CTIER CENTRE FOR TECHNOLOGY, INNOVATION AND ECONOMIC RESEARCH

S&T as a Driver of China's Economic Agenda

Janak Nabar, Soumya Misra,
Dipti Singhania and
Chaitanya Lekharaju

CTIER Research
Article 9

Suggested citation:Nabar, J., Misra, S., Singhania, D., Lekharaju, C. (2023), "S&T as a Driver of China's Economic Agenda (CTIER Research Article 9)", Centre for Technology, Innovation and Economic Research

Cover: Sameer Karmarkar
Typesetting and design: Satisifice Designs Pvt. Ltd., Pune

China's quest for global technology dominance has been telling in recent years. The China story when it comes to science and technology (S&T) is one which has evolved over the past four decades - one only needs to see the successive plans and announcements out of China since the 1980s that have stressed the importance of science and technology as a key driver of the country's long term economic agenda.

The purpose of this essay is to highlight some of the key announcements that have been made by Chinese policymakers since the 1980s and capture its R&D and innovation landscape as it stands today. This period also coincided with China having seen extremely high rates of growth - the average GDP growth rate between 1980 and 1990 was 9.3 percent, between 1990 and 2000 was 10.4 percent, between 2000 and 2010 was 10.6 percent and between 2010 and 2020 was close to 7 percent.[1] These high rates of growth sustained over several decades, driven by rapid industrialisation, have also seen China become one of the largest polluters globally. The country today is faced with serious environmental concerns. Our data suggests that investments in S&T in several crucial sectors is helping China strive for a balance between the quest for technology dominance and the environmental concerns she faces.

Highlights of Key S&T Related Policy Announcements

There have been several key policy announcements in China since the 1980s that have been introduced to transform its R&D and innovation landscape. While our essay "Public R&D in India: Pathways to increasing its effectiveness" highlights some examples of the transformation that took place in China's public research ecosystem, a separate and more comprehensive overview of China's S&T related policies would need to be undertaken that also encompasses other policies related to talent and skilled manpower needed for R&D. We highlight a few policies here to showcase some of the key focus areas identified by Chinese policymakers.

The "National Program for Key Science & Technology Projects" which was first introduced in 1982, and continues to be an important element of China's five year plans, aimed at supporting the development of high

1 The average GDP growth rates have been calculated using data from the IMF WEO Database, April 2023

technology sectors, improving the quality of the country's economic development and enhancing its S&T capabilities.[2] This was followed by the 1985 Decision on the Reform of Science and Technology Management System that laid emphasis on improving research competitiveness, increased linkages between various institutions and commercialisation of research (Gu, 1995). The 1985 Decision also laid the ground for subsequent programmes like the National High Technology Research and Development in 1986 (also called 863 programme) and the Torch Programme in 1988. The 863 programme aimed to achieve breakthroughs in the areas of biotechnology, space technology, information technology, lasers, automation, energy, and advanced materials. The Torch Program in 1988 pushed for the creation of high and emerging technology industry development zones.[3] Subsequently in 1995, the Decision on Accelerating Scientific and Technological Progress aimed at boosting competitiveness through the development of high technology products, and also emphasised the need for collaborations between medium and large enterprises and research institutes for the development of high technology products. Furthermore the 1995 Decision stressed on catching up with the advanced economies in fields such as electronic communications, biology, new materials, new energy source, aeronautics, etc.[4] In 2006, China announced a strategy for increasing indigenous innovation through the National Medium and Long Term Program (MLP) for Science and Technology (2006-2020). The MLP set a target for China's national R&D expenditure as a share of GDP to reach 2.5 percent by 2020, for China to become one of the top five nations in terms of patents granted to its residents and for the contribution of S&T to the economy to reach 60 percent (Sun and Cao, 2021).

