Marcin Piatkowski

Will China Become a Global Technological Giant?

China has achieved a remarkable economic success since the beginning of its reforms in 1978. Over these 40 years, it has increased its GDP per capita by more than 25 times, more than any country ever before (and likely ever again). It has already become the largest global economy in terms of total GDP adjusted for purchasing power. It is also only a matter of time before it beats the US also in terms of the size of its GDP based on the nominal exchange rate, by 2030 at the latest. By 2025 or so, it is also slated to become a high-income country, as defined by the World Bank.

This remarkable performance has been increasingly driven by technology absorption and innovation. Gone are the days when China was merely a global manufacturing "sweatshop". Chinese firms are progressively developing their own new technologies, improving their position in the global patent rankings, and expanding into the global markets. China already leads the world in e-commerce, mobile payment technologies, bike-sharing and high-speed train technology.

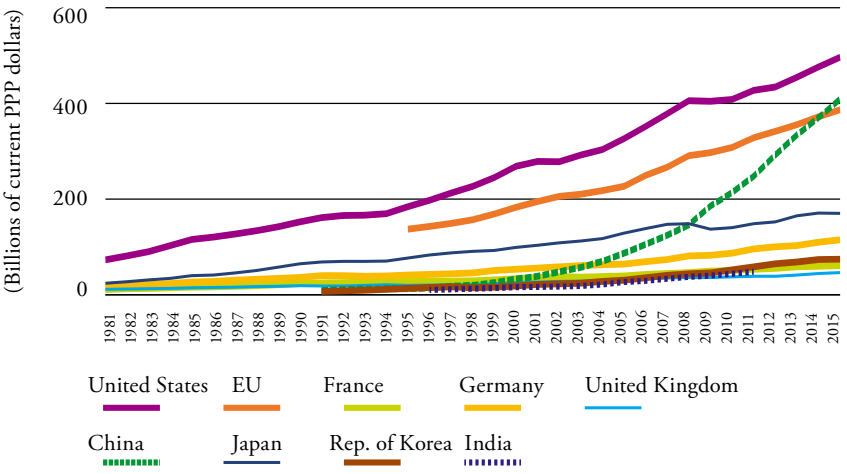
Will this progress continue? Will China become a global technological giant? This will much depend on whether China will be able to deal with several challenges that may undermine their innovation-led growth in the future. These include the quality of innovation outputs, efficiency of public support for innovation, protection of intellectual property rights and the quality of managerial practices among Chinese firms. China will also need to deal with rising Western technological protectionism, which may block access of Chinese firms to Western technology and markets.

The article is structured as follows: the first section documents China's progress in innovation. The second section analyses the challenges. The last section summarizes and shares conclusions.

China's progress in innovation

China's progress in innovation has been impressive. Its total R&D spending (in current PPP dollars) increased from USD 33 billion in 2000 to USD 409 billion in 2015, which allowed China to become the second largest R&D investor in the world, after the US and ahead of the EU (Figure 1). In proportion to GDP, China's R&D investment reached 2.1 percent in 2017 and was higher than the OECD average. China invested into R&D more than twice as much as, for instance, Poland, even though Poland's income was almost twice as high as that of China. Given China's plans to increase R&D spending to 2.5 percent of GDP in 2020, the US and China would then account for more than half of the world's R&D spending.

Figure 1 **R&D spending in China and selected economies, 1980-2015, in billions of current PPP dollars**

