FAST INDIA
FOUNDATION FOR ADVANCING SCIENCE AND TECHNOLOGY

The Rise of Science and Technology in Asian Economies

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This working paper is a part of the ongoing effort by the Foundation for Advancing Science and Technology India (FAST India) to stimulate thought and action in the science and technology (S&T) ecosystem, learning from a variety of Asian economies such as China, South Korea, Taiwan and others that have seen significant S&T growth in recent decades. The objective of this effort is to identify common trends and effective drivers of Asia's growth in global S&T, and not endorse any specific country's policies or approach towards S&T.

China: Developing and Nurturing S&T talent

Over the past few years, China has established itself as a significant global competitor in various fields of science and technology, surpassing countries like the United States, South Korea, and the United Kingdom. China has transformed from being known as an 'imitator of technology' and 'manufacturer of low cost goods' to an emerging leader in future technologies with an exponential (~20x) increase in its gross expenditure on R&D (GERD) from 2000 to 2020, to the amount of ~USD 600Bn,[1] as well as a systematic increase in its S&T capabilities.

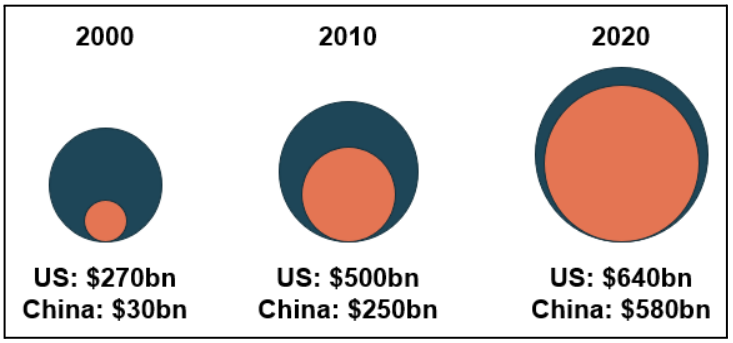

Figure 1: US and China Gross Expenditures in R&D (in bn USD 2020) (Source: OECD data[1])

As a consequence, China is now considered *the force* to be reckoned with across fields such as supercomputing, Artificial Intelligence, quantum computing, biotechnology and many others. Figures 2[2] and 3[3] show some more aspects of this predominance. Multiple enablers across the policy spectrum were responsible for a steady growth of S&T in China that have been discussed below.

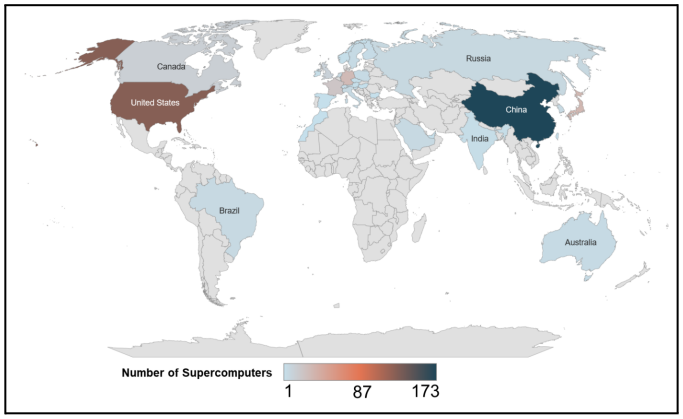

Figure 2: Share of 500 fastest supercomputers in the world, by country[2]

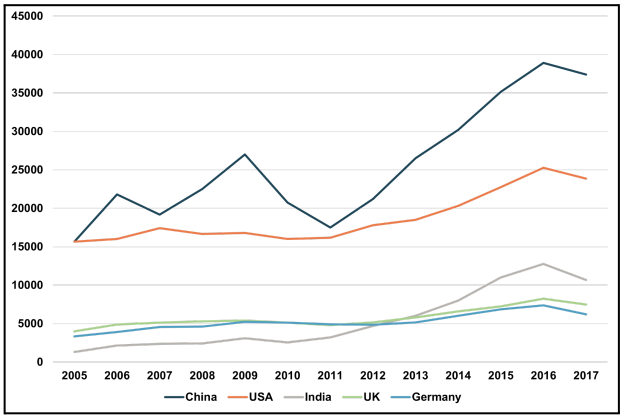

Figure 3: AI research outputs[3]