The Belt and Road Initiative (BRI) announced in 2013 and the Made in China 2025 initiative announced in 2015 further consolidated its efforts towards indigenous innovation while aiming to expand its market through trade and investment opportunities. The BRI's goal has been to increase China's strategic, economic and cultural ties with a number of

2 Consulate General of the P. R. China in San Franscisco. (2003, Nov. 18). Science and Technology Program in China, 2003. available at http:sanfrancisco.china-consulate.gov.cn/eng/kj/kjjh/

3 ibid

4 For a useful commentary on the Decision on Accelerating Scientific and Technological Progress, refer to US Embassy, Beijing, "PRC State Council on 'Decision on Accelerating S&T Development'" (November 1996) and Fan and Watanabe (2006)

economies through establishing economic corridors (OECD, 2018). The Made in China initiative, on the other hand, has focused on reducing the dependency on technology imports while significantly increasing its own innovations in key areas such as advanced information technology, energy saving and new energy vehicles, medicine and medical devices, and aerospace equipment (Institute for Security & Development Policy, 2018). More recently, the 14th Five Year Plan for National Economic and Social Development (2021-2025) and Long-Range Objectives for 2035 re-emphasises the development of innovative capabilities and strengthening research in S&T fields such as artificial intelligence, biotechnology, quantum information, high-end medical equipment and innovative drugs, and new energy vehicles (Center for Security and Emerging Technology, 2021).

The key focus areas in the policies over the years mentioned above clearly covered diverse areas such as increasing high technology products in the economy, increasing collaborations between enterprises and research institutes, strengthening indigenous innovation capabilities and focusing on frontier technologies. More importantly several of the policies also laid an emphasis on S&T being an underlying driver for the country's economic development. As we shall see in China's R&D landscape below, China has come close to its target of 2.5 percent for national R&D as a share of GDP while strategically increasing its presence in several high technology sectors through significant investments in industrial R&D.

China's R&D and Innovation Landscape

Over the last four decades, China has witnessed a notable increase in its R&D expenditure as a share of GDP, driven largely by its spending on industrial R&D. China has a significant presence in the EU Industrial R&D Investment Scoreboard 2022 that lists the top 2,500 firms in terms of R&D spending. It is one of the top destinations for venture capital funding after the US, is the second after the US in terms of total publication output for publications considered between 2017 - 2021 and ranked third in terms of patents granted by the United States Patent and Trademark Office (USPTO) in 2021.

Table 1 R&D and Industrial R&D in China

	1990	2000	2010	2020
R&D as a % of GDP	0.6	0.9	1.7	2.4
Share of Industry in Total R&D (%)	43	60	73	76

Source: UNESCO Institute of Statistics (various years), UIS.stat, available at: http://data.uis.unesco.org/ ; World Development Indicators (various years), Indicators available at http://data.worldbank.org/; OECD, Main Science and Technology Indicators, available at https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#; The Struggle and the Promise (2022)

