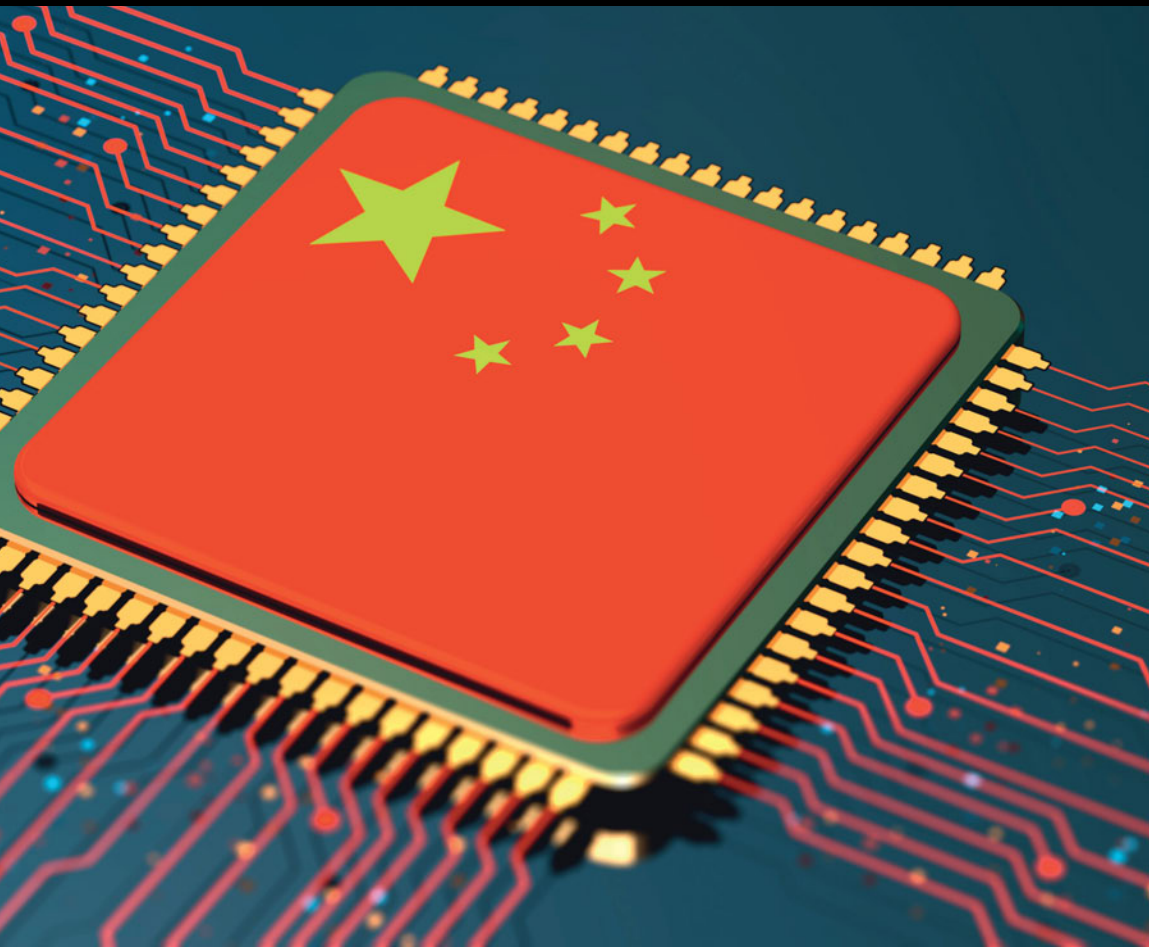
The Political Economy of Science, Technology, and Innovation in China

Policymaking, Funding, Talent, and Organization

Yutao Sun and Cong Cao



The Political Economy of Science, Technology, and Innovation in China

There are a variety of reasons underlying the remarkable development of science and technology (S&T) and innovation in post-1978 China. This book seeks to achieve an understanding of such development from an institutional or a political economy perspective. Departing from the literature of S&T and innovation studies that treats innovation as a market or an enterprise's behavior in the Schumpeterian sense, Sun and Cao argue that it involves politics, institutions, and the role of the state. In particular, they examine how the Chinese state has played its visible role in making innovation policies, allocating funding for R&D activities, making efforts to attract talent, and organizing critical R&D programs. This book appeals to scholars in S&T and innovation studies, political economy, innovation governance, and China studies as well as policymakers and business executives.

