A "Dual-Track System" Proposal for Reforming China's Scientific Research System and R&D System (Postprint)

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Abstract

Through a review of three exemplary research systems and R&D frameworks—those of the United States, Germany, and Japan—this article identifies six common characteristics of research systems and R&D frameworks. Building upon this foundation, it analyzes the current state and existing challenges within China's research system and R&D framework. Finally, the article proposes the establishment of a "dual-track" research system and R&D framework: on the one hand, creating a "new track" of R&D policies oriented toward the private sector to address the fundamental questions of "why innovate," "where to innovate," and "how to innovate" for private enterprises; on the other hand, gradually reforming the "old track" of research policies for research universities and institutions, while simultaneously promoting the development of "outside-the-system" research universities and institutions, research funding agencies, publishers, and academic journals to catalyze institutional reform among their "within-the-system" counterparts.

Full Text

Preamble

Concept of Dual-track System for Enhancing China's Scientific Research Institution and R&D System

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Abstract

Through an analysis of the scientific research institution and R&D system of three typical models in the United States, Germany, and Japan, this study summarizes six common characteristics of the scientific research institution and R&D system. Based on this, it analyzes the current status and issues of China's scientific research institution and R&D system. Finally, this study proposes the establishment of a dual-track scientific research institution and R&D system. On the one hand, it suggests creating a new track of R&D policies aimed at the private sector to address questions like why innovate, where to innovate, and how to innovate for private enterprises. On the other hand, it recommends gradually reforming the old track of policies for scientific research aimed at universities and research institutions, promoting the development of off-system universities and research institutions, research funding sponsors, as well as publishers and academic journals, to drive institutional reform within the on-system relevant institutions.

Keywords: scientific research institution, R&D system, dual-track system, private enterprises, research universities

1. Three Typical Scientific Research Institution and R&D System Models Worldwide

Historically, the world's scientific center has shifted from Italy to Britain, France, Germany, and finally to the United States. The prosperity of these world science and technology centers has been supported by national scientific research institutions and R&D systems. The scientific research institution is the foundation for achieving breakthroughs in basic research—the "from 0 to 1" stage—primarily oriented toward fundamental theoretical research, with research universities and institutions as its main actors. The R&D system, meanwhile, is critical for transforming basic research into applied technology, representing the "from 1 to 10" stage of technological innovation and application, with enterprises as its primary actors. This section analyzes three typical scientific research institution and R&D system models: the United States' neoliberal science-R&D integration model, Germany's scientific institutionalization and industrial laboratory model, and Japan's private enterprise-led model.

1.1 United States: Neoliberal Science-R&D Integration Model

By the end of the 20th century, under the influence of neoliberal economic thought, neoliberal forces had entered scientific development, making the U.S. research institution highly market-oriented and tightly integrating science and technology to serve present and future market demands [1]. Under neoliberal economic logic, three main actors—government, enterprises, and research universities—jointly dominate the development of the U.S. scientific research and R&D system, with market actors such as venture capital institutions playing a key role in the technological transformation of basic research [2]. Silicon Valley in the San Francisco Bay Area exemplifies the perfect combination of neoliberalism-led research institutions and R&D systems.

Meanwhile, although the excessive marketization of scientific research in certain fields has weakened the basic research capabilities of some U.S. research universities and disciplines, many top-tier research universities and disciplines have maintained considerable autonomy in basic research. These institutions grant scientists full freedom to explore academic fields and directions, ensuring that most globally original basic research breakthroughs remain concentrated in the United States.

1.2 Germany: Scientific Institutionalization and Industrial Laboratory Model

During the mid-to-late 19th century and early 20th century, Germany held the highest position in global science and technology development, thanks to German university education reforms and the university-industry cooperation model represented by industrial laboratories. In terms of research institutions, German university reforms transformed the traditional model where teaching was primary and research secondary, emphasizing that scientific research should be professors' foremost task. The reforms also adopted an academic corporate autonomous structure that institutionally guaranteed universities' research freedom. Academic corporations were generally prestigious professors within universities who possessed both administrative and academic functions, serving as a buffer and intermediary between the government and researchers to prevent government interference in specific scientific research.

In the R&D system, the university-industry cooperation model represented by industrial laboratories was an important institutional innovation. Germany's industrial laboratories first emerged in the 1860s in the German dyeing industry and were subsequently applied to other pillar industries, integrating scientific research into enterprise development. The boundary between entrepreneurs and scientists became blurred, enabling rapid transformation of research results. Numerous merchants with scientific knowledge created new German-style economic forms, such as Siemens, Bayer, and Krupp.