Note: Data reported as 1990 is for 1996

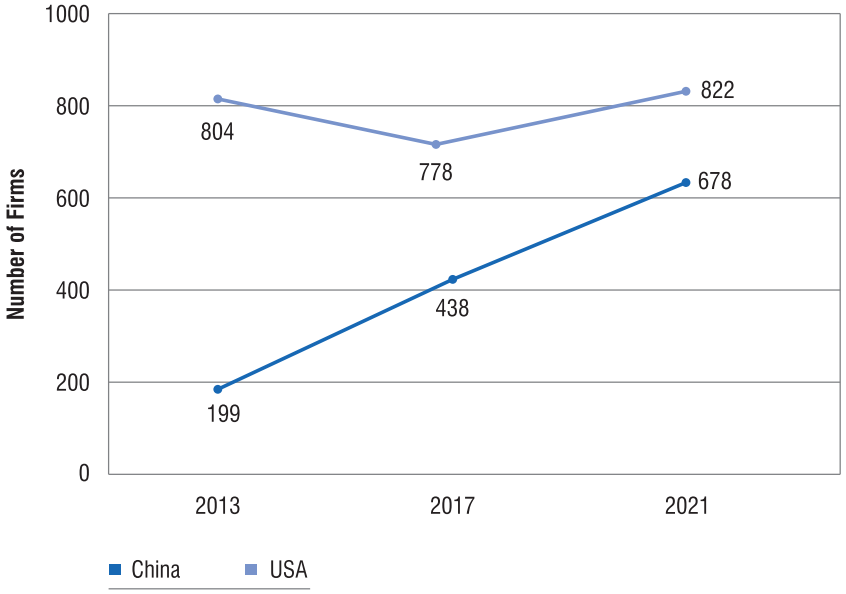
As of 2020, China's national R&D spending as a share of GDP was 2.4 percent compared to 0.6 percent in 1990. As can be seen in Table 1, the share of industry in total R&D was 76 percent in 2020 having increased from 43 percent in 1990. In the last decade there has been a sharp increase in the number of firms from China that make it to the top 2,500 spenders R&D list - currently there are 678 firms compared to 199 in 2013. Here too, China ranks second after the US in terms of the number of firms present in the top R&D spenders list. Figure 1 compares the number of firms from the US and China in the EU Industrial R&D Investment Scoreboard 2022.

Chinese firms are present in all the top 10 global R&D sectors by spending. They have a higher presence than the US, in terms of the number of firms, in sectors such as automobile & parts, electronic & electrical equipment, industrial engineering, construction & materials, chemicals and general industrials. By spending, Chinese firms dominate the electronic & electrical equipment, industrial engineering and construction & materials sectors.

Figure 2 captures the top 10 R&D sectors for China. This is based on the R&D spending by the 678 Chinese firms that are present in the global top 2,500 industrial R&D spenders list. These top 10 sectors cover over 80 percent of the R&D spending by the 678 firms, and seven sectors are in common with the global top 10 R&D sectors. For China, the top sectors include technology hardware & equipment, software & computer services and construction & materials. Pharmaceuticals & biotechnology which is the top ranked R&D sector by spending globally is ranked sixth for China. Industrial metals & mining that forms a part of China's top

10 R&D sectors does not feature in the global top 10 R&D sectors by spending. This diverse spending pattern of China's industrial R&D, that goes beyond the traditional high technology sectors, is interesting and is covered in further detail in the next section.

Figure 1 Number of Firms in Top 2500

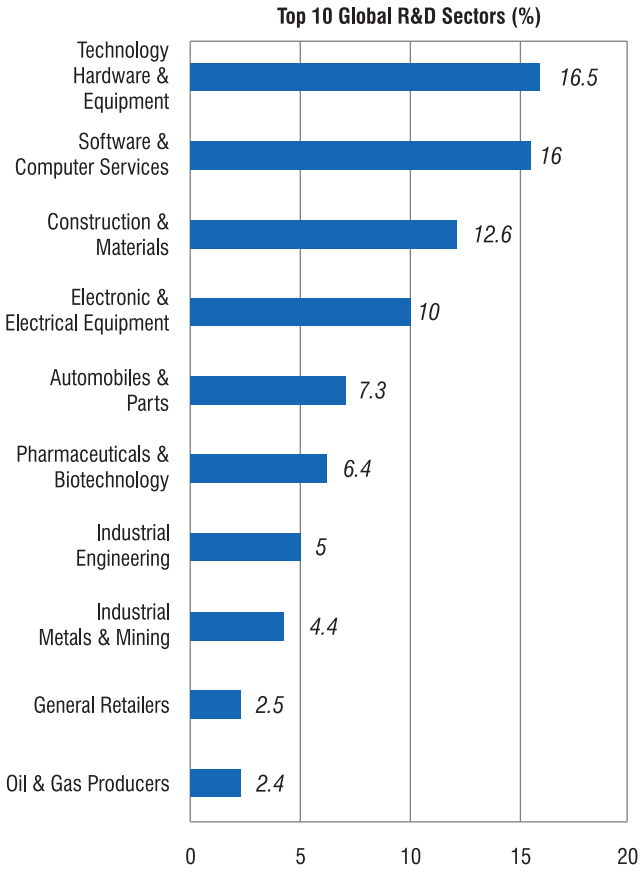


Source: EU Industrial R&D Investment Scoreboard (various years); Centre for Technology, Innovation and Economic Research (CTIER)