Substantive paradigm shift: The Chinese government decided to shift to a market driven economy in the late 1980's[4] and privatised many state-owned enterprises. For enterprises, the government reformed the S & T sector through a number of programs such as 'Program 863', the 'Torch Program' and the 'Spark Program' that incentivised and promoted research and development of advanced technologies such as new materials, IT and biotechnology.[5,6] On the education side, the government launched programs like 'Project 211', 'Project 985' and the recent 'Double first-rate university program' in order to build higher education frameworks capable

1 Main Science and Technology Indicators, OECD data. Access at https://www.oecd.org/sti/msti.htm
2 https://www.top500.org/
3 China AI Development Report 2018 by China Institute for Science and Technology Policy at Tsinghua University. Access at: https://indianstrategicknowledgeonline.com/web/China_AI_development_report_2018.pdf
4 Chen, 2003. The Academic Profession in China. Access at: https://link.springer.com/chapter/10.1057/9781403982568_5
5 Guan and Yam, 2015. Effects of government financial incentives on firms' innovation performance in China: Evidences from Beijing in the 1990s. Access at https://www.sciencedirect.com/science/article/abs/pii/S0048733314001577
6 Liu et al, 2011. China's innovation policies: Evolution, institutional structure, and trajectory. Access at: https://asu.pure.elsevier.com/en/publications/chinas-innovation-policies-evolution-institutional-structure-and-

enough to compete with the world in S&T.[7] In parallel, the Chinese government supported large increases in expenditure on R&D over the years spanning between 1995-2018; with GERD as a percentage of GDP more than doubling in the given time frame. In order to attain global competitiveness, the Chinese government has made a concerted effort to look towards the future and ensure the demand for new and high technologies is met by a continuous and high quality supply of human capital through efforts such as the '**National Talent Development Plan (2010-2020)**'[8] launched in 2010. China's efforts to nurture, attract and retain top talent in the field of S&T form the bedrock of the plan.[9] **It is important to note that the Chinese government put in concerted efforts (financial aid, accountability as well as policy support) over a period of 20-25 years before the outcomes started to show as illustrated in Figure 4.**

