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ISSUE BRIEF

# CAN CHINA TRANSFORM ITS ECONOMY TO BE INNOVATION-LED?

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After several decades of spectacular growth, a variety of structural problems have become more challenging for China. Growth based on investment and export has slowed in recent years. Importantly, China's population is aging rapidly with the labor force having already shrunk.[1] Its massive investment of 43% of GDP has reached the diminishing returns stage: more investment funded by debt has produced less value added—or GDP.[2] As a consequence, total factor productivity growth has been slowing—to 1.1% per year in the past decade and a half, less than a third of the rate in the previous three decades.[3] In addition, China is engaging in a strategic competition with the US and Europe, making for a difficult, and at times hostile, world environment for its economy compared with the previous period. Against this backdrop, Chinese leaders especially President Xi Jinping have tried to transform the Chinese economy from the old investment and export based model to one driven by innovation—basically to improve productivity and compensate for the declining labor force.

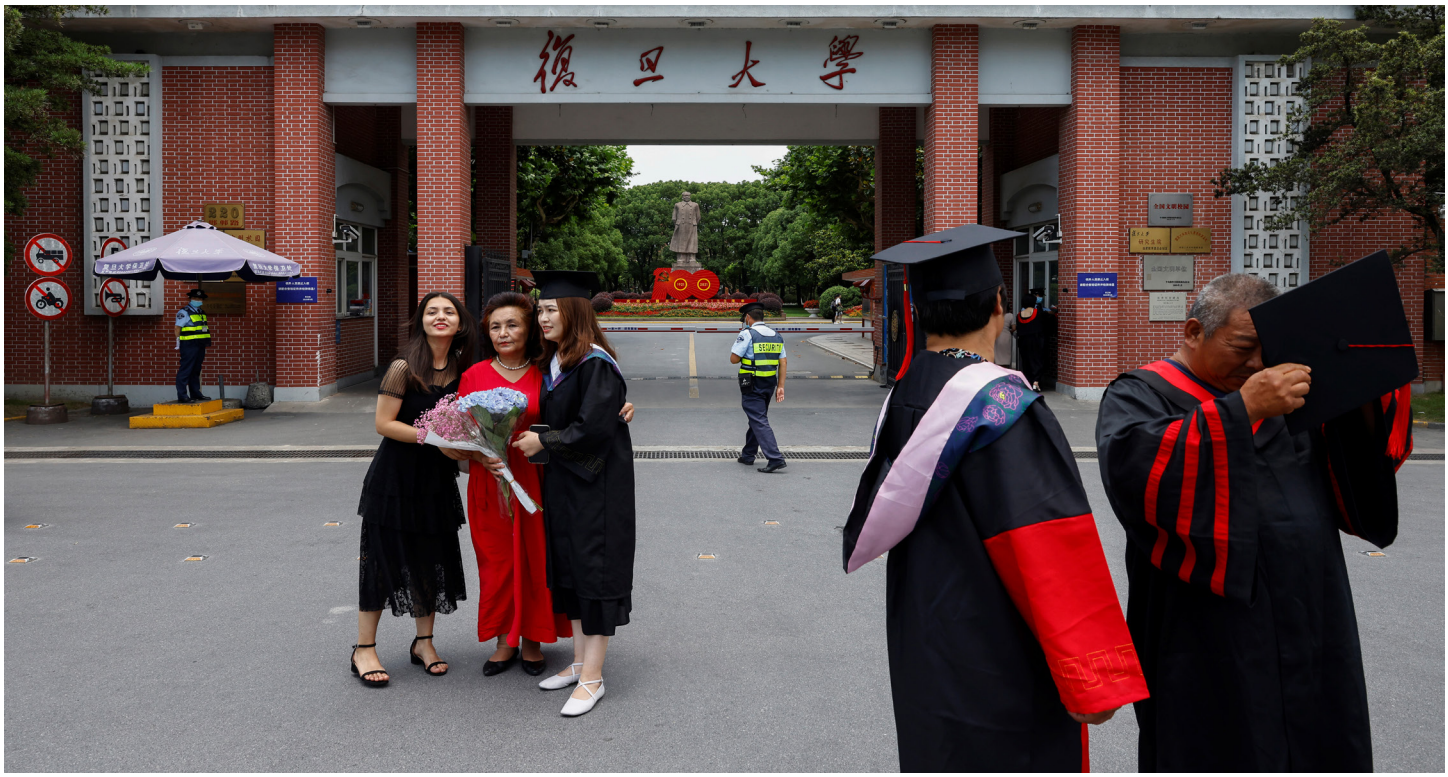
This paper examines the factors that could support or hinder China's efforts to transform its economy to one driven by innovation; using a three stage framework to analyze the process of producing and using innovations—namely, the input mobilization stage, the R&D stage and the output implementation stage. This framework can help assess the relative strengths and weaknesses of China's governance model combining party/state political control with market mechanism. Such a governance model, and until recently together with favorable global conditions and China's demographic tailwind, delivered spectacular