Note: India had 24 firms in 2013, 31 firms in 2017 and 24 firms in 2021 that featured in the global top 2500 Industrial R&D spenders

For other indicators too that reflect its science, technology and innovation capabilities, China ranks among the top countries globally. China is the top destination for VC funding after the US and received USD 114 billion in VC funds in 2021, double the amount it received in 2016. The country again ranks second in terms of publication output during the period 2017 - 2021, accounting for 19 percent of global publication output. China's top areas of publications (Table 2) have seven subject areas in common with the top ten global areas of publications. Some of the top areas of publications for China include electrical & electronic engineering, multidisciplinary material science, multidisciplinary physics, multidisciplinary chemistry, environmental sciences, energy & fuels, telecommunications, and computer science information systems. The impact of these publications as measured by the Category Normalized Citation Impact (CNCI) score according to Web of Science is above

Figure 2 Sectoral Share of R&D Spending by Top R&D Firms in China (2021)



Source: EU Industrial R&D Investment Scoreboard (2022); Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) The sample comprises 678 Chinese firms that featured in the global top 2500 Industrial R&D spenders. Total for the top 678 firms according to EU Industrial R&D Investment Scoreboard (2022) for the year was USD 221 billion

(ii) The EU Industrial R&D Investment Scoreboard reports Mining and Industrial Metals & Mining as two separate sectors. If these two sectors are combined the revised sector share of spending would increase to 5 percent in the table above

(iii) Figures in euros were converted to dollars using the EUR-USD exchange rate of 1.13 as at 31 December 2021

Table 2 China's Top Areas of Cumulative Publications (2017 - 2021) - Impact, Industry Collaborations, International Collaborations and Comparisons with Global Averages

Rank	Top Areas of Chinese Publications	Chinese Publications	Chinese Share of World Publications (%)	Category Normalized Citation Impact		Industry Collaborations (%)		International Collaborations (%)	
				World	China	World	China	World	China
1	Electrical & Electronic Engineering	305360	30.3	1	1.1	4.7	4.6	22	24.8
2	Multidisciplinary Materials Science	295268	37	1	1.2	2.4	1.6	26.6	25.9
3	Applied Physics	165956	32.1	1	1.3	2.8	1.8	26	25.2
4	Physical Chemistry	159976	37.6	1	1.4	2.1	1.5	28.8	26.8
5	Multidisciplinary Chemistry	159532	28.9	1	1.5	1.8	1.1	23.8	25.7
6	Environmental Sciences	156960	30.2	1	1.2	1.3	1.4	30.7	29.9
7	Energy & Fuels	123058	34.9	1	1.1	4.3	6.6	24.5	25
8	Oncology	112372	20.5	1	1	3.3	1.2	18.7	15.6
9	Tele communications	111674	33.8	1	1	4.6	4.2	24.3	28
10	Computer Science, Information Systems	111424	32.1	1	1.1	4.2	4.5	25.7	29

Source: InCites (based on data from Web of Science), data downloaded from the platform on 3 November 2022; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Cumulative publication output for China during the period 2017 to 2021 was 2900679.

one, i.e. above world average for most of the country's top areas of publications. The share of international collaborations for these top areas of research is comparable with the world average for nearly all the areas of research, while the share of industry collaborations is well above world average for energy & fuels and comparable for many of the others.

With respect to patents, China ranked third in terms of patents granted by the United States Patent and Trademark Office (USPTO) in 2021, above South Korea and Germany. The number of patents that China has been granted by the USPTO has seen a seven fold increase to 23,707 in 2021 from 3,173 in 2011. Unlike India where the number of patents granted by the domestic patent office is significantly higher for non-residents

compared to residents, China is similar to South Korea and Japan where the respective domestic patent offices have been granting more patents to their residents compared to non-residents. Lastly, China's high technology exports as a share of manufactured exports has consistently remained above 30 percent oer the last decade.

