Science and Technology Development Strategy Research Guiding Future Innovation Directions: Postprint

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Abstract

How can we seize the opportunities of the new round of scientific and technological revolution and industrial revolution without missing them, so as to achieve new economic prosperity? How can we accurately grasp and timely deploy the direction and priorities of scientific and technological innovation to gain the initiative in competitive development? These are all major topics that science and technology development strategy research focuses on. This article analyzes and expounds upon the contemporary connotations, important roles, and characteristics of science and technology development strategy research, reviews and summarizes the successful practices of China and the Chinese Academy of Sciences (CAS) in this domain, and identifies that the main directions of science and technology development strategy research are studies on S&T development trends, S&T monitoring and evaluation, and research on S&T governance systems. The article further discusses the basic requirements and methodologies of science and technology development strategy research, proposing that such research should adhere to the principles of being ideological, constructive, scientific, forward-looking, and independent; with a focus on influence and contribution, it establishes value criteria for evaluating the outcomes of science and technology development strategy research across five dimensions: development concepts and strategies, regulations, planning and methodologies, institutional mechanisms, and policies and measures; and advocates for continuous innovation in research methods to enhance research quality and effectiveness, thereby better serving macro-level decision-making and guiding the direction of future innovation development.

Full Text

Special Topic: Modern Think Tank Construction and Communication

Using Science and Technology Development Strategic Research to Lead Future Innovation Directions

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Abstract

How can we seize the opportunities presented by the new round of scientific and technological revolution and industrial transformation to achieve new economic prosperity? How can we accurately identify and timely deploy the directions and priorities of scientific and technological innovation to gain the initiative in competitive development? These are major questions that science and technology (S&T) development strategic research must address. This paper analyzes and explains the contemporary connotation, important role, and characteristics of S&T development strategic research, reviews and summarizes the successful practices of China and the Chinese Academy of Sciences (CAS) in this field, and points out that the main directions of S&T development strategic research are studies of S&T development trends, S&T monitoring and evaluation, and research on S&T governance systems. The paper also discusses the basic requirements and methods of S&T development strategic research, proposing that such research should adhere to the principles of being ideological, constructive, scientific, forward-looking, and independent. From the perspective of impact and contribution, it proposes value criteria for evaluating S&T development strategic research outputs across five levels: development concepts and strategies, regulations and planning methods, institutional mechanisms, policies, and measures. The paper concludes that we must continuously innovate research methods and improve research quality to more effectively serve macro-level decision-making and lead future innovation directions.

Keywords: science and technology development, strategy research, future direction
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Among all factors affecting human social development, scientific and technological innovation is revolutionary, profoundly and comprehensively influencing the direction and progress of human civilization, and in a sense determining the rise and fall of nations and peoples. In today's world, waves of scientific and technological innovation are emerging one after another. How to seize the opportunities of the new round of scientific and technological revolution and indus-

trial transformation to achieve new economic prosperity, and how to accurately identify and timely deploy the directions and priorities of scientific and technological innovation to gain the initiative in competitive development—these have become important priorities for major countries when formulating development strategies, plans, and policies. They are also crucial considerations for China in promoting innovation-driven development and building itself into a world S&T power. This requires high-end S&T think tanks to continuously conduct in-depth S&T development strategic research and provide scientific consulting advice and systematic solutions for national macro-level decision-making.

1. The Role and Characteristics of S&T Development Strategic Research

S&T development strategic research generally involves scientific foresight, technology foresight, studies of S&T development patterns and characteristics, and analysis of the S&T demands of economic and social development. Through such research, we can grasp the frontiers and general trends of global S&T development, understand the nation's immediate and long-term S&T needs, and propose alternative directions, strategies, objectives, and priorities for S&T development, thereby providing scientific foundations for strategic S&T choices and national macro-level decision-making.

1.1 Important Role in Promoting Development and Serving Decision-Making

Through S&T development strategic research, we can observe and analyze global S&T development changes and their impacts on economy and society from comprehensive, multi-angle, and systematic perspectives, and provide forward-looking, strategic, and scientific consulting suggestions and research reports on national planning and layout, strategic priorities, and policy measures to effectively serve macro-level decision-making.