1 Dexter Tiff Roberts, " Can China's Communist Party defuse its demographic time bomb?" *Atlantic Council*, December 21, 2021, https://www.atlanticcouncil.org/blogs/new-atlanticist/can-chinas-communist-party-defuse-its-demographic-time-bomb/.

2 C. Textor, "Total investment as a share of gross domestic product (GDP) in China from 1980 to 2020 with forecasts until 2026," *Statista*, October 21, 2021, https://www.statista.com/statistics/1197064/china-total-investment-as-gdp-share/.

3 "China's future economic potential hinges on its productivity," *The Economist*, August 14, 2021, https://www.economist.com/briefing/2021/08/14/chinas-future-economic-potential-hinges-on-its-productivity.




Students take graduation photo in front of the statue of Chinese leader Mao Zedong at Fudan University in Shanghai, ahead of the 100th founding anniversary of the party, in Shanghai, China . *REUTERS/Aly Song*

economic growth in the past four decades. The key question now is whether it can turn China into an autonomous innovation powerhouse, driving growth in the future. By and large, many if not most observers in the West are skeptical of China's ability to do so, mainly based on their negative view of Xi Jinping's increasingly autocratic rule, tightening central control over society and the economy. While such a negative assessment of Xi's concentration of power has merits, to summarily conclude that China's technology push is destined to fail—no matter how intuitively appealing this conclusion is—risks underestimating China. This is not a wise thing to do while engaging in a strategic geopolitical struggle against the world's largest economy (in purchasing power parity terms). It is better to strive for deeper insights into China's strengths and weaknesses—to better evaluate the prospects of the Chinese economy and of the technological rivalry which forms a key part of the US-China geopolitical and strategic competition.

## Input Mobilization Stage

China's political system—dominated by the Chinese Communist Party (CCP)—gives the party/government the ability to mobilize resources, institutions and actors, both in the public and private sectors, as inputs to the innovation process with clearly defined priorities and goals. China has big advantages with its whole of government/society approaches—especially adopting the civil/military/security fusion policy which can pool resources, create synergies and diffuse innovations across different sectors of the economy.

In terms of human inputs, China has produced significantly more university graduates in Science, Technology, Engineering and Mathematics (STEM) than any other countries—according to latest available data, 4.7 million graduates in China 2016 compared to 2.5 million in India and 568,000 in the US.[4] More importantly, according to Georgetown University's Center for Security and Emerging Technology, China has overtaken the US in 2007 in producing STEM

4 Niall Mccarthy, "The Countries with the Most STEM Graduates," *Forbes*, February 2, 2017, https://www.forbes.com/sites/niallmccarthy/2017/02/02/the-countries-with-the-most-stem-graduates-infographic/?sh=55dff877268a.

A worker stands next to a high-speed train at the maintenance and repair depot of China Railway High-speed (CRH) rail service during a media tour in Beijing, China, August 30, 2018. *REUTERS/Thomas Peter*

PH.Ds and is expected to turn out almost twice as many STEM PH.Ds in 2025 (77,000 vs. 40,000 in the US).[5] Presumably, the quality of Chinese STEM Ph.Ds—admittedly a difficult thing to measure—is improving over time as almost half of new PH.Ds every year (80% of which are in STEM) come from the top 42 "double first class" universities administered and resourced by the central government. It's noteworthy that 21 of those 42 belong to the top 200 universities in the world. Those STEM graduates and PH.Ds play a crucial role in implementing and developing new technologies for the economy.