1.3 Japan: Private Enterprise-Led Model with High Independence

Post-WWII Japan achieved world-renowned results in science and technology. By the early 21st century, 22 Japanese scientists had received Nobel Prizes in natural sciences, ranking second only to the United States. The fundamental reason lies in a research institution and R&D system with private enterprises as the main actors, where enterprises, research institutions, and research universities each have distinct focuses and relatively strong independence [3]. In terms of research institutions, Japan reformed its research university system by introducing market mechanisms and corporate management models, separating research universities from the national budget and civil service system to grant them sufficient autonomy in scientific research [4,5]. Additionally, the government substantially increased basic research funding for research universities, maintaining the proportion of basic research in total research funding at around 15% for a long period .

In the R&D system, the market demand-oriented R&D model of private enterprises enabled Japan to not only quickly capture market demands but also efficiently achieve transformation of research results. For a considerable period, Japanese enterprises with certain scale and strength established internal central research institutes and maintained high R&D investment year-round, enabling Japanese enterprises to possess strong sustainable innovation capabilities in various frontier fields [6].

1.4 Six Common Characteristics of the Three Models

Despite differences in historical periods and national conditions underlying the three models, they share six common characteristics in their scientific research institutions and R&D systems. These characteristics are considered crucial to their success.

(1) Research Institution Characteristics. The U.S., German, and Japanese models all share three features: First, a free and open research environment. Although serving government or wartime needs at different times, all three countries have reduced direct administrative intervention in scientific research, providing a free and open environment. On the one hand, scientific research itself stems more from curiosity and interest, and a free environment can ensure that curiosity-based scientific exploration is less constrained by disciplinary, religious, or political boundaries. On the other hand, an open environment facilitates talent mobility and exchange, enabling collisions of knowledge from different cultures and backgrounds.

Second, a group of domestic and foreign scientists with scientific spirit, along with numerous world-class research universities and research institutions. Experience from the three countries shows that world-class research universities are key to attracting top scientists, while a free and open research environment is the prerequisite for establishing and developing such universities.

Third, a scientific and innovation-friendly research system, most critically reflected in research funding management models and researcher evaluation systems. Compared with the diverse funding sources in the United States, Germany and Japan primarily rely on government funding and encourage university-industry cooperation to reduce dependence on government funds. In evaluation systems, all three countries adopt multi-dimensional assessment models, emphasizing that peer review systems require greater transparency and independence, valuing the quality of performance assessments and international cooperation outcomes rather than purely pursuing quantity.

(2) R&D System Characteristics. The United States, Germany, and Japan all share three common features: First, a stable, advanced, and highly growth-oriented domestic and international market. Markets reflect broad consumer demands and business opportunities. Whether in Silicon Valley in the United States or Tokyo in Japan, the transformation of scientific and technological achievements is often based on stable domestic market demand and extends to high-growth markets in different regions worldwide.

Second, a group of product suppliers capable of timely responding to and meeting these market demands—namely, private enterprises. Empirically, except for Britain and France during the imperial period, private enterprises have been the main actors in technological innovation in most cases. Japan's post-war economic success further demonstrates the flexible innovation capabilities of private enterprises in the R&D process.

Third, sufficient and sustainable funding and talent investment in technological innovation activities from enterprises, government, and society. Compared with basic research, applied technology research is often capital-intensive, requiring substantial R&D funding and personnel investment. On the one hand, from the perspective of enterprises and social capital, a growth-oriented market is key to supporting continuous investment in applied technology research. On the other hand, from the government's perspective, it is necessary to create a policy environment that encourages innovation and supports and guides social capital investment in technological innovation activities through direct or indirect means. In addition to R&D funding investment, the reserve of R&D personnel is also crucial, which is why historical world science centers have undoubtedly been world talent centers, including not only scientists but also engineering and technical talents in various fields.