Balancing the Quest for Technology Dominance and Growing Environmental Concerns

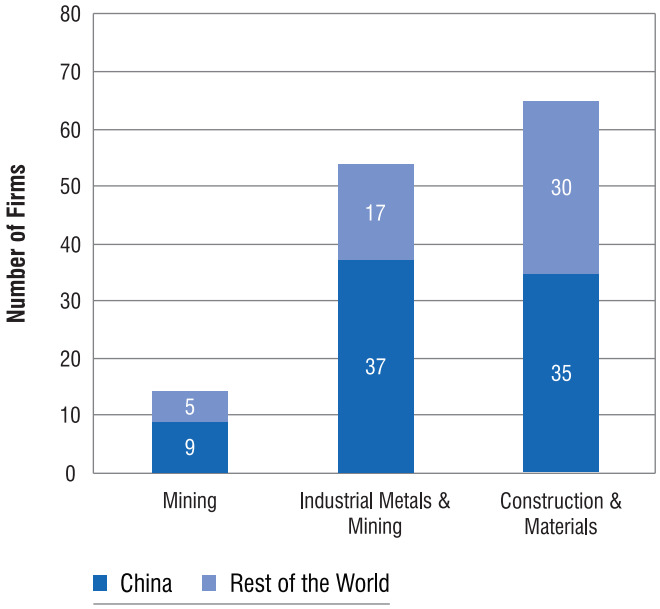
The high GDP growth and rapid industrialisation that China experienced over four decades between 1980 and 2020, driven mainly by investment and exports, saw the country become a manufacturing powerhouse and also resulted in China becoming one of the top emitters of greenhouse gases globally. The country today is faced with serious environmental concerns (The World Bank Group, 2022). As we have noted above, China has increased her R&D presence in several high technology sectors. Several of these technologies whether in the technology hardware & equipment sector, the electronics & electrical equipment sector, the automobiles & parts sector or even the chemicals sector depend on rare earths. Rare earths are used to manufacture a wide range of products that include consumer electronic products like smartphones and smartphone cameras, screens for televisions and defence equipment. They are also critical to green technologies like electric vehicles and batteries, hydrogen fuel cells and for the storage of green hydrogen. China has access to huge reserves of rare earths - the country accounts for almost 40 percent of global rare earth reserves. Furthermore, China accounts for over 60 percent of global production of rare earths and dominates the processing of rare earths (Institute for Energy Research, 2021).

While the mining of rare earths has bolstered the development of China's high technology sectors, it has added to the country's environmental woes. Furthermore, China's urbanisation and infrastructure requirements have resulted in the construction sector contributing significantly to carbon emissions. In 2019, the construction sector accounted for 50 percent of its national carbon emissions (Wu, 2022). To add to the environmental concerns, drought and heat waves in 2022 impacted China's hydroelectric power plants resulting in power outages - this

forced China to restart over a 100 of its coal-based power plants that had been shut down in the previous year (Yeung, 2023).

In striving to balance the quest for technology dominance with the goal of transitioning to a low carbon economy (China has set a goal to peak carbon emissions by 2030 and carbon neutrality by 2060), it is

Figure 3 Number of Chinese Firms in Top 2500 Global R&D Spenders (in Mining, Industrial Metals & Mining and Construction & Materials Sectors)