It is also important to note that China has used various schemes, most notably the Thousand Talents Program, to lure Chinese overseas graduates home; and it has largely succeeded.[6] In 2001, the rate of returnees was only 14%; since 2013 about four in five overseas graduates have done so.[7] Those returning graduates, many of whom have had experiences working in Western corporations and research institutes, can bring valuable knowledge and skills to complement domestically trained scientists and engineers.

China has launched plans for technology and innovation development to articulate a set of priorities and timelines to focus and guide national efforts. For example, the "Made in China 2025" plan launched in 2015 aims to develop China into a manufacturing superpower by raising the domestic content in the production in ten key technological sectors to 65%-90% in the period 2020-2030.[8] So far, the plan seems to make some progress—China has posted an annual trade surplus of $75-80 billion in high-tech

5 Remco Zwetsloot et al., *China is Fast Outpacing U.S. STEM PhD Growth*, (Washington, DC: Center for Security and Emergy Technology, 2021), 2, https://cset.georgetown.edu/wp-content/uploads/China-is-Fast-Outpacing-U.S.-STEM-PhD-Growth.pdf.

6 Hepeng Jia, "What's in China's Thousand Talents Plan?" *Naturejobs Career Guide: China*, January 17, 2018, https://www.nature.com/collections/bxzlnkkfnf.

7 "China's future economic potential hinges on its productivity," *The Economist*, January 21, 2021, https://www.economist.com/special-report/2021/01/21/as-attitudes-to-the-west-sour-chinas-students-turn-home.

8 Congressional Research Service, " 'Made in China 2025' Industrial Policies: Issues for Congress," August 11, 2020, https://sgp.fas.org/crs/row/IF10964.pdf

products.[9] However China still relies of foreign high-tech components—so that excluding computers and telecommunications the trade in high-tech turns into a deficit of around $300 billion per year.

In October 2020, the 14th Five Year Plan 2021-2025 was announced by the CCP leadership to increase R&D spending by 7% per year in the next five years to achieve breakthroughs in 7 fields: AI, Quantum technology, integrated circuits and semiconductors, brain science, genomics and biotechnology, clinical medicine and health; and deep space, deep earth, deep sea and polar research.[10] This was later supplemented with a specific five-year plan to promote smart manufacturing—with the goal of achieving digitalization and network transformation of 70% of China's large-scale manufacturing enterprises.[11] In addition, in November 2021, Xi Jinping approved a three year plan to revamp its state science and technology system to help China attain "self sufficiency and self empowerment in technology".[12] More recently, China unveiled its Five-Year Plan for National Informatization, the first such plan for the country and probably the world.[13] The Plan aims to develop digital technology to "create a more sustainable, balanced and green economic development model".

Implementing those plans, China has mobilized significant financial resources for technology development—total R&D spending rose to 2.4% of GDP in 2020,[14] catching up with the OECD average of 2.5% and the US at more than 3%.[15] In particular, spending by corporations, spearheaded by Huawei, Baidu, Alibaba and Tencent which are among global companies with substantial R&D budgets, increased from 1.26% of GDP in 2010 to 1.85% in 2020–at a rate faster than in most developed countries.[16] Presumably, corporate R&D is more attune to the needs and opportunities of corporations, therefore more commercially useful. It is important to keep in mind that Chinese companies, not only state-owned enterprises (SOEs) but increasingly private ones, can get subsidies and preferable tax and regulatory treatments from the central and local governments when they undertake R&D activities according to state plans.

Despite the strengths described above, China also face risks in this stage. In particular, the top-down decision making regime, which has become more authoritarian in recent years amid a growing personality cult around Xi Jinping, runs the risk of prematurely picking the wrong winner—promising technology which would be rendered obsolete by later and better innovations. Moreover, the whole government approach relies on a huge party and government bureaucracy with its inherent weaknesses including turf fighting—leading to inefficiency and wastes of resources.

## R&D Stage

The R&D stage depends on the ability and efficiency of actors/institutions to carry out R&D plans to produce scientific innovations. Results of R&D activities can be measured by the number of scientific papers published in professional journal, patents especially those having been commercialized, and importantly receipts of royalties and licensing fees from foreign countries. According to Japan's National Institute of Science and Technology Policy, China has overtaken the US in terms of the number of scientific papers published in professional journals, accounting for 19.9% of the global total in 2016-2018 compared with the US at

9 Maximilian Nadickbernd, "Made in China 2025 – A Halftime Analysis" *China Tech Blog*, March 3, 2020, https://www.chinatechblog.org/blog/madeinchina2025

10 Alic Tsang, C. H. Poon, "China's 14th Five-Year Plan: Research Priorities and Industrial Policies," *Hong Kong Trade and Development Council*, July 15, 2021, https://research.hktdc.com/en/article/Nzk3NTY5NzUx.