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To Fengchao Liu, Denis Fred Simon, Jinqin Su, and Richard P. Suttmeier, mentors, colleagues, collaborators, comrades, and friends

Contents

Figures

Tables

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Abbreviations

AAAS	American Association for the Advancement of Science
ABOC	Agricultural Bank of China
ACFIC	All-China Federation of Industry and Commerce
ACFTU	All-China Federation of Trade Unions
ACWF	All-China Women's Federation
BRICS	Brazil, Russia, India, China, and South Africa
CAC	Office of the Central Cyberspace Affairs Commission
CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Sciences
CASS	Chinese Academy of Social Sciences
CAST	China Association for Science and Technology
CBIRC	China Banking and Insurance Regulatory Commission
CBRC	China Banking Regulatory Commission
CCCCYL	Central Committee of the Chinese Communist Youth League
CDB	China Development Bank
CIBC	Commerce and Industry Bank of China
CIRC	China Insurance Regulatory Commission
CMA	China Meteorological Administration
CMC STC	Science and Technology Committee of the Central Military Commission
COSTIND	Commission of Science, Technology, and Industry for National Defense
CPC	Communist Party of China
CPC CC	Communist Party of China's Central Committee
CPC CC CEW	CPC CC Commission on Enterprise Work
CPC CC DOO	CPC CC Department of Organization

CPC CC DOP	CPC CC Department of Propaganda
CPC CC FAO	CPC CC Foreign Affairs Office
CPPCC	National Committee of the Chinese People's Political Consultative Conference
CSRC	China Securities Regulatory Commission
CSTC	Central Science and Technology Commission
EIBOC	Export–Import Bank of China
GAC	General Administration of Customs
GAPP	General Administration of Press and Publication
GAQSIA	General Administration of Quality Supervision, Inspection, and Quarantine
GAS	General Administration of Sport
GDP	Gross domestic product
GERD	Gross expenditure on research and development
GFS	Government Finance Statistics
GII	Global Innovation Index
GVC	Global value chain
IP	Intellectual property
IPR	Intellectual property right
KIP	Knowledge Innovation Program
MCT	Ministry of Culture and Tourism
MEE	Ministry of Ecology and Environment
MEM	Ministry of Emergency Management
MEPS	Mega-Engineering Programs
MLP	Medium and Long-term Plan for the Development of Science and Technology (2006–2020)
MMRDs	Mission-oriented mega-R&D programs
MNR	Ministry of Natural Resources
MOA	Ministry of Agriculture
MOARA	Ministry of Agriculture and Rural Affairs
MOCA	Ministry of Civil Affairs
MOE	Ministry of Education
MOF	Ministry of Finance
MOFA	Ministry of Foreign Affairs
MOFCOM	Ministry of Commerce
MOHRSS	Ministry of Human Resources and Social Security
MOHURD	Ministry of Housing and Urban-Rural Development

MOIIT	Ministry of Industry and Information Technology
MOJ	Ministry of Justice
MOLR	Ministry of Land and Resources
MOMB	Ministry of Machine Building
MOMI	Ministry of Mechanical Industry
MOPS	Ministry of Public Security
MOST	Ministry of Science and Technology
MOT	Ministry of Transport
MOWR	Ministry of Water Resources
MSP	Mega-Science Programs
NAC	National Copyright Administration
NAO	National Audit Office
NASSP	National Administration of State Secrets Protection
NBS	National Bureau of Statistics
NCMCPDSRS	National Commission on the Management and Coordination of Post-Doctoral Scientific Research Stations
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NFGA	National Forestry and Grassland Administration
NFSRA	National Food and Strategic Reserves Administration
NHC	National Health Commission
NIS	National Innovation System
NLGST	National Leading Group for Science and Technology
NPC	National People's Congress
NSFC	National Natural Science Foundation of China
NSTPs	National S&T Programs
OCMCCSC	Office of the Central Mental Civilization Construction Steering Committee
OECD	Organization for Economic Co-operation and Development
OSTP	Office of Science and Technology Policy of the USA
OMB	Office of Management and Budget of the USA
PBOC	People's Bank of China