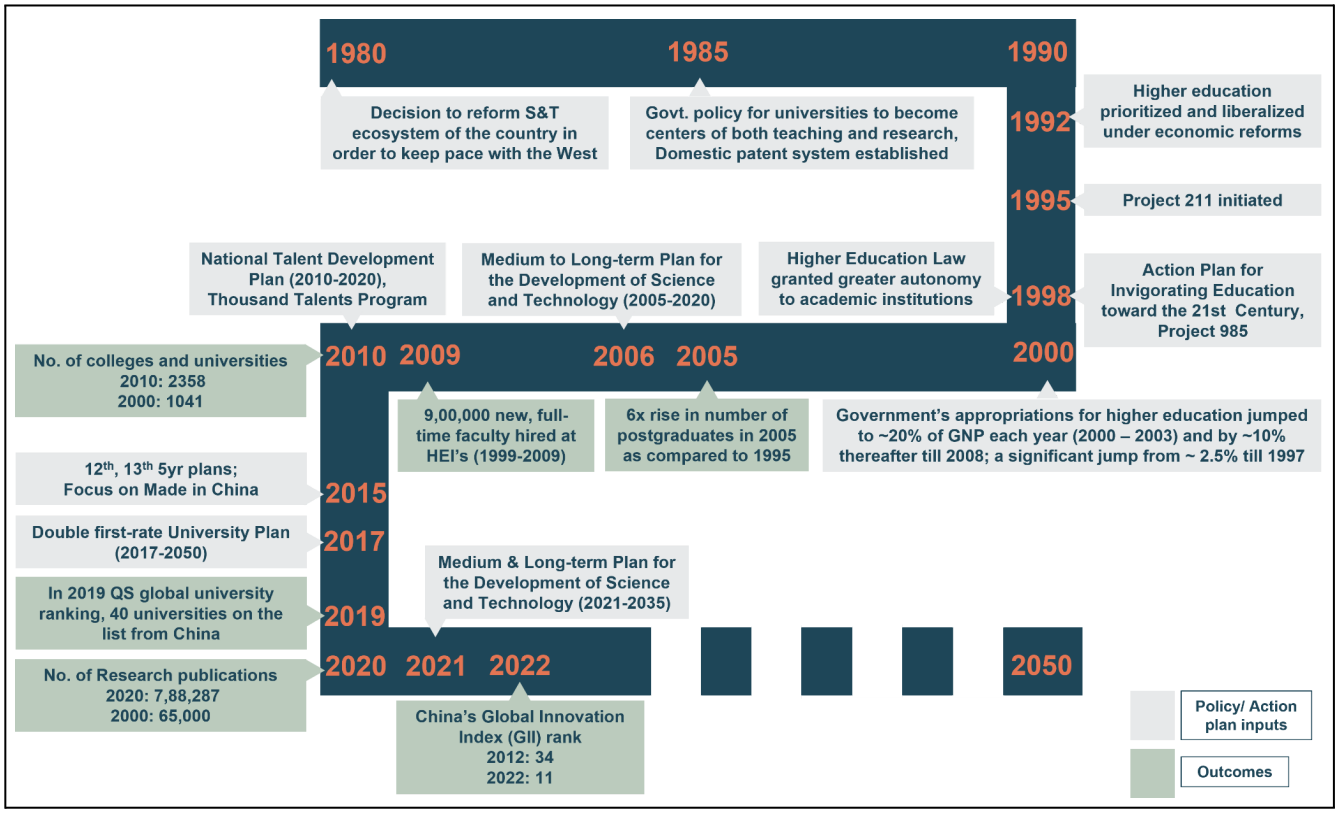

Figure 4: A timeline of China's Science and Technology ecosystem development[10]

The chronology of S&T transformation in China:

1. **Universal education:** With a focus on the transformation of various sectors and fostering new growth points in the national economy, the Chinese government placed education at the strategic foundation for economic success.[11] What followed was a systemic upgrade of the entire education system in the following parameters-
    a. Promoting education
    b. Upgrading the Quality of Education and Research
    c. Upgrading the Quality of Higher Education Institutes
    d. Upgrading the Quality of Educators and Researchers
    e. Providing autonomy in the management and governance of HEI's
    f. Upgrading the Quality of enrollments in HEI's and job market

7 Zong and Zhang, 2017. Establishing world-class universities in China: deploying a quasi-experimental design to evaluate the net effects of Project 985. Access at: https://www.tandfonline.com/doi/abs/10.1080/03075079.2017.1368475
8 Chinese Central Government Portal. National Talent Development Plan 2010-2020. Access at: http://www.gov.cn/jrzg/2010-06/06/content_1621777.htm
9 Huiyao, 2011. China's National Talent Plan: Key Measures and Objectives. Access at: https://robohub.org/wp-content/uploads/2013/07/Brookings_China_1000_talent_Plan.pdf
10 FAST India Analysis, Kirby, William C, 2022. Empires of Ideas: Creating the Modern University from Germany to America to China
11 Ministry of Education, China. Action scheme for invigorating education towards the 21st century. Access at: https://www.edu.cn/english/education/laws/21st/index_1.shtml

2. **Focus on Higher Education:** As an outcome of the *'Action Plan for Invigorating Education toward the 21st Century'*[11], Projects 211 and 985 focusing on 'scaling up higher education' and thereafter 'expanding on success', respectively followed in the late 1990's[12] and led to the creation of an exclusive league of higher education institutions (the C9 League)[13] including universities like Tsinghua University and Peking University. The guiding principles of these interventions were to build the capacity of higher education graduates to become on par with others around the world and enhance the country's competitiveness[12]. The next task was to build world-class universities and first-class disciplines in order to become world leaders in disciplines that drive technology of the future. The Double first-rate university plan spanning from 2017-2050 is currently underway but the results are already starting to show looking at the QS World University Rankings.[14]

