Cambridge University Press & Assessment
978-1-108-79603-3 — The Political Economy of Science, Technology, and Innovation in China
Yutao Sun, Cong Cao
Excerpt
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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.

1 Studying Science, Technology, and Innovation

Bringing the State In

As indicated in the Introduction, China's impressive progress in science, technology, and innovation in the past several decades could be attributed to various factors, among which is the inarguable role of the Chinese state. A variety of theories have advanced scholarly understanding of the role of the state in innovation. In this book, we focus on one that is based on political economy, which typically refers to the study of the process through which politics affects the economy, and the economy in turn shapes politics.

As a rather elusive term, political economy has a long and rich history. While its application to the study of science, technology, and innovation is quite recent, "How are the states getting rich?" has been a lingering question. For Adam Smith (1776 [1999]), the division of labor is the key. Friedrich List (1841 [2005]) introduced political economy to inquire about how a nation can obtain prosperity, civilization, and power. Inspired by List, Joseph Schumpeter was the first who tried to answer the question by using the concept of innovation (Knell, 2018). Karl Marx also viewed science as a fundamental factor in explaining the exceptional growth in productivity and humanity's capacity to drive progress (Perelman, 1978).

Especially for Schumpeter (1939), innovation, as essentially an economic concept, is an enterprise's behavior, through which the enterprise dominates the market by creating temporary monopolies ("first-mover advantage"). Such monopolistic status in turn affords the enterprise abnormal profits that would soon be competed away by rivals and imitators, as well as incentivizing it to develop new innovative and commanding products and processes. In a word, entrepreneurial activities and accompanying innovation-originated market power provide enterprises with better results than the "invisible hand" and competition.

To the extent that it is an economic concept, innovation also is subject to political decisions. Indeed, innovation is more than an enterprise's behavior *per se*. For innovation to happen and sustain requires an environment that encourages the enterprise to be innovative. In this regard, government can make a huge difference, according to List (1841 [2005]: vol. 2: 94) by formulating a set of "institutions, regulations, laws, and conditions on which the economy of the individual subjects of a State is dependent, and by which it is regulated." It is the joint effort of market's "invisible hand" and the government's "visible hand" that levels the playing field for innovative enterprises and eventually makes some of the nations rich technologically and economically. While Smith (1776 [1999]) rejected government interference in market activities, John Maynard Keynes believed it necessary for government to stimulate the economy by investing in infrastructure, education, and other areas for their "public goods" nature (1936 [1973]).

This chapter visits the theories that have been developed to explain the role of the state in innovation and economic growth. Our focus is the literature on the political economy of science, technology, and innovation, starting with and extending from the neoclassical economics and the national innovation system (NIS) approach. We will especially highlight the literature's relevance to China and to our book. Doing so will help acquaint our reader with the knowledge of how political economy is useful in advancing our understanding of science, technology, and innovation in general and that in China in particular. We will end up with discussions of how our book contributes to the literature.

The Roles of Science, Technology, and Innovation in National Economic Growth

Theoretical approaches regarding conceptualization and theorization of the national economy and economic growth did not consider factors other than labor and capital. Nor did they capture why there exist relatively huge differences among countries with similar levels of economic development. It is neoclassical economists who viewed technology as a key element of production that drives economic growth and impacts national economies.

In particular, Solow (1956) defined productivity growth as rising output with constant input of capital and labor. However, part of the growth is not accountable when capital is accumulated and labor increased. The so-called Solow residual, or the unaccounted-for part in his growth model, measures productivity gain through technological progress, which in turn is associated with research and development (R&D); human capital development through education, on-the-job training, and healthcare; institutionalization of technology; technical competence; institutional/organizational restructuring and management; and production methods. For Helpman (1998), in addition to the importance of physical and human capital accumulation, economic activities are organized around the effects of technological factors on the rate of this accumulation; the process of knowledge creation and its influence on productivity; the interdependence of the growth rates of different countries; and, finally, the role of economic and political institutions in encouraging knowledge accumulation, innovation, and technological changes. That is, both Solow and Helpman imply explicitly that state is a prime player in a nation's technological changes and economic development.

Indeed, the introduction of changes in technology has become a major factor in explaining the economic growth and development of a country (Nelson, 1959; Romer, 1990, 2000). And the neoclassical economic doctrine had dominated the global narrative for quite some time and had been practiced in some developed and developing countries (Aghion *et al*., 2008).

National Innovation System

Over time, the scholarly community has reached a consensus that innovation is an essential factor of economic growth. Economists and innovation scholars have gained increased knowledge of innovation systems and technology adoption in developed and more recently developing countries.

The application of political economy to the study of science, technology, and innovation probably dates back to List, who is credited with the genesis of the NIS approach (Freeman & Perez, 1988; Freeman, 1995; Soete *et al*., 2010). In his seminal work, *National System of Political Economy*, List (1841 [2005]) critiqued the free-market doctrine and suggested that the government should be responsible for nurturing the productive resources of its country. For List, a true political economy study should start from the point of view of the interests of nations (Knell, 2018). As such, the Listian political economy means to provide the economic rationale for using industrial policy measures