PLA DGL	People's Liberation Army Department of General Logistics
PLA GAD	People's Liberation Army General Armament Department
R&D	Research and Development
SA	Standardization Administration
SAA	State Archives Administration
SAFE	State Administration of Foreign Exchange
SAFEA	State Administration of Foreign Experts Affairs
SAIC	State Administration of Industry and Commerce
SAMR	State Administration for Market Regulation
SASAC	State-owned Assets Supervision and Administration Commission
SASTIND	State Administration of Science, Technology and Industry for National Defense
SAT	State Administration of Taxation
SATCM	National Administration of Traditional Chinese Medicine
SC GO	State Council General Office
SC HMO	State Council Hong Kong and Macau Affairs Office
SC OCAO	State Council Overseas Chinese Affairs Office
SC PAD	State Council Leading Group Office of Poverty Alleviation and Development
SCOPSR	State Commission Office for Public Sector Reform
SDPC	State Development and Planning Commission
SEC	State Economic Commission
SEI	Strategic Emerging Industries
SETC	State Economic and Trading Commission
SIPO	State Intellectual Property Office
SMEs	Small and Medium-sized Enterprises
SNA	Social network analysis
SOA	State Oceanic Administration
SOEs	State-owned enterprises
SPC	State Planning Commission
SPCC	Supreme People's Court
SPP	Supreme People's Procuratorate
SSTC	State Science and Technology Commission

S&T	Science and Technology
TTP	Thousand Talents Program
WIPO	World Intellectual Property Organization
YTTP	Youth Thousand Talents Program

Introduction

In 1978, soon after China initiated the reform and opening-up policy, the American Association for the Advancement of Science (AAAS) Board of Directors organized a three-week visit to China aiming to arrange cooperation between AAAS and its counterpart, the China Association for Science and Technology (CAST). Afterward, in 1979, *Science*, the flagship journal of AAAS, published a special issue, "China in Transition." One of the papers (Abelson, 1979), "Education, Science, and Technology in China," for the first time raised a very critical and provocative question: "Why hasn't China developed faster and more extensively?"

Forty-five years later, China has become not only the second largest economy in the world but also a juggernaut in science, technology, and innovation. If visiting China today, the AAAS delegation might end up with a completely different but somehow hyped question: "When will China impose a serious overall threat to the competitiveness and scientific leadership of the USA?"

There is no doubt that the development of science, technology, and innovation in post-1978 China has been nothing short of remarkable. With increasing and sustained government and societal efforts, in 2021, China reported to spend RMB2.79 trillion ($439 billion, current US dollars) on research and development (R&D) (NBS, 2022). This was twice as much as that of six years ago and 56 times that of 1995 when the "rejuvenating the nation with science, technology, and education (*kejiao xingguo*)" strategy was proposed. In 2019, China's R&D expenditure reached $525.7 billion (PPP US dollars), accounting for about 22 percent of the global total and close to the level of the USA ($668.4 billion, or 28 percent of the global total) (NSB & NSF, 2022: 23). In 2021, China's R&D intensity, or gross expenditure of R&D (GERD) as a percentage of gross domestic product, reached 2.44 percent, more than tripled since 1996. China's R&D intensity reached 2 percent in 2013 for the first time and has maintained or surpassed

this level thereafter. Although China did not fulfill the R&D intensity target set in the *Medium and Long-Term Plan for the Development of Science and Technology (2006–2020)* (MLP) for 2020, which is 2.5 percent, it has retained the momentum to help transform the nation's economic structure and stimulate the next stage of economic and social development by technology and innovation. The country is likely to set an even more ambitious target for its R&D intensity. Presumably, the level will be 3 percent for the next 15-year MLP (2021–2035), which the Chinese government has been formulating.[1]

China's talent pool is the largest in the world. In 2020, China's R&D personnel reached 5.24 million person-year in full-time equivalent terms, more than any other country in the world (NBS, 2021: Table 20–21). Its human resources pipeline is full as a result of the expansion of higher education that started in the late-1990s. In 2020, the number of undergraduate graduates in China reached 7.97 million and postgraduates 662,451 with 66,176 at the doctoral level (MOE, 2021).