In promoting S&T development, we continuously scan and analyze global S&T frontiers, assess the directions and impacts of scientific and technological revolutions, understand the environment of S&T competition and development, identify major innovation fields and S&T issues related to national development, and propose directions, objectives, and strategic priorities for S&T development. This provides a decision-making basis for correctly formulating S&T development strategies and plans, and for selecting and deploying research tasks. In promoting economic and social development, we comprehensively analyze domestic and international competitive advantages and disadvantages, clarify major issues in economic and social development, people's livelihood and health, and national security, identify key obstacles affecting the close integration of S&T with economy, education, and society, pinpoint the junctions of innovation chains with industrial and capital chains, and find breakthrough points where S&T innovation can drive comprehensive innovation. We propose ideas

and strategies that support current development and lead future development, providing decision-making foundations for strategically selecting development fields and directions, making planning arrangements, and formulating policy measures.

Major countries worldwide have conducted S&T development strategic research. For example, the United States has released its "Strategy for American Innovation" in 2009, 2011, and 2015, strengthening R&D and innovation investment policies and improving the innovation ecosystem. The U.S. has also implemented major plans such as the Manhattan Project, the Human Genome Project, the Information Superhighway Initiative, the Advanced Energy Initiative, the Materials Genome Initiative, and the Advanced Manufacturing Partnership. Japan organized the world's first large-scale technology foresight exercise in 1971 and has conducted one every five years since. In 2015, Japan conducted its 10th science and technology foresight survey, covering 8 research fields, 84 themes, and 932 key technologies, providing a basis for Japan's 5th Science and Technology Basic Plan. Since 1998, many countries including the United States, United Kingdom, Germany, France, and South Korea have conducted technology foresight and key technology selection studies, with results applied to government decision-making. Germany introduced its first national high-tech strategy plan in 2006, and in 2010 released "Ideas • Innovation • Growth—Germany's High-Tech Strategy 2020" to stimulate enormous scientific and economic potential. In 2013, Germany proposed the new high-tech strategy "Industry 4.0" to support the R&D and innovation of a new generation of revolutionary industrial technologies and seize the initiative in the new round of industrial revolution.

China attaches great importance to promoting S&T development through S&T planning. For instance, in 2003, the State Council established a leading group and organized 20 thematic groups to conduct strategic research, with over 2,000 S&T experts participating. After two years, they produced strategic research reports totaling millions of words, laying a solid foundation for the formulation of the National Medium- and Long-Term Program for Scientific and Technological Development and the formation of various S&T plans for the 11th Five-Year Plan period. This work also became the basis for selecting many major projects. The 18th National Congress of the Communist Party of China proposed implementing an innovation-driven development strategy to promote comprehensive innovation with S&T innovation at its core. After nearly three years of systematic and in-depth research, the central government promulgated the "National Innovation-Driven Development Strategy Outline" in 2016, clarifying that China's S&T development goals are to become an innovative country by 2020, to rank among the top innovative countries by 2030, and to become a world S&T power by the 100th anniversary of the founding of the People's Republic of China. At the recently held National Conference on Science and Technology Innovation, General Secretary Xi Jinping delivered an important speech titled "Strive to Build China into a World S&T Power," proposing that at this new historical starting point of China's development, we must place S&T innovation in a more important position and determining the grand blueprint

and strategic tasks for China's S&T development in the next 30 years.

1.2 Foresight, Guidance, and Leadership

Major countries worldwide emphasize S&T development strategic research to foresee S&T frontiers and directions, focus on how S&T innovation promotes economic growth and sustainable social development, and timely propose innovation strategies, S&T plans, or programs and pilot projects to lead innovation development directions.