Source: EU Industrial R&D Investment Scoreboard (2022); Centre for Technology, Innovation and Economic Research (CTIER)

interesting to note China's industrial R&D investments are visible in areas that go beyond the high technology sectors and include sectors like mining and construction & materials. The EU Industrial R&D Investment Scoreboard (Grassano et al., 2022) that provides a list of the top 2,500 global R&D spenders across various sectors, shows 14 firms that feature in the mining sector. Of these 14, there are 9 firms from China that spent around USD 1.4 billion on R&D in 2021 and accounted for 74 percent of total R&D spending by the top global spenders in the mining sector. If one expands this list to include firms classified under industrial metals & mining, there are 46 Chinese firms out of a total of 68 top R&D spenders that feature in the combined sectors of mining and industrial metals & mining. Similarly if one considers firms in construction & materials, of the 65 global R&D spenders, there are 35 firms from China (Figure 3). The 35 firms from China spent around USD 28 billion in 2021 accounting for

80 percent of the total R&D spending by the 65 global firms. In Figure 2 above, we saw that both construction & materials and industrial metals & mining are among the top 10 sectors in industrial R&D in China. In fact for construction & materials, the R&D spending by the firms in China has been one of the key drivers for this sector to enter the top 10 global R&D sectors by spending.

Besides the spending on R&D towards better mining technologies and methods, or better construction materials, an article in the South China Morning Post highlighted how Chinese scientists had devised a new method for the extraction of rare earths using electric power that would be more effective in extraction and less damaging to the environment compared to the traditional ammonia leaching method that is used (Tong, 2022). As several economies try to reduce their dependence on China's rare earths by increasing their own production (Tang, 2020) greater availability of rare earths for domestic purposes and better extraction methods will further aid China's high technology as well as green technology pursuits. The R&D investments being made in the construction & materials sector will no doubt help China lower its emissions in the construction sector.

While there is clear increased investment in industrial R&D in a number of sectors, China's dominant position in publications output (Table 2) is also evident in areas that include electrical & electronic engineering, multidisciplinary materials science and multidisciplinary chemistry among others. Some of these are critical scientific areas behind key technologies being developed. Another important area to note is the publication output in environmental sciences - China is the leading contributor here with around 30 percent of the global publication output during 2017 - 2021, compared to the US that contributed just under 20 percent.5 The citation impact of the publications in this area is above world average with a strong element of international collaborations. Several of China's leading and reputed research institutions like the Chinese Academy of Sciences, the University of Chinese Academy of Sciences and other higher education institutions that are ranked within the top 200 of the Times Higher Education World University rankings, namely Tsinghua University, Zhejiang University, Nanjing University, Peking University, Fudan University, University of Science and Technology of China and Shanghai Jiao Tong University have been major contributors to the environmental sciences publications. Based on available data,

there are several more academic institutions in China that are now pursuing research in environmental sciences.6 This area will likely remain a priority given the emphasis the country has placed on transitioning to a low carbon economy.

Lessons from China's Balancing Act

The emphasis placed by China on science, technology and innovation in successive plans as a core component of its economic development has played out and is likely to continue to play out in the indicators captured above. The high GDP growth in China over several decades has resulted in China also becoming one of the top emitters of greenhouse gases globally. The country's huge reserves of rare earths will no doubt aid China in her ambitions to develop advanced as well as green technologies. The data above suggests that significant R&D investments are being made in sectors that go beyond the high technology sectors and include investments in better mining technologies and extraction methods to reduce environmental damage, as well as construction materials that will help reduce carbon emissions in the construction sector. The publications data too reflects a focus on scientific areas that are key for advanced technologies being developed in China as well as addressing environmental concerns. The intense focus on innovation by China's policy makers to achieve technology dominance while transitioning to a low carbon economy offers lessons to governments worldwide.

