The Core Competence of the Corporation. *Harvard Business Review*, May-June, 79–90.
- Richard, L.-H. (2017, May 11). China's Embracing Innovation Leads to its Peaceful Rise. *China Policy Institute: Analysis*. <https://cpianalysis.org/2017/05/11/chinas-embracing-innovation-leads-to-its-peaceful-rise/>
- Rogers, E. M., & Shoemaker, F. F. (1971). *Communication of Innovations; A Cross-Cultural Approach*.
- Romer, P. M. (1986). Increasing Returns and Long-Run Growth. *The Journal of Political Economy*, 94(5), 1002–1037.
- Sabir, R. I., & Sabir, R. M. (2010). Managing technological innovation: China's strategy and challenges. *Journal of Technology Management in China; Bradford*, 5(3), 213–226. <http://dx.doi.org.proxy.library.cornell.edu/10.1108/17468771011086238>
- Sauermann, H., Vohland, K., Antoniou, V., Balázs, B., Göbel, C., Karatzas, K., Mooney, P., Perelló, J., Ponti, M., Samson, R., & Winter, S. (2020). Citizen science and sustainability transitions. *Research Policy*, 49(5), 103978. <https://doi.org/10.1016/j.respol.2020.103978>
- Schmid, J., & Wang, F.-L. (2017). Beyond National Innovation Systems: Incentives and China's Innovation Performance. *Journal of Contemporary China*, 26(104), 280–296.
- Sha, K., Song, T., Qi, X., & Luo, N. (2006). Rethinking China's urbanization: An institutional innovation perspective. *Building Research & Information*, 34(6), 573–583.
- Shang-Jin, W., Xie, Z., & Zhang, X. (2017). From “Made in China” to “Innovated in China”: Necessity, Prospect, and Challenges. *The Journal of Economic Perspectives*, 31(1), 49–70.
- Soete, L. (2011). *The Role of Foreign Technology and Indigenous Innovation in Emerging Economies: Technological Change and Catch-up*.
- Somerén, T. C. R. van, & Someren-Wang, S. van. (2014). *Innovative China: Innovation Race Between East and West*. Springer Science & Business Media.
- Swanson, E. B. (1994). Information Systems Innovation Among Organizations. *Management Science*, 40(9), 1069–1092. <https://doi.org/10.1287/mnsc.40.9.1069>
- Tassey, G. (2008). Globalization of technology-based growth: The policy imperative. *The Journal of Technology Transfer*, 33(6), 560–578. <https://doi.org/10.1007/s10961-008-9092-0>
- Todorova, G., & Durisin, B. (2007). Absorptive capacity: Valuing a reconceptualization. *Academy of Management Review*, 32(3), 774–786.

- Wapner, J. (2016). Technology Transfer: The leap to industry. *Nature*, 533, S13–S15.
- WIPO. (2018). *Global Innovation Index 2018*. <http://www.globalinnovationindex.org/Home>
- World Intellectual Property Organization. (2019). *Global Innovation Index 2019*. World Intellectual Property Organization. <https://www.wipo.int/publications/en/details.jsp?id=4434>
- World Intellectual Property Organization. (2020, April 7). *China Becomes Top Filer of International Patents in 2019*. [https://www.wipo.int/pressroom/en/articles/2020/article\\_0005.html](https://www.wipo.int/pressroom/en/articles/2020/article_0005.html)
- Yang, J. Y., & Li, J. (2008). The development of entrepreneurship in China. *Asia Pacific Journal of Management: APJM; Singapore*, 25(2), 335–359.
- Yip, G. S., & McKern, B. (2016). *China's Next Strategic Advantage: From Imitation to Innovation* (1 edition). The MIT Press.
- Yu, X., Dosi, G., Grazzi, M., & Lei, J. (2017). Inside the virtuous circle between productivity, profitability, investment and corporate growth: An anatomy of Chinese industrialization. *Research Policy*, 46(5), 1020–1038. <https://doi.org/10.1016/j.respol.2017.03.006>
- Zahra, S. A., & George, G. (2002). Absorptive Capacity: A Review, Reconceptualization, and Extension. *The Academy of Management Review*, 27(2), 185–203.