11 "MIIT Leads Release of 14th Five Year Smart Manufacturing Development Plan," *China Banking News*, December 30, 2021, https://www.chinabankingnews.com/2021/12/30/miit-leads-release-of-14th-five-year-smart-manufacturing-development-plan/.

12 Xinmei Shen, "US-China tech war: Beijing draws up three-year plan to revamp state technology system," *South China Morning Post*, November 25, 2021, https://www.scmp.com/tech/policy/article/3157384/us-china-tech-war-beijing-draws-three-year-plan-revamp-state-technology

13 Rogier Creemers et al, trans., *14th Five-Year Plan for National Informatization – Dec. 2021*, DigiChina Project, Stanford Cyber Policy Center, January 24, 2022, https://digichina.stanford.edu/work/translation-14th-five-year-plan-for-national-informatization-dec-2021/.

14 Huaxia, "China Increases R&D spending on science, technology: white paper," *Xinhua*, September 28, 2021, http://www.news.cn/english/2021-09/28/c_1310214248.htm.

15 OECD, OECD *Main Science and Technology Indicators: Highlights on R&D expenditure*, March 2021, https://www.oecd.org/sti/msti-highlights-march-2021.pdf.

16 "China's R&D Spending Picks Up Amid Competition and Desire for Self Reliance," *FitchRatings*, October 21, 2021, https://www.fitchratings.com/research/corporate-finance/chinas-corporate-r-d-spending-picks-up-amid-competition-desire-for-self-reliance-21-10-2021.


A woman sits in front of an image of a robotic arm at the Beijing World Robot Conference 2021 in Beijing, China September 10, 2021. *REUTERS/Tingshu Wang*

18.3%.[17] The quality of Chinese scientific papers has also caught up with that of the US. Of the top 10% of cited papers, the US led with 24.7% share, just a touch ahead of China with 22%. Among the top 1% of cited papers, the US lead widened with 29.3% against China's 21.9%. China has also led in the numbers of filed patents—in 2019 China filed 1.4 million patents worldwide, accounting for 43.4% of the total.[18] More importantly, China surpassed the US that year to become the top country in international patent filings under the Patent Cooperation Treaty administered by WIPO (World Intellectual Property Organization).[19] Traditionally China has imported foreign technology, having made substantial international payments on royalty and license fees, reaching $37.8 billion in 2020. More recently, it has begun to receive such payments from foreign companies, amounting to $8.5 billion in the same year.[20]

Overall, China has steadily moved up the WIPO Global Innovation Index ranking—to number 12 in 2021 from 14 the previous year; ahead of Japan (13) and Canada (16).[21] China is at the top of the group of high middle income countries.

However, China has a quality problem. Specifically, despite leading the world in the number of patent filings, their patents have reached only one-third

17 Noriaki Koshikawa, "China passes Us as world's top researcher, showing its R&D might," *Nikkei Asia*, August 8, 2020, https://asia.nikkei.com/Business/Science/China-passes-US-as-world-s-top-researcher-showing-its-R-D-might.

18 Alex He, "What Do China's High Patent Numbers Really Mean?" *Centre for International Governance Innovation*, April 20, 2021, https://www.cigionline.org/articles/what-do-chinas-high-patent-numbers-really-mean/.

19 WIPO, *World Intellectual Property Indicators 2020* (Geneva: World Intellectual Property Organization, 2020), https://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2020.pdf

20 Trading Economics, *China – Royalty And License Fees, Payments (BoP, Current US$)*, https://tradingeconomics.com/china/royalty-and-license-fees-payments-bop-us-dollar-wb-data.html.