China has become the world's most prolific country for knowledge production. Measured by the number of papers published in journals catalogued by *Science Citation Index (SCI)*, a bibliometric database compiled by Clarivate Analytics, China has ranked first in the world for quite a number of years. China's share of top 0.1 percent high-impact papers in Scopus, another bibliometric database, has grown from less than 1 percent in 1997 to about 20 percent in 2016 (Yang, 2016). China has witnessed continuous growth in patent applications and grants of domestic resident invention patents and patents with the Patent Cooperation Treaty (PCT), an international patent law treaty. In 2021, the number of PCT applications filed by Chinese inventors reached 69,540, putting China first in the world for the first time, ahead of the USA (59,570). Huawei Technologies, China's largest telecommunications equipment maker, ranked first with 6,952 PCT patent applications (WIPO, 2022). In addition, China's number of "triadic" patents – a set of patents filed with the European Patent Office, the

[1] In fact, the innovation-driven development strategy, released by the Communist Party of China's Central Committee and China's State Council in May 2016, stipulated to increase China's R&D intensity to 2.8 percent by 2030 (Communist Party of China's Central Committee and the State Council, 2016).

US Patent and Trademark Office, and the Japan Patent Office for the same invention, by the same applicant – has grown from less than 100 per year before 2000 to more than 5,000 in 2018 (OECD, 2022).

China also has become increasingly technologically sophisticated. Since the establishment of Zhongguancun in Beijing, the capital, as the first high-tech park, China has witnessed quite a number of its cities that rival Silicon Valley and the world's other high-tech zones. And three clusters of big-science research infrastructures in Beijing's Huairou, Shanghai's Zhangjiang, and Anhui's Hefei have turned these cities into the nation's comprehensive science centers. China is among the leaders in the number of leading high-tech companies, including those emerging "unicorns" valued at $1 billion and over, venture capital investment, high-tech trades, Internet and especially mobile Internet users, and volume of e-commerce. Overall, the Global Innovation Index, an index produced by Cornell SC Johnson College of Business, INSEAD, and the World Intellectual Property Organization to benchmark the innovation ecosystem performance of more than 130 economies, ranked China the 12th in 2021, a significant improvement over the 34th in 2012 (WIPO, 2021).

Indeed, various quantitative measures – from rapidly rising expenditure on R&D, a larger and high-quality talent pool, to impressive scientific publication and patenting statistics – indicate that China has been on its rapidly rising trajectory to becoming a formidable player, if not a superpower yet, in science, technology, and innovation. More importantly, China's catching up with and even leapfrogging Western countries in certain areas of science and technology (S&T) has to do with its possession of institutional capacity to mobilize human, financial, and material resources to achieve high-priority, national-development objectives (Suttmeier, 1981; Xue, 1997). Major accomplishments in national defense as well as in certain fields of basic research and technologies are just some of the examples. Meanwhile, the general inefficiency of transferring R&D achievements to production, even amid the reform of the S&T system that started in 1985, also makes it clear that overcoming structural uncertainty of China's science, technology, and innovation system is imperative if the system were to meet the demand for successful innovation in an increasingly market-oriented and knowledge-based economy (Breznitz & Muphree, 2011).

Why Another Book on Science, Technology, and Innovation in China?

In this book, we seek to achieve an understanding of China's development in science, technology, and innovation from an institutional or a political economy perspective. Over the years, scholars have tried to explain China's innovation from the enterprise's or economic perspective in the context of the enterprise-centered innovation system (Zhang *et al.*, 2009; Fuller, 2016; Yip & McKern, 2016; Lindtner, 2020). However, in examining the extent to which the Chinese state has led innovation (Appelbaum *et al.*, 2018), most of the studies are neither systematic nor comprehensive.

We were not that satisfied with the literature as science, technology, and innovation are more than a market or an enterprise's behavior in Joseph Schumpeter's sense but involve politics, institutions, and the role of the state. Indeed, behind China's innovation is the undeniable role of the Chinese state. Therefore, in around 2010, we started to work together. We have collected data from government and other credible sources, painstakingly demystifying and piecing together information on policy documents, R&D expenditure, and talents, among others. We have interviewed policymakers, policy analysts, academics, entrepreneurs, and other stakeholders involved in science, technology, and innovation activities and governance to achieve an appreciation of the evolving structure, process, operation, and characteristics of China's S&T system. We have actively participated in and contributed to the studies of China's science, technology, and innovation so as to accumulate first-hand knowledge and come up with new and insightful findings, some of which have been well received in the scholarly and policy communities.

In the ensuing years, we also have looked for a novel perspective and given serious thoughts to and tried to solve some of the burning questions pertaining to science, technology, and innovation in China. They include: What are the key government agencies handling S&T and innovation within the Chinese state and what are their respective roles? What are the structure and change of the relations between these government agencies? How do these government agencies and their relations play a role in making S&T and innovation policy,

funding scientific research, attracting talents, and organizing R&D programs? Having accumulated enough material, we feel that it is the time to tackle the above-mentioned questions by writing this book. We hope that our efforts represent a right step toward achieving a more thorough and nuanced understanding of science, technology, and innovation in China.