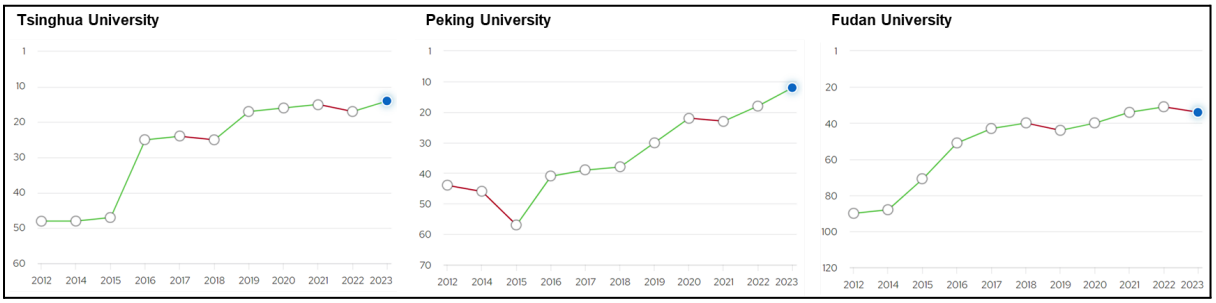

Figure 5: QS Rankings (2012-2023) of 3 Chinese universities under the C9 Program[14]

3. **Forward looking policy planning:** The Chinese government, through its science and technology policies, envisioned "speeding up the construction of an innovation system that takes enterprises as the centre, the market as guide, with commercialization and research interwoven".[15] The introduction of the 2006 ***'Medium to Long-term Plan for the Development of Science and Technology (2005-2020)'***[16] laid the foundation for government investments and incentives for key technology and engineering projects with commercial applications. With the clear intention of focusing on commercialisation of research, the guiding principles of China's S&T policies embibe "indigenous innovation, world-leader in priority fields, enabling development, and leading the future" as their metrics of success, identified by highly-ranked central authorities.[16]

4. **Talent development:** Having addressed the issues surrounding universal education, establishment of high quality educational institutes and providing financial backing for the development of S&T, the next step for the Chinese government was to ensure a steady supply of highly trained and talented workforce that can help transform China from an investment driven economy to a talent driven economy[17]. A number of factors prompted Chinese policymakers to rethink the national development strategy as described below:

    a. Population dividend: China's One-Child policy led to an ageing population and the rise in the number of college graduates also caused concerns of unemployment[17] . While China built its economy on the foundation of cheap labour, making it the manufacturing centre of the world, it had to face the uphill task of creating new jobs to suit the growing population of highly educated graduates.

12 Li, 2020. Changes in Higher Education Policies: A Case Study of Projects in China. Access at: https://www.repository.cam.ac.uk/bitstream/handle/1810/317371/202001-article4.pdf?sequence=1
13 C9 league of institutions. Access at: https://www.google.com/url?q=http://en.people.cn/203691/7822275.html&sa=D&source=docs&ust=1668589456563965&usg=AOvVaw2dDIFv2ZAxuLwKTqFWwP85
14 QS World University Rankings. Access at: https://www.topuniversities.com/university-rankings/world-university-rankings/2023
15 Springut et al, 2011. University of Texas at Austin. Access at: https://sites.utexas.edu/chinaecon/files/2015/06/USCC_Chinas-Program-for-ST.pdf
16 The State Council, PRC. Medium to Long term Plan for the development of Science and Technology (2005-2020). Access at: https://www.itu.int/en/ITU-D/Cybersecurity/Documents/National_Strategies_Repository/China_2006.pdf
17 Huiyao, 2011. China's National Talent Plan: Key Measures and Objectives. Access at: https://robohub.org/wp-content/uploads/2013/07/Brookings_China_1000_talent_Plan.pdf

b. Global recognition: China's days as a manufacturing economy that relied on cheap labour to produce low priced goods that undercut market competition were long gone and the nation needed to build globally recognised and trusted brands in the field of science and technology in order to compete with global superpowers. This could only be achieved through technological innovation which, in turn, is spurred on by trained professionals.
c. Financial capital to Human capital: The Chinese government spent a considerable amount of financial resources since the 1980's to transform itself to a knowledge based economy. One of the challenges China faced was in retaining talent. China had sent out 1.62 million students and scholars since 1978 to get trained in STEM fields, but as of 2011, only 497,000 returned to China[17]. The Chinese government realised that **financial resources by themselves can not ensure sustainable growth unless skilled human resources are also available.**
d. Hardware to Software: With the next set of technological breakthroughs heavily reliant on education, a shift in focus was required to ensure development of human resources, R&D capabilities, public health, energy efficiency, environmental protection and social welfare. This shift required a change of mindset that had over the past few decades entirely focused on building hardware. The need of the hour was to build an intellectual community and a talented and highly skilled workforce.