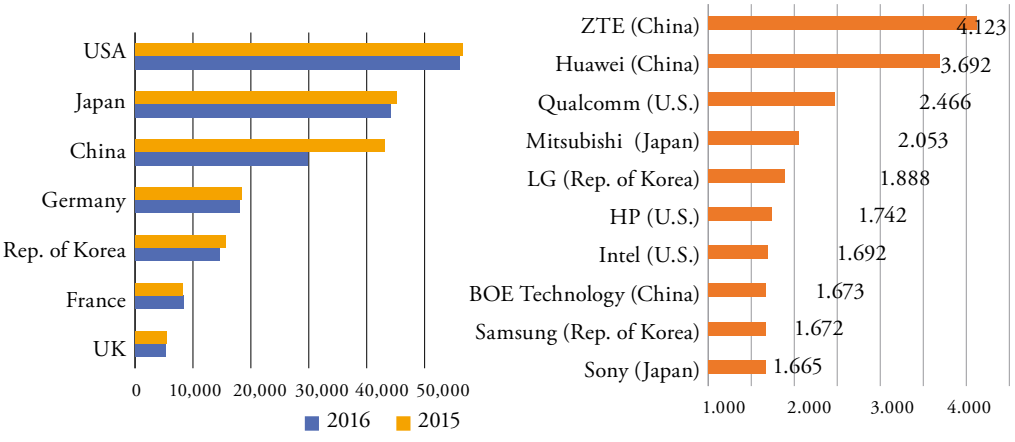


Source: author's own based on NSF [2018].

The increase in R&D spending has been accompanied by a rise in the number of graduates in science and engineering (STEM). In 2014 alone, China "produced" almost 1.5 million bachelors with a STEM degree, almost three times as many as the top 8 EU countries (569,000 graduates) and four times as many as in the US (377,000 graduates). The number of STEM PhD graduates was also higher than in the US [NSF, 2018].

High R&D spending has translated into a booming number of patents. In 2016, 3.5 million patents were submitted to China's patent office, almost twice as many as in the US, making China the world's No. 1 in the number of patent applications [WIPO, 2016]. The number of high-quality international patents has also increased, as reflected in the number of Chinese international patent applications (PCT) counted by the World Intellectual Property Organization (WIPO). Judging by the speed of the increase in the number of patents, in 2017, China has already overtaken Japan to become the second-largest source country of patent applications, behind the United States (Figure 2, left panel). Chinese firms also now lead the world in patenting: two telecommunication firms, ZTE and Huawei, have be-

Figure 2 **Country patent applications to WIPO and the global top PCT patenting firms, 2015-2016**



Note: PCT applications published in 2016 (right panel).

Source: author's own based on WIPO Statistics Database, September 2017.

come the global leaders in WIPO's 2016 patent ranking (Figure 2, right panel).

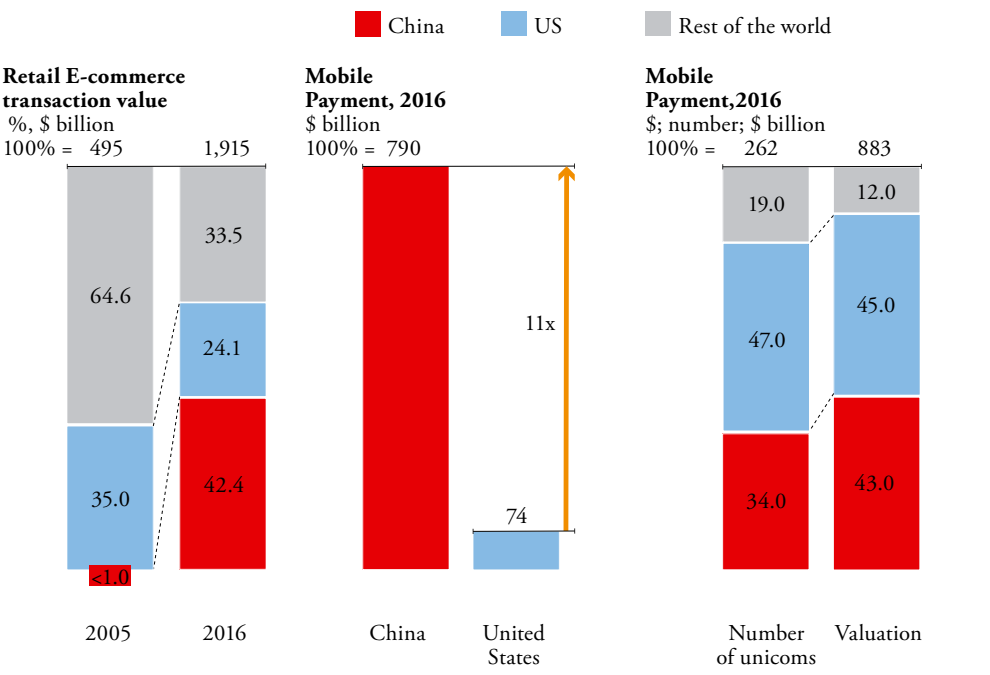
Other data confirm China's unbelievable rise in innovation input and output: for example, in 2017, venture capital investment in Beijing alone amounted to around USD 20 billion, which was almost on par with the total VC investment in the whole of Europe [KPMG, 2018]. In the same year, Beijing had 67 unicorns (start-up companies with an estimated value above $1 billion), more than any other city in the world except San Francisco/Silicon Valley. Beijing also ranked first among 500 cities in the world in scientific research output in the *2017 Nature Index Science City* published by "Nature" magazine, followed by Paris and New York. China's overall global ranking in terms of citation of scientific papers rose from the 4th place in 2015 to 2nd place in 2017 [ISTIC, 2018]. China's position in various global innovation has also improved: for instance, in the WIPO/INSEAD/Cornell Global Innovation Index for 2016, China moved from 29th to 25th place (just behind Estonia) [WIPO, 2016]. Finally, China has become a leading global force in the digital economy: in 2016, 42.4 percent of the world's retail e-commerce transactions took place in China versus 24.1 percent only in the US. China has also had an unparalleled lead in mobile payments and a strong position in the number of technological "unicorns" (Figure 3).