21 WIPO, *Global Innovation Index 2021: Tracking Innovation through the COVID-19 Crisis* (Geneva: World Intellectual Property Organization, 2021), https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2021.pdf.

of non-Chinese patent quality benchmarks—raking rather low in three key quality metrics.[22] The scope of patent filings has been narrow, with only 9.7% having been filed abroad compared with 45.3% for the US. The grant ratio (of granted patents to patent applications) is 39% in China, much lower than 59.4% in the US or 63% in Japan. Finally, Chinese patents have had a low commercialization or industrialization rate. For example, China National Intellectual Property Authority (CNIPA) found that research institutions account for 7.8% of China's granted patents but have an industrialization rate of 18.3% and a licensing rate of only 2%. By contrast, according to the US National Science Board, in 2018 US universities account for 4% of granted patents but 40-50% of those have been licensed for commercial use.

In addition, China has to deal with several non-innovation motives in R&D work—mainly a focus on the quantity of outputs to meet targets and win bureaucratic recognition which will bring prestige and resources for the researcher. Overall, China has many weaknesses and gaps in key areas of science and technology—as revealed by the US-China trade war.[23] Chinese scientists and engineers have won recognition from international peers for adopting and adapting foreign innovations to implement incremental improvements. The foreign innovations have been acquired by a variety of measures such as requiring the transfer of technology from foreign companies to their Chinese joint venture and business partners as well as through other legal (paying royalties and fees to acquire foreign technology) and illegal (industrial espionage and theft) means. In the future, China's acquisition of foreign technology will face more US and European scrutiny and control, especially with regard to the most advanced and sensitive technologies.

Importantly, Chinese scientists as a whole have yet to win recognition as authoring major original scientific breakthroughs. This skepticism has been reflected in a recent survey of China experts by MERICS—only 6% think that China would become an innovation powerhouse able to shape economic developments in the foreseeable future.[24] Interestingly enough, the Western assessment of China's technological prowess has been echoed by a recent report entitled "The strategic competition between the US and China in technology areas: analysis and outlook", published by Peking University's Institute of International and Strategic Studies (the report has been taken off the university's website after being mentioned in the international media).[25] The report highlights that while China has caught up with the US in terms of quantity (of scientific papers and patents ect.) it still lags behind in terms of quality, with lower national spending on basic fundamental scientific research. After the US started to restrict high tech exports to China a few years ago, China has experienced bottlenecks in some of its high tech sectors such as AI, semiconductor and aircraft engine industries. The report concludes "both the US and China will be hurt by the decoupling, but now it looks like China will lose more".

More generally, China's authoritarian top down political system poses the risk of restraining free thinking and sharing of ideas and information—both domestically and internationally—that are crucial in stimulating scientific research and discoveries.

## Output Implementation Stage

Modern transforming technologies require timely and effective roll out to build sufficiently enabling infrastructures or ecosystems; for example for 5G bases, EV charging station, widespread use of solar panels etc. Without sufficiently enabling infrastructures, new technologies can not be properly implemented and their potentials fully exploited. Through its whole government/whole society approach, China has the ability to quickly scale up the rolling out of new technologies to reach mass usage and economy of scale, reaping network benefits. Moreover, the Chinese population has gone through the most profound lived changed experiences in the world in the past four decades, therefore has been prepared and able

22 Alex He, "What Do China's High Patent Numbers Really Mean?" *Center for International Governance Innovation*, April 20, 2021, https://www.cigionline.org/articles/what-do-chinas-high-patent-numbers-really-mean/.

23 Qiang Zha,"Why is China falling behind on breakthrough innovation?" *University World News*, July 17, 2021, https://www.universityworldnews.com/post.php?story=20210716111646690

24 "MERICS Survey on European China Policy" MERICS China Forecast 2022, https://merics.org/sites/default/files/2022- 01/220126_Presentation_SurveyResults2022_final.pdf#msdynttrid=adwQzjc0u304FSYjnQCM-cSeq_sLo_0m9A7bgBrQUuo

25 Jeff Pao, "Academic report unveils China's high-tech bottlenecks," *Asia Times*, February 4, 2022, https://asiatimes.com/2022/02/academic-report-unveils-chinas-high-tech-bottlenecks/


China's official app for digital yuan is seen on a mobile phone next to 100-yuan banknotes in this illustration picture taken October 16, 2020. *REUTERS/Florence Lo/Illustration*

to embrace changes.[26] In other words, the Chinese population has the highest propensity in the world to embrace and adopt technological changes and products/services, significantly helping the rolling out of new technologies.