The numerous consulting research reports and recommendations proposed by various U.S. think tank research organizations have supported the introduction of a series of national S&T plans reflecting strategic intentions, such as the Manhattan Project, the Human Genome Project, the Information Superhighway Initiative, the Advanced Energy Initiative, the Materials Genome Initiative, and the Advanced Manufacturing Partnership. The RAND Corporation, a globally influential think tank, studies major and hot issues in economy, S&T, education, society, and politics. Its research is standardized and rigorous, widely employing research methods such as systems analysis, policy analysis, strategic planning, mathematical programming, and systems modeling, and developing new research methods to ensure report quality. The U.S. National Academy of Sciences is a government consulting organization for S&T, and the National Research Council (NRC) is its executive agency. The NRC is responsible for most policy research of the National Academy of Sciences. Research projects are usually authorized by special committees of the U.S. Congress or proposed by federal government departments. Each year, the NRC organizes over 6,000 experts from various fields to form hundreds of project committees to study major issues in S&T and economic and social development, providing important policy recommendations for the U.S. government and exerting important influence on society as a whole.

2. Successful Practices in S&T Development Strategic Research

Developed countries have many specialized strategic research organizations that conduct extensive strategic research and provide consulting recommendations for national, corporate, and various organizational decision-making. The United States is the most typical example, possessing a strategic research network system with wide coverage, strong professionalism, and diverse activity forms, composed of numerous consulting research institutions, research groups, and researchers. Think tanks, as institutionalized and professional consulting research organizations, are important components of national soft power, and their role is increasingly significant. The Party and government attach great importance to think tank construction. In July 2013, General Secretary Xi Jinping explicitly required CAS to "take the lead in building a national high-level S&T think tank." The Third Plenary Session of the 18th CPC Central Committee passed

the "Decision of the CPC Central Committee on Some Major Issues Concerning Comprehensively Deepening Reform," explicitly proposing to "strengthen the construction of new-type think tanks with Chinese characteristics and establish and improve the decision-making consultation system." In 2014, the central government issued the "Opinions on Strengthening the Construction of New-Type Think Tanks with Chinese Characteristics," making the construction of such think tanks an important measure to advance the modernization of the national governance system and governance capabilities and to enhance national soft power. The goal was to focus on building a number of high-end think tanks with significant influence and international reputation by 2020. By the end of 2015, 25 institutions, including CAS, were selected as the first batch of pilot units for national high-end think tank construction. Establishing the CAS Institutes of Science and Development is a key task for CAS in carrying out the national high-end think tank construction pilot program and an important vehicle for CAS to take the lead in building a national high-level S&T think tank.

CAS has always attached importance to S&T development strategic research, regarding providing scientific foundations for national macro-level decision-making and leading China's scientific and technological development as its important responsibilities. Since its establishment, CAS has taken the lead in conducting problem-oriented and goal-oriented strategic research during critical periods of national development, based on S&T, facing national needs, global trends, and future development, comparing competitive development situations, identifying S&T frontier directions, pinpointing key S&T issues, and proposing policy recommendations for developing China's S&T, thereby determining CAS's reform and innovation development strategies in serving the nation's overall development.

In 1956, under the leadership of the central government and with CAS experts as the main body, more than 700 scientists studied the draft long-term national economic plan and the long-term S&T plans of various ministries and commissions, clarified the S&T needs of the national economy, and understood the world S&T level and development trends. After seven months, they completed the "1956-1967 Long-Term Plan for the Development of Science and Technology." The formulation and implementation of this plan greatly promoted China's S&T development and laid the foundation for the establishment and rapid development of new disciplines at CAS.

In 1975, Comrade Hu Yaobang was delegated by Comrade Deng Xiaoping to work at CAS, where he went deep into research institutes, understood the situation, analyzed problems, and extensively listened to S&T personnel's opinions. He researched and formed the "Outline Report on CAS Work," which clearly defined CAS's development direction, tasks, and rectification content. Many viewpoints were reiterated at the 1978 National Science Conference and, to a certain extent, became important foundations for the conference and subsequent S&T policy formulation.