2. Current Status and Problems of China's Scientific Research Institution and R&D System

2.1 Current Status and Problems of the Research Institution

Since the founding of the People's Republic of China, China's science and technology development has achieved remarkable accomplishments, ranking at world-class levels in fields requiring basic research support such as aerospace technology, deep-sea science, supercomputing, and nanoscience. However, objectively speaking, breakthroughs in individual basic research fields in China do not equate to systematic and structural transformation. On the contrary, China still lags far behind world-class levels in numerous basic research fields. The key reason lies in the administrative nature of China's current research institution, which is manifested in research universities and institutions, research funding agencies (National Natural Science Foundation of China, Ministry of Science and Technology, Ministry of Education, etc.), publishers, and academic journals. The essence of this administrative nature is government dominance, but a government-dominated system struggles to produce "from 0 to 1" breakthroughs in basic research, achieving more “from 1 to 10” applied research breakthroughs instead.

First, a government-dominated system inevitably has value orientations and ideological orientations, making it impossible to form a completely free research environment across all fields. The research environment here refers broadly to the political, social, and economic environment affecting scientific research activities, whose directions are inevitably influenced by this macro-environment. Objectively, freedom is always relative, and absolute freedom does not exist, even in the United States under neoliberalism. Although absolute freedom does not exist, the impact on scientific research differs enormously between non-government-dominated pluralistic cultures and societies versus government-dominated relatively homogeneous social environments. Taking the post-WWII United States and Soviet Union as examples, during the U.S.-Soviet competition, the technology war was the most critical competitive arena. The Soviet Union, relying on its whole-nation system, once took the lead in fields such as aerospace for a period. However, simultaneously, the relatively homogeneous and rigid social environment dominated by the Soviet government suppressed the emergence and dissemination of new ideas and theories, lacking sustainable innovation capacity, and was eventually overtaken and far surpassed by the more dynamic United States. Today, China faces comprehensive suppression and containment from the U.S.-led Western world. The first meeting of the 20th Central National Security Commission on May 30, 2023, emphasized that the complexity and difficulty of national security issues we currently face have significantly increased. Obviously, under severe external circumstances, China does not have the objective conditions to create a free political and economic environment in the short to medium term. Therefore, at this stage, we must recognize and accept the fact that we do not yet possess the objective conditions to create a continuously innovative research environment in basic research.

Second, government-dominated research universities and institutions inevitably lead to administrative/political logic overwhelming academic logic. Researchers cannot truly obtain research funding based on interest but must conduct research that aligns more with government needs. Such an environment cannot attract and cultivate scientists with pioneering spirit. In the early days of the People’s Republic of China, China’s research universities and institutions basically adopted the Soviet model, which was centrally government-dominated with highly centralized management. Research universities and institutions were directly subordinate to corresponding government departments and organized and managed by the government. After the reform and opening up, research universities and institutions have undergone several major reforms and adjustments, particularly in the relationship between the government and research universities and institutions. The government’s role has shifted from direct management to providing policy support and funding guarantees. On the one hand, this has given research universities and institutions greater autonomy to decide on personnel, salaries, and research directions according to their respective circumstances. On the other hand, it has allowed research universities and institutions to independently conduct economic activities, such as cooperatively establishing enterprises and undertaking science and technology projects. These reforms have undoubtedly greatly improved the vitality and research output of research universities and institutions, enabling China to leap to first place in the world in important research indicators such as the number of scientific papers published and patent applications. However, it must be acknowledged that China still has a huge gap with leading countries in frontier basic research. So far, the number of Chinese scientists who have won Nobel Prizes is few and far between, lagging far behind not only the United States but also developed countries such as Japan. One important reason is that China's research universities and institutions are still essentially indirectly government-dominated, lacking truly independent research universities and institutions, even in Chinese-foreign cooperative education. On the one hand, institutionally, the government still dominates the appointment of presidents and party secretaries of most schools, and school leaders generally have term limits, making research universities and institutions more inclined to pursue short-to-medium-term research results while neglecting basic research projects requiring long-term investment. On the other hand, from the perspective of research funding, government-dominated research funding management still basically follows the principle of government needs priority. However, realistically, government needs do not always align with research value, especially for basic research. Moreover, administrative-dominated research funding allocation inevitably becomes output-oriented, making the choice of research directions unable to be adventurous. Achieving "from 0 to 1" breakthroughs can only rely on "luck" or "coincidence."

2.2 Current Status and Problems of the R&D System

Since the reform and opening up, China's R&D system has continuously improved and upgraded under the shaping of global market demands and rules, with the common characteristics of the U.S., German, and Japanese R&D systems all reflected in China.