In particular, China has advantages and good track records in building infrastructure. For example, China has built the longest network of highs speed railways in the world: 37,900 km (23,500 miles) traveling at maximum speed of 350 km/hour (217 miles/hour) connecting 75% of cities with population over 500,000–all built since 2008.[27] Current plans envisage doubling the high speed railway length to 70,000 km by 2035. By comparison, the second placed country Spain has about 2,000 miles of high speed railway; while the fastest train in the US—the Acela—attains the maximum speed of 150 miles/hour only in three sections totaling 34 miles of the 231 miles segment of the Northeast Corridor High Speed Rail System connecting Washington DC to New York City.[28]

Going forward, the focus is on building digital and clean energy infrastructure which China has also made significant headways. For example, China has put in use 1.15 million 5G base staions, more than 70% of the global total.[29] The 5G penetration rate reached 15% in 2020 and has been planned to attain 56% in 2021. By contrast, the US has installed about 100,000 5G base stations by mid-2021.[30] In the case of promoting uses of electric vehicles (EV), China has built 2.2 million charging stations throughout the country-about half

26 Zak Dychtwald, "China's New Innovation Advantage," *Harvard Business Review*, May-June 2021, https://hbr.org/2021/05/chinas-new-innovation-advantage

27 Ben Jones, "Past, present and future: The evolution of China's incredible high-speed rail network," *CNN*, February 9, 2022, https://www.cnn.com/travel/article/china-high-speed-rail-cmd/index.html.

28 Texas Department of Transportation, "U.S. System Summary: Northeast Corridor," https://ftp.txdot.gov/pub/txdot-info/rail/high_speed/system-summaries/northeast-corridor.pdf

29 Juan Pedro Tomás, "China aims to triple the number of 5G base stations by end-2025: Report," *RCR Wireless News*, November 17, 2021, https://www.rcrwireless.com/20211117/5g/china-aims-triple-number-5g-base-stations-end-2025-report

30 John McCormick, Meghan Bobrowsky, Dan Strumpf, "Huawei, Ericsson or Nokia? Apple or Samsung? U.S. or China? Who's Winning the 5G Races," *Wall Street Journal*, October 12, 2021, https://www.wsj.com/articles/huawei-ericsson-nokia-apple-samsung-u-s-china-winning-5g-race-11634000044?st=9o4c1xvq1cdvynh&reflink=article_copyURL_share.

public and half privately owned.[31] By comparison, the US has 43,000 public charging stations.[32]

China has also quickly climbed up the world league table of industrial robot density—the number of robots deployed per 10,000 employees. From the 25th position with 49 robots/10,000 employees[33] in 2015, China was ranked 9th last year with 246 robots—compared with 255 units for the 7th ranked US and 932 for the top-ranked South Korea. This will help improve China's industrial productivity.

The People's Bank of China has ramped up efforts to rollout the digital yuan—called the e-CNY—probably by issuing it through the state-owned banks.[34] The digital yuan can be used with its digital wallet as well as on popular mobile apps offered by Alipay and WeChatPay—which have more than a billion of users—and on the platform of e-commerce giant JD.com. Even before the rollout of the digital yuan, China already has the most advanced digital payment system in the world. The digital yuan will foster further developments of a digital economy.

According to one metric on the role of innovation in the economy, China has increased the share of innovative industries in its industrial value added from 31.80% to 33.97% in 2017-2021.[35] At this level, China is at par with the US (33.5%—but far from being at the cutting edges), and still behind the EU at 36.4%.

The key risk in this stage is the possibility of the top leadership making a wrong bet on technology. This will create waste and inefficiency as the chosen technology and its enabling infrastructure is quickly rendered obsolete by later discoveries and technologies which are superior.

## Conclusion

On balance, China can be said to have relatively more strengths in the input mobilization and output implementation stages; and more weaknesses in the R&D stage. In other words, China has been a good innovation sponge, but yet to show that it can be an innovation leader. Specifically, in the next 10-20 years, there are still many benefits in fully rolling out cutting edged but known technologies such as 5G/6G telecommunication, the Internet of Things (IoT), EV/batteries/charging stations, smart cities and homes, automation and robotics etc. Doing so quickly at scale will give China first mover benefits as well as the ecosystem with which to foster further developments of the digital economy and society. Arguably, this can enhance productivity, sustain economic growth and improve the quality of life of the people.