4.1 National Talent Development Plan

As an answer to the above mentioned factors, the '***National Talent Development Plan (2010-2020)***'[18] was developed, with cultivation of human talent as its central philosophy, shifting focus from development of physical resources such as institutes, labs, schools etc. According to the plan, spending on human resources would account for 15% of the country's GDP by 2020 with the ultimate aim of transforming the country's human capital to a highly skilled workforce.

Target	Unit	2008	2015	2020
Total no. of *Rencai* (highly educated and skilled individuals)	10,000	11385	15625	18025
Ratio of R&D Rencai in labour force	Person/10,000	24.8	33	43
Ratio of High Skilled Rencai in labour force	%	24.4	27	28
Ratio of labour force who have Higher Education	%	9.2	15	20
Ratio of Human Capital investment with GDP	%	10.75	13	15
Ratio of talent contribution to GDP	%	18.9	32	35

Table 1: Main Indicators of China National Talent Development Plan[18]

The Plan laid out National Development Targets (see Table 1) that emphasised the focus on increasing the overall talent pool from 114 million people in 2010 to 180 million by 2020. Additionally, the Plan also aimed to increase the ratio of citizens with a higher education background in the workforce from 9.2% in 2008 to 20% by 2020.

18 Chinese Central Government Portal. National Talent Development Plan 2010-2020. Access at: http://www.gov.cn/jrzg/2010-06/06/content_1621777.htm

The Plan indicated the following 6 categories to address talent development:

a. Political leaders and officials
b. Business entrepreneurs
c. Technical professionals
d. Highly skilled *Rencai* in different industries
e. Practical *Rencai* for rural areas and agriculture
f. Professional social workers

The areas had been selected to allow development of talent across sectors and fields. While political leaders and officials help build policies and laws for the future, the presence of business entrepreneurs and highly skilled *Rencai* in industries and agriculture has allowed the Chinese economy to grow and keep up with the global economy. Additionally, the Plan also touched on specific sectors that human capital needed to align with. Equipment manufacturing, information technology, biotechnology, new materials, aeronautics and astronautics, oceanography, finance and accounting, international business, environmental protection, energy resources, agricultural technology, and modern traffic and transportation had been identified as critical sectors. Furthermore, spotlight was given to R&D with estimates that of every 10,000 people in the labour force, at least 43 professionals should be working on R&D. Based on this Plan Huiyao (2011) estimated the number of R&D professionals would amount to 3.8 million by 2020,[19] while the actual data recorded in 2020 showed the number stood at 5.09 million[20] indicating a steady growth of the world's largest pool of R&D personnel.

4.2 Thousand Talents Program

Of the 12 talent programs launched under the Plan, the '*Thousand Talents Program*' received much attention. It called for China to attract 2,000 overseas highly skilled individuals to move to China in the space of 5-10 years. The former president of China, Wen Jaibao stated the following on attracting overseas talent, "*We will increase spending on talent projects and launch a series of initiatives to offer talent-favourable policies in households, medical care and the education of children.*" Offering high salaries, visa privileges, and other bonuses, the program has since attracted over 7000 overseas and returning scholars to China[21]. While the program has also come under scrutiny by western countries over fears of stealing research findings,[22] but independent of the geopolitical implications, the program seems to have solved its intended purpose - attracting top class scientific talent to China and receiving dividends such as patents, research projects and published papers.[23, 24] The success of the Thousand Talents Program extends beyond these tangible metrics as well and led to an overall improvement in stature and quality of education of Chinese Universities was also seen. As a consequence, the Shanghai-based Academic Ranking of World Universities placed 32 Chinese universities in the top 500 globally in 2014, up from 7 in 2004.[23]

19 Huiyao, 2011. China's National Talent Plan: Key Measures and Objectives. Access at: https://robohub.org/wp-content/uploads/2013/07/Brookings_China_1000_talent_Plan.pdf
20 China Daily, 2021. China records a surge in R&D experts. Access at: https://global.chinadaily.com.cn/a/202109/02/WS61306379a310efa1bd66ce79.html
21 Jia, 2018. What is China's Thousand Talents Program. Access at: https://media.nature.com/original/magazine-assets/d41586-018-00538-z/d41586-018-00538-z.pdf
22 NY Times, 2020. China's Lavish funds lured US Scientists. What did it get in return? Access at: https://www.nytimes.com/2020/02/06/us/chinas-lavish-funds-lured-us-scientists-what-did-it-get-in-return.html
23 Robbins, 2016. The Thousand Talents Program : Lesson From China About Faculty Recruitment and Retention. Access at: https://www.researchgate.net/publication/321172646_The_Thousand_Talents_Program_Lesson_From_China_About_Faculty_Recruitment_and_Retention
24 Farrer, 2014. China Wants You: The Social Construction of Skilled Labor in Three Employment Sectors. Access at: https://journals.sagepub.com/doi/abs/10.1177/011719681402300405?journalCode=amja