(1) Market Demand Perspective. Since the reform and opening up, China's per capita GDP had not reached a high level. Although it has a large population, domestic market demand has long been insufficient to form high-quality market demand to drive technological progress. During this stage, China's technological development was mainly driven by the demands of mature Western markets, continuously improving China's technological levels in various fields. Research universities and institutions played a key role in technological breakthroughs, forming numerous battle-tested R&D teams in various fields. After decades of development since the reform and opening up, China's per capita GDP reached US$13,000 in 2023, reaching the level of upper-middle-income countries (according to World Bank and United Nations Development Programme standards). Many authoritative institutions estimate that China's middle-class population has reached 400 million, meaning that China has formed a huge domestic market. Meanwhile, China has become the largest trading partner of more than 140 countries and regions, and it can be said that China's technology and products meet market demands worldwide. Therefore, China has also become the only country in the world that possesses all industrial categories listed in the United Nations industrial classification, with manufacturing capabilities in most fields at world-leading levels.

(2) Private Enterprise Perspective. For many years, China's private economy has contributed more than 50% of tax revenue, over 60% of GDP, more than 70% of technological innovation achievements, over 80% of urban employment, and more than 90% of the number of enterprises. In the economically developed southeastern coastal regions, the contribution of private enterprises is even greater. Additionally, the private economy has become China's largest foreign trade entity. In 2022, the proportion of private enterprises in import and export scale reached 50.9%, exceeding 1/2 for the first time annually, contributing 80.8% to foreign trade growth. Whether for domestic or foreign markets, private enterprises have become the main actors in responding to and meeting market demands, while also developing strong technological innovation capabilities to timely respond to market demands. Although the rectification of the internet and education training industries in 2022 raised concerns about the prospects of the private economy, the pillar position of the private economy in China's economic development cannot and will not be reversed, and private enterprises will continue to be the main actors in technological innovation.

(3) R&D Funding Investment and Researcher Reserve and Training Perspective. In 2021, China's R&D funding investment reached 2.44% of GDP, ranking 12th among major countries in the world in R&D intensity, further approaching the OECD country average (2.67%). Additionally, the number of R&D personnel and research output in China ranks among the top in the world. It is certain that after decades of capital and talent accumulation, China has a solid foundation and strong willingness to support both funding and personnel.

It can be said that China's R&D system has initially formed over the past decades and has played a sustainable supporting role in applied technology innovation. However, we must be fully aware that under the great changes unseen in a century, the social and economic environment sustaining the three major elements of high-growth domestic and international markets, enterprising private enterprises, and continuously increasing funding and personnel investment has undergone fundamental reversals. Past institutions and policies can no longer address these challenges.

3. Dual-Track Concept for Scientific Research and R&D Policies

3.1 Establishing a "New Track" of R&D Policies for Private Enterprises

First, we must clearly recognize that the "super globalization" dividends China has enjoyed since the reform and opening up have disappeared, replaced by a wave of de-globalization and comprehensive confrontation between China and the United States in trade, technology, finance, and other areas under great power competition. On the one hand, the international market is no longer an unconditionally open market for China but an uncertain market influenced by international politics. On the other hand, the unfriendly international environment makes overseas capital more cautious and even resistant to investing in Chinese enterprises. Neither China's large technology enterprises nor emerging small and medium-sized technology enterprises can easily obtain international capital, especially U.S. capital, as in the past.

Second, under the increasingly unfriendly international market and capital environment, the living space for central and state-owned enterprises in the international arena is further squeezed. Additionally, the institutional constraints of central and state-owned enterprises make it difficult for them to possess original innovation capabilities. Therefore, to improve and optimize the existing R&D system, continue China's existing advantages in applied technology research and innovation, and maintain the catching-up momentum with Western frontier technologies, the key lies in private enterprises rather than state-owned or central enterprises.

Finally, since the decisive role of private enterprises in technological innovation has been clarified, the government's role lies in designing institutions and policies that encourage private enterprises to innovate. The government needs to address the issue of private enterprise confidence, that is, to answer the "why" question: "Why should private enterprises innovate?" This study recommends that the central government provide clear top-level design, explicitly stating the principal position of private enterprises in scientific and technological innovation. The government needs to answer the "what" question, that is, "Where should private enterprises innovate?" This study recommends that local governments in economically developed regions should take the lead in clarifying fields that state-owned enterprises cannot enter (especially in industries with higher marketization levels) and specify constraints on state-owned capital investment in private enterprises, such as shareholding ratios and board member proportions, to avoid the impact of state-owned assets and enterprises on the independent operation of private enterprises as much as possible through institutional design. The government needs to answer the "how" question, that is, "How should private enterprises innovate?" This study recommends that the National Development and Reform Commission, Ministry of Science and Technology, Ministry of Industry and Information Technology, and other departments jointly establish a technology innovation fund for private enterprises, with industry associations in different fields as advisory units, to provide research funding support for private enterprises to carry out innovation activities according to the technological innovation needs of different industries. Additionally, national key laboratories, research universities, and research institution equipment and other resources that do not involve secrets should be opened to private enterprises to reduce the costs and risks of innovation activities for private enterprises, especially small and medium-sized private enterprises.