Beyond this foreseeable future, however, China may encounters difficulties in fostering major transformative innovations due to its authoritarian regime which restricts the free flow of ideas and information. As such, its ability to establish an autonomous innovation leadership position in the world and use it to drive economic growth remains an open question.

Perhaps China's efforts to reduce its reliance on foreign-sourced semiconductors can serve as an example to encapsulate the country's strengths and weaknesses in promoting home-grown innovations. After the US banned Huawei and other Chinese high-tech companies from purchasing advanced computer chips containing US inputs, China has tried to boost domestic production of semiconductors by using supportive policies including subsidies and procurement preferences to stimulate massive investment in the semiconductor sector. In 2021, China announced 26 new wafer fabrication construction projects totaling $26 billion. The effort seems to pay off to some extent: China has been able to produce 359 billion integrated circuits (ICs) in 2021, up 33.3%

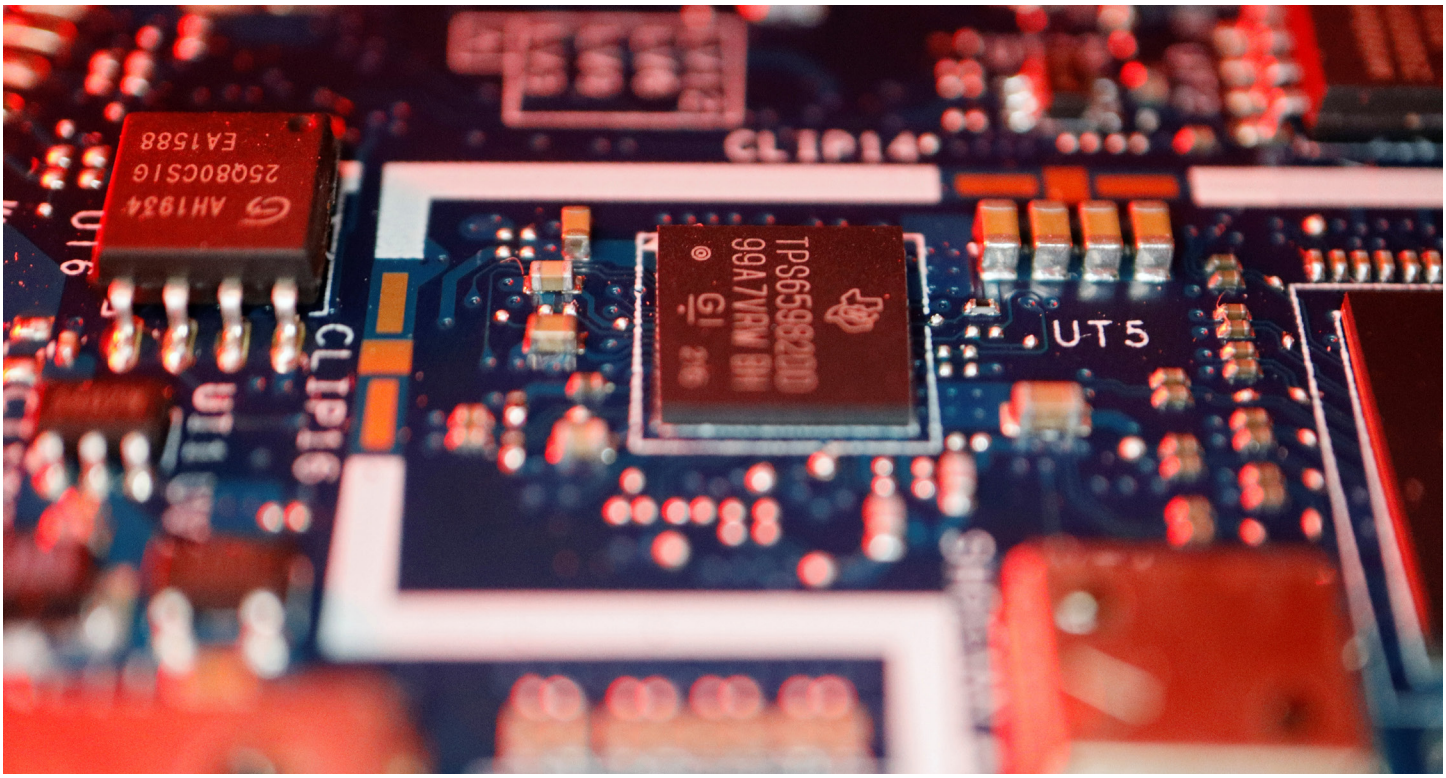
31 Scooter Doll, "China claims title of having world's largest EV charging network," *Elecrek*, October 29, 2021, https://electrek.co/2021/10/29/china-claims-title-of-having-worlds-largest-ev-charging-network/