Outcomes of interventions

Chinese universities have been scaling the ladder of world university rankings and now find themselves competing directly with the top US Universities. The Chinese research output has also dramatically increased over years, now second only to the United States (Figure 6)[25].

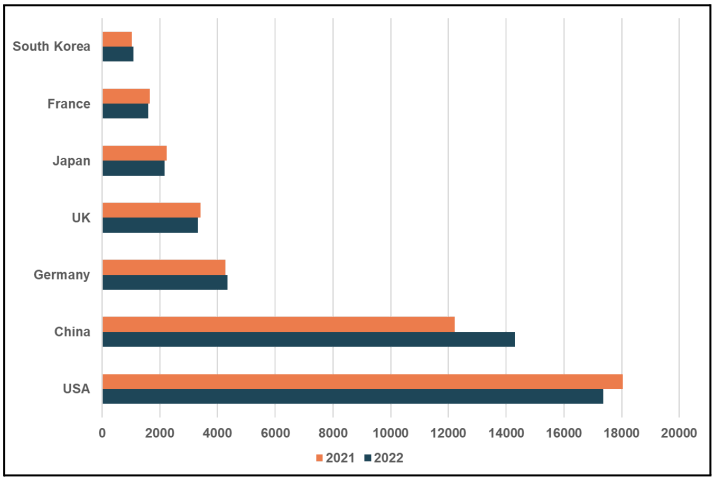

Figure 6: Research output rankings by share in Nature Index[25]

China has also successfully increased industry participation in R&D, with more than 75% of research expenditure contributed by industry partners. Universities and industry forged alliances for research output commercialization and have found huge success.[26] As a result, China saw an improvement in a number of areas such as university-industry collaborations and university spin off formations[27] in addition to an overall upliftment of faculty and student quality. The country has also been experiencing a strong wave of innovation with USD 50Bn+ VC investments and 122 unicorns as of 2020.[28] China has also consistently been on an upward trajectory as per the Global Innovation Index (GII) rankings, jumping from a global rank of 34 in 2012 to 11 in 2022[29].

Concluding remarks:

China's shift in focus from a command economy to a *de facto* market economy in the 1980's heralded a significant change in the nation's socio-economic status. The government's push to create world class centres of learning and ensure universal education for its citizens led to China's development into a world leader in S&T today, with all its attendant geopolitical implications[30] for Asia and the World. Centrally coordinated policies with a long term focus, structured mechanisms for the implementation of policies, strict accountability to drive processes, and finally, financial backing by the central government have been the key ingredients for China's successes in the last 30 years.

It is evident that for any large country aiming to establish a robust and productive S&T ecosystem, it is important to look at the various relevant sectors and stakeholders that are involved, and to ensure coordinated policy making that is aligned with market incentives.

25 Nature Index. Access at: https://www.nature.com/nature-index/
26 Su and Sohn, 2011. Why do Beijing Universities play important roles in regional innovation systems? Based on resource-based view. Access at: /https://academicjournals.org/journal/AJBM/article-full-text-pdf/B6ED73120565
27 Su et al, 2015. Government-driven university-industry linkages in an emerging country: the case of China. Access at: https://www.researchgate.net/publication/283129460_Government-driven_university-industry_linkages_in_an_emerging_country_the_case_of_China
28 National Bureau of Statistics of China. Access at: http://www.stats.gov.cn/english/
29 Global Innovation Index Report 2022. Access at: https://www.globalinnovationindex.org/gii-2022-report
30 MI5 and FBI warn of China's desire to 'steal' Western technology. Access at: https://eandt.theiet.org/content/articles/2022/07/mi5-and-fbi-warn-of-chinas-desire-to-steal-western-technology/