Structure of the Book

We organize our discussions on the political economy of science, technology, and innovation in China in seven chapters. The first chapter reviews the political economy of science, technology, and innovation literature, including the evolution from the national innovation system to a political economic approach, and proposes a conceptual framework to open the "black box" of the state related to S&T and innovation activities.

The second chapter is about how China's innovation policies have evolved to reflect our changing and supposedly better understanding of innovation by China's policymakers. It carries out a quantitative analysis of 630 innovation policies issued by China's central government ministries from 1980 to 2019. In fact, China has shifted its S&T and industrial policy-centered innovation strategy to pursuing a more coordinated innovation-oriented economic development by giving increasing attention to a portfolio of policies that also include financial, tax, and fiscal measures. There has been a gradual departure from the pattern in which innovation policies were formulated by one single government agency, therefore steering China to a different and probably more promising innovation trajectory.

Taking the policy network approach, the third chapter investigates three mechanisms – policy agenda, power concentration, and heterogeneity dependence – underlying the evolution of inter-government agency relations in China. Operationally, the chapter adopts a social network analysis–based method to quantitatively study China's innovation policy network. The findings show that the formal policy network for innovation has not only sustained through the intervention of policy agenda but also become self-organized because of policy network's nature of power concentration and heterogeneity dependence. The presence of such mixed mechanisms in the evolution of China's innovation policy

network differs from the findings from industrialized countries where self-organization plays a central role. The findings advance our theoretical understanding of the evolution of innovation policy network and have implications for policymaking in emerging economies.

China's rapid growth of R&D expenditure has attracted wide attention from the international scientific and policy communities. We try to open the "black box" of China's central R&D expenditure based on an analytical framework of "funding–performing" in the fourth chapter. Specifically, the chapter solves a major mystery regarding China's central government's R&D expenditure – who spends how much on what. By using data released by central government agencies with mission in S&T and innovation between 2011 and 2020, we find that the allocation of the central R&D expenditure has become decentralized and diversified, which has posed new challenges for China's R&D budget management. Much of the public money has financed scientific research, but the nation's overall R&D funding has been oriented toward development research, thus pointing to a possibility that China's efforts to build an enterprise-centered innovation system may lack a solid scientific foundation. The findings are helpful for understanding China's S&T budgeting process and spending patterns as well as funding structure.

In examining the effect of Chinese talent-attracting programs launched by the Chinese government, with few exceptions, studies have rarely assessed these programs empirically and pertinently. We intend to fill the gap by evaluating an important central government program – the Youth Thousand Talents Program – in the fifth chapter. We start with proposing a transnational migration matrix of the academics to clarify the dynamic mechanism of achieving an academic brain gain at the high end. The transnational migration matrix suggests that the academics with high ability have competitiveness in both overseas and domestic academic job markets and can especially enjoy a higher salary and academic reputation in the host (overseas) academic job market due to its more mature mechanism of academic evaluation relative to their home country. The results show that some scholars whose last employer's academic ranking is among the world's Top 100 have stronger willingness to return, and the negative effect of academic ranking decreases with time passing. Compared to scholars with an overseas tenure-track position, those with a tenure position or a permanent position tended to stay overseas, the rate of their staying

abroad increased with ages. Therefore, China's talent-attracting programs only have partially succeeded in bringing back the academics at the high end.

The sixth chapter extends theoretical and empirical interests in understanding the role of the Chinese government through its organization of mission-oriented mega-R&D programs (MMRDs). In particular, this chapter proposes a theoretical framework with a particular focus on such programs' three contextual characteristics – technical goal of the mission, dominant actor, and end-user. We then apply the framework to ten cases across different historical periods and sectors in different countries to test its validity. The finding suggests that exploitative R&D programs with a clear and singular technical goal whose performer and end-user are public actors entails government to adopt MMRDs, while in doing so government also should take into consideration such factors as economic efficiency, national security, and public interests. In the case of China, the state-led innovation model favors to concentrate resources on initiating MMRDs.

Our final chapter concludes the book by summarizing the findings from our studies of the political economy of science, technology, and innovation in China, discussing tensions faced by China through the perspective of the political economy in the studies of science, technology, and innovation in China, and drawing some governance implications for the political economic study of China's science, technology, and innovation in general.