32 Tina Bellon, Paul Lienert "Factbox: Five facts on the state of the U.S. electric vehicle charging network," Reuters, September 1, 2021, https://www.reuters.com/world/us/five-facts-state-us-electric-vehicle-charging-network-2021-09-01/.

33 "Global robot density nearly doubles, IFR reports," *Control Design*, December 20, 2021, https://www.controldesign.com/industrynews/2021/global-robot-density-nearly-doubles-ifr-reports/

34 Coco Feng and Che Pan, "China's digital yuan: e-CNY wallet tops download charts in Apple and Xiaomi app stores ahead of Lunar New Year," *South China Morning Post*, January 10, 2022, https://www.scmp.com/tech/big-tech/article/3162847/chinas-digital-yuan-e-cny-wallet-tops-download-charts-apple-and.

35 Asia Society Policy Institute and Rhodium Group, *Innovation: Innovation Policy Reform*, Winter 2021, https://chinadashboard.gist.asiasociety.org/winter-2021/page/innovation




Semiconductor chips are seen on a circuit board of a computer in this illustration picture taken February 25, 2022. *REUTERS/Florence Lo/Illustration*

from 2021 which recorded an increase of 17.2% from the previous year. However, it appears that China has mainly produced low-end semiconductors, not the more advanced ones such as 5 nanometer computer chips, produced mainly by Taiwan's Semiconductor Manufacturing Corporation (TSMC) and South Korea's Samsung Electronics.[36] These advanced chips are crucial to develop new cutting edged electronic and telecom products. Tellingly, China's largest semiconductor company, Semiconductor Manufacturing International Corporation (SMIC) in Shanghai only ranks 25th on the list of global chip makers.

At the same time, to meet the economy's needs China has imported $432 billion worth of semiconductors in 2021, a 23.6% rise from the previous year.[37] In short, despite great efforts to become self sufficient in semiconductors—efforts which have made some progress—China still depends on foreign suppliers, especially for the more advanced chips. If China continues to have access to this and other high-tech products, it can buy time to develop domestic alternatives with incremental improvements which it has been good at. However, if the US-China rivalry intensifies and the US undertakes to make the blockade of high-tech goods to China more binding, that would seriously disrupt the latter's economy and its innovation efforts. In other words, China's technological push also depends on the state of geopolitical rivalry and tension; and that represents another source of risk and vulnerability to China.

To sum up, it is clear that China has been trying to develop an innovation system with Chinese characteristics—different in many respects from the generally accepted understanding of how and why

36 Charlie Campbell, "Inside the Taiwan Firm That Makes the World's Tech Run," Time, October 1, 2021, https://time.com/6102879/semiconductor-chip-shortage-tsmc/.

37 Che Pan, "US-China tech war: Chinese semiconductor output surged 33 per cent last year, double the growth rate in 2020," *South China Morning Post*, January 17, 2021, https://www.scmp.com/tech/tech-war/article/3163668/us-china-tech-war-chinese-semiconductor-output-surged-33-cent-last

innovation occurs, as experienced in many OECD countries. As a recent RAND Corporation's report on China's innovation in the 21st century concludes, instead of reaching premature conclusions because China's model is different, it is important to develop accurate instruments of observations as well as indicators and measurements to gain insights into and better gauge the progress of China's innovation efforts.[38] This is crucial to better assess the prospects of the Chinese economy going forward as well as possible outcomes of the strategic competition between China and the West—both of these developments have tremendous implications for the rest of the world and worthy of close monitoring.

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38 Steven. W. Popper et al., *China's Propensity for Innovation in the 21st Century: Identifying Indicators of Future Outcomes* (Santa Monica, CA: RAND Corporation, 2020), https://www.rand.org/content/dam/rand/pubs/research_reports/RRA200/RRA208-1/RAND_RRA208-1.pdf

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