Key challenges to innovation-based development

Despite the astonishing progress, China faces several challenges, which–if let unresolved – may thwart its efforts to become one of the leading global technological powerhouses.

First, the quality of innovation outputs has not kept pace with the increase in the volume. The quality of patents, for instance, a key proxy for the overall innovativeness, continues to lag the global peers. This is reflected in the fact that many of the high-value patents are developed by foreign multinationals rather than domestic firms: the former were responsible for more than two-thirds of all

Figure 3 **Digital development in China, the US and the rest of the world**



Source: McKinsey [2017].

Chinese USTPO patents in 2010 [Cusolito, Maloney, 2018]. The overall quality of patents is also relatively low: high-quality patents registered abroad represented only 4 percent of all Chinese patents. Other measures of patent quality – foreign citations received by patent, claims on Chinese-owned patents or patents that represent frontier technologies – paint a similar picture [Boeing, Mueller, 2018].

Lastly, most Chinese patents are "utility" patents, which are usually of lower economic value that invention patents [DRC and the World Bank, 2018].

Similarly, the quality of research outputs also leaves scope for improvement. While China's has become the world's top producer of scientific publications, largely driven by monetary incentives (researchers can receive on average $44,000 to publish a paper in "Nature", a prestigious science journal [Enago, 2018]), the quality of research outputs, as measured by the number of citations, has not risen in step with the volume. There are also no Chinese researchers among the authors of the top 100 most cited scientific papers of all time [Van Noorden, et al., 2014]. The number of research papers published as part of international cooperation, a good proxy for the quality of output, has risen to more than half of all international publications, but has remained below the global peers [Staniland, 2017].

Second, there is uncertainty as to the efficiency of public support for innovation. While the Chinese government seems to have deployed comprehensive support measures across the whole technological and business life of a firm, there is little evidence of their impact. One of the reasons is the fact the public innovation policies are rarely monitored and evaluated. In addition, a large part of public support seems to accrue to state-owned enterprises, which tend to be less efficient in generating innovation than private firms [Liu, et al., 2017]. Third, the innovation support system seems to be suffer from fragmentation, duplication and lack of transparency: there are at least 170 innovation support policies at the central level alone [DRC, World Bank, 2018]. The results of a survey conducted by the National Academy of Innovation Strategy in 2017 suggest that policy and institutional fragmentation may indeed be a challenge [http://it.people.com.cn/n1/2018/0702/c1009-30098935.html].

Moreover, despite much recent progress, protection of intellectual property rights (IPRs) is still lacking. According to a 2017 survey by China's State Intellectual Property Office, more than 60 percent of patent holders (down from 70 percent a year before) believed that patent protection in China was incomplete. A similar proportion on respondents also thought that patents could be easily copied [SIPO, 2017]. Foreign investors were even more critical [AmCham China, 2018]. While IPR legislation has improved a lot, and is almost in line with international good practice, improvement in the enforcement of IPRs seems to have been slower [China IP Index Report, 2016].