References

Center for Security and Emerging Technology (2021), "Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035", available at https://cset.georgetown.edu/publication/china-14th-five-year-plan/, accessed on 19 January 2023

Fan, Peilei, and Chihiro Watanabe. "Promoting industrial development through technology policy: Lessons from Japan and China." Technology in Society 28.3 (2006): 303-320, available at https://foxc-j.com/list/Watanabe_TS2.pdf ,accessed on 30 March 2023

Grassano, N., Hernandez Guevara, H., Fako, P., Nindl, E., Georgakaki, A., Ince, E., Napolitano, L., Rentocchini, F., Tübke, A (2022), "The 2022 EU Industrial R&D Investment Scoreboard", available at https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard, accessed on 22 March 2023

IMF (2023), World Economic Outlook Database, available at https://www.imf.org/en/Publications/WEO/weo-database/2023/April, accessed on 30 April 2023

InCites, Clarivate Analytics, derived from Web of Science. Data downloaded with assistance from Clarivate Analytics analyst, data downloaded on 3 Nov 2022. This is a subscription-based database

Institute for Energy Research (2021), "China and the Rare Earth Supply Chain Policy Brief", available at https://www.instituteforenergyresearch.org/renewable/china-and-the-rare-earth-supply-chain-policy-brief/ , 5 April 2023

Institute for Security & Development Policy (2018), "Made in China 2025", available at https://isdp.eu/content/uploads/2018/06/Made-in-China-Backgrounder.pdf, 28 March 2023

Leiderman, L. and Propper, E. (2021), "China's Five-Year Plan: Striving for Reforms and Openness while Strengthening Party Control", The Institute for National Security Studies (INSS), available at https://www.inss.org.il/publication/china-five-year-plan/, accessed on 8 April 2023

OECD (2018), The Belt and Road Initiative in the global trade, investment and finance landscape, In OECD Business and Finance Outlook 2018, OECD Publishing, Paris, available at https://www.oecd.org/finance/Chinas-Belt-and-Road-Initiative-in-the-global-trade-investment-and-finance-landscape.pdf, accessed on 22 September 2022

Shulin Gu (1995), "A Review of Reform Policy for the S&T System in China: From Transactions for Technology to Organizational Restructuring", The United Nations University, available at https://archive.unu.edu/hq/library/Collection/PDF_files/INTECH/INTECHwp17.pdf, accessed on 1 April 2023

Consulate-General of the People's Republic of China in San Francisco (2003), "Science and Technology Programs in China", available at http://sanfrancisco.china-consulate.gov.cn/eng/kj/kjjh/, accessed on 31 March 2023

Scopus, data downloaded with assistance from Ahmedabad University, data downloaded from the platform on 3 May 2023

Sun, Y., Cao, C. (2021), "Planning for science: China's "grand experiment" and global implications", Humanit Soc Sci Commun 8, 215, available at https://www.nature.com/articles/s41599-021-00895-7#citeas, accessed on 9 March 2023

The World Bank Group (2022), "China Country Climate and Development Report", available at https://www.worldbank.org/en/country/china/publication/china-country-climate-and-development-report, accessed on 25 March 2023

Tang, F. (2020), "China's rare earth export plunge caused by coronavirus, not Beijing agenda, industry group says", South China Morning Post, available at https://www.scmp.com/economy/china-economy/article/3097847/chinas-rare-earth-export-plunge-caused-coronavirus-not, accessed on 6 April 2023

Tong, Z. (2022), "Chinese rare earth tech innovation aims for faster, cleaner extraction: paper", South China Morning Post, available at https://www.scmp.com/news/china/science/article/3198732/chinese-rare-earth-tech-innovation-aims-faster-cleaner-extraction-paper, accessed on 31 January 2023

U.S. Embassy Beijing (1996), "PRC State Council Decision on Accelerating S&T Development", available at https://nuke.fas.org/guide/china/doctrine/stdec2.htm, accessed on 4 April 2023

Wu, Y. (2022), "China's Green Building Materials Sector: Policies and Investment Opportunities", China Briefing, available at https://www.china-briefing.com/news/chinas-green-building-materials-sector-policies-and-investment-opportunities/, accessed on 31 January 2023

Yeung, J. (2023), “China approved equivalent of two new coal plants a week in 2022, report finds”, CNN, available at https://edition.cnn.com/2023/02/27/energy/china-new-coal-plants-climate-report-intl-hnk/index.html, accessed on 9 March 2023