3.2 Reforming the "Old Track" of Policies for Research Universities and Institutions

Experience from the United States, Germany, and Japan shows that the key to reforming the research institution lies in research universities and institutions. In fact, discussions and attempts on research system reform have continued for decades, but they have been unable to fundamentally change the administrative nature of the research system. Decades of reform attempts have achieved only gradual improvements, unable to promote reform in the true sense. This indicates that the existing research system involves not just the interests of some vested interest groups but the interests of the entire research system, making it difficult to shake. Therefore, this study recommends taking the medium to long term as the reform timeframe. While maintaining and strengthening existing research system reform policies, it suggests gradually promoting the development of off-system research universities and institutions, research funding sponsors (foundations in various fields), and publishers and academic journals to force institutional reform of on-system relevant institutions. Taking the U.S. research system as a reference, the goal is to finally form a new research system where the off-system research system is the main body and the on-system research system provides support.

Specifically, this study recommends that the following two aspects of policies can begin to be promoted at the current stage. First, clearly identify scientific and technological fields related to national security, and provide sufficient free space for fields that do not or minimally involve national security, creating as open and free a research environment as possible to avoid over-generalization of security and politicization in scientific fields. This measure should particularly be launched within the on-system research system because, realistically, although the existing government-dominated research system is overly administrative and lacks adventurous spirit, a relatively free academic environment still benefits a very small number of "unofficial" researchers within the system to carry out original research. Simultaneously, creating a good academic environment will also help increase the diversity within the administratively dominated system, providing soil for subsequent deep reform of the research system.

Second, gradually form an off-system research system that includes research universities, research funds, academic journals, etc. Gradually open applications for off-system research universities, increase Chinese-foreign cooperative education institutions, and form another system in China that is distinct from the existing research system and more internationalized and conducive to original innovation through the connection of these institutions with the Western research system. Additionally, gradually open the establishment of off-system research funds, encourage domestic and overseas consortia to establish research funds for different fields in China, and provide relatively 宽松的 research funding support for off-system researchers. Apart from relying on institutions and research funding, another very important fulcrum in the research system is publishers and academic journals. China should also gradually open the authority for off-system research universities and institutions to establish new academic journals in China to more comprehensively form an off-system research system.

4. Conclusion

Both the scientific research institution and the R&D system involve not only a complex system with multiple actors such as government, enterprises, research universities, research institutions, research funds, publishers, and academic journals but are also influenced by various aspects beyond scientific research and technological development, including political systems, economic systems, fiscal and tax systems, disciplinary development history, history of science and technology, and social culture. Therefore, the current problems in China's scientific research institution and R&D system cannot be attributed to a single actor or specific policy. Correspondingly, improving and optimizing China's scientific research institution and R&D system cannot rely solely on a single actor or specific policy but should be implemented through systematic and comprehensive institutional design, policy planning, and science popularization and publicity.

This article focuses on this complex policy issue, briefly summarizes the problems of China's scientific research institution and R&D system based on international experience comparison, and proposes a dual-track concept for scientific research and R&D policies. It must be acknowledged that, on the one hand, whether sorting out international experience or summarizing domestic problems, this article only touches upon several representative aspects of this issue. On the other hand, the dual-track concept proposed in this article represents more bold thinking oriented toward system reform directions rather than fully demonstrating the specific policy presentation methods and effects of the concept. Therefore, the questions raised in this article have certain limitations, and the policy recommendations given may not necessarily be highly operable. However, under the increasingly severe situation of technological containment by the United States and its Western allies, this article hopes that by proposing these immature views, it can prompt the scientific and policy communities to once again seriously and systematically consider and plan the future of China's scientific research institution and R&D system.

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Note: Figure translations are in progress. See original paper for figures.