Finally, the managerial practices of Chinese firms are weaker than elsewhere. There is evidence that strong management practices at the firm level are key to efficient technology absorption, innovation and growth in productivity [Bloom, et al., 2017]. However, while Chinese firms have several strengths, including strong focus on production targets and cost competitiveness, they lag behind global peers in long-run strategic planning, monitoring and evaluation and sophisticated HR policies. As a result, Chinese firms' managerial capabilities are below those of many

competitors, ranking between Greece and Turkey (Figure 4). In addition, the best performing Chinese firms lag behind their US peers in management quality more than the less productive firms [Bloom, et al., 2017].

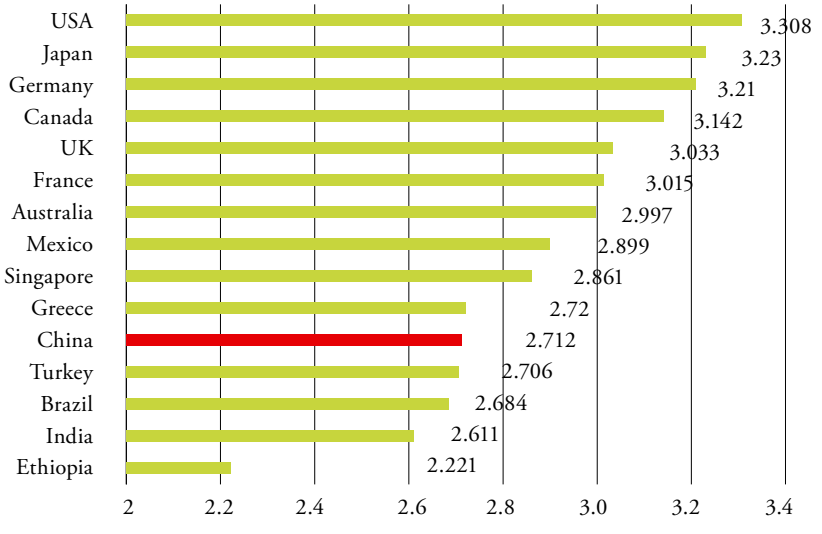
Summary and conclusions

China has achieved a truly unprecedented economic success over the past 40 years, which is unlikely to be repeated by any other country, ever. The rapid growth has been increasingly supported by technology absorption and innovation. Progress so far suggests that China is well on its way in moving from the old, imitation-based growth model, to a new, innovation-based growth model. Despite its still low level of income, amounting to less than one third of the income per capita in the US in PPP terms, China has already become a global leader in several technologies such as mobile payments or high-speed trains. Chinese firms are also starting to lead the global patent and innovation rankings. Given the trends in R&D spending, the strong commitment of the Chinese governments, and the emergence of new technologies, such as artificial intelligence or autonomous vehicles, in which China can get a head start over its global competitors, the future of China's innovation seems promising. It may be only a matter of time before it becomes one of the global technological giants.

However, this optimistic scenario may not come to fruition if China is blocked by the West from absorbing cutting-edge technology and cooperating with the best global firms and researchers. There is a limit to what a country can innovate on its own. Innovation autarky may be sufficient to build a sputnik, as was the case of the former Soviet Union, but it will fail to produce an iPhone.

China may also stop short of becoming a global technological leader it fails to deal with several domestic challenges. These include a relatively low quality of innovation outputs, lack of information on the efficiency of public support for innovation, still weak protection of intellectual property rights, and below-par managerial practices of Chinese firms. To face these challenges, China could benefit from studying international good practice and adjusting it to its own context. Such "innovation policies with Chinese char-

Figure 4 **Quality of managerial capabilities across countries**



Note: average management scores, 15,489 observations during 2004-2014.

Source: author's own based on Bloom, Sadun and Van Reenen [2017].

acteristics" would go a long way towards helping China continue its innovation-based development, to the benefit of China and the world at large.

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Marcin Piatkowski, Assistant Professor, Kozminski University.