In 1997, facing 21st-century development and responding to the Asian financial crisis, CAS conducted systematic analysis of global knowledge economy development trends and the opportunities and challenges China faced. Based on this analysis, CAS produced the strategic research report "Embracing the Era of Knowledge Economy, Building a National Innovation System." The report made judgments that the 21st century would be dominated by the knowledge economy and that the national innovation system would be the cornerstone of sustainable national economic development. It proposed ideas for building China's national innovation system for the 21st century and strategic choices for CAS in the new era, and recommended that the state organize and implement the "Knowledge Innovation Program" and pilot it at CAS. This research report received high attention from the Party Central Committee and the State Council, providing basic ideas for the strategic decision to build a national innovation system with Chinese characteristics and providing a decision-making basis for the State Council's approval of CAS to pilot the "Knowledge Innovation Program."

In 2007, focusing on China's goal of basically achieving modernization by the mid-21st century, CAS conducted S&T development strategic research oriented toward 2050. Starting from the requirements of modernization construction and responding to the international financial crisis, CAS organized more than 300 high-level S&T, management, and intelligence experts over two years to systematically study roadmaps for S&T development in 18 important fields, including energy, water resources, mineral resources, oceans, oil and gas resources, population and health, agriculture, ecology and environment, biomass resources, regional development, space, information, advanced manufacturing, advanced materials, nanotechnology, large scientific facilities, major interdisciplinary frontiers, and national and public security. In 2009, the Chinese and English versions of the "Innovation 2050: Science, Technology and China's Future" strategic research series reports were published successively, including the general report "Science and Technology Revolution and China's Modernization—Thoughts on China's S&T Development Strategy Toward 2050" and 18 strategic research reports on S&T development roadmaps in important fields. The research reports, oriented toward China's vision of achieving modernization by 2050, analyzed the evolution and patterns of S&T development from historical and future perspectives, summarized historical lessons of China repeatedly missing opportunities in S&T revolutions since modern times, explained the decisive role of S&T in modernization construction, made strategic judgments that the world is on the eve of a new round of S&T revolution, proposed that China must prepare for the arrival of the new S&T revolution, and put forward overall concepts and S&T development roadmaps for eight economic, social, and strategic systems supported by S&T innovation. This was China's first set of panoramic research reports forecasting the S&T development blueprint for 2050, receiving widespread attention at home and abroad. Many viewpoints and research results have been adopted by government decision-making departments, research institutions, enterprises, and social organizations, and the reports won the high-

est award in China's press and publication field—the third China Publishing Government Award for Books. Taking the English version as an example, according to incomplete statistics, the number of downloads has reached 56,000 times (the number of times the entire e-book was purchased) to date. The general report identified 22 strategic S&T issues affecting China's modernization process, which have gained widespread recognition. Most of these strategic S&T issues have been transformed into content of major national S&T projects and major research plans, as well as CAS's strategic pilot S&T programs. The viewpoints and recommendations of the research reports laid the foundation for CAS to deeply implement the Knowledge Innovation Program and launch the new ten-year plan "Innovation 2020."

In 2011, to seize opportunities from the new S&T revolution and accelerate the building of an innovative country, CAS organized more than 200 experts from various fields to conduct strategic research oriented toward 2020. After more than one year, in 2013, CAS published the strategic research report "New Trends in S&T Development and Strategic Choices for 2020." The report deeply analyzed new trends and characteristics of global S&T development in the next decade and China's S&T needs for economic and social transformation, and forwardly predicted 22 major S&T events that might occur in the world and 19 major S&T breakthroughs that might occur in China in the next 5-10 years. It proposed strategic choice recommendations for China's S&T development toward 2020, generating widespread influence in society. Some of the predicted major S&T events and breakthroughs have begun to become reality, such as the confirmation of the existence of the Higgs particle, whose predictors were awarded the Nobel Prize in Physics. This research report has become an important basis for macro-level decision-making in S&T, economy, and society, and also provided a research foundation for CAS's "Pioneer Action Plan" to layout strategic S&T priorities.

From the S&T development roadmap research oriented toward 2050 to the S&T strategic choice research oriented toward 2020, CAS not only produced abundant ideological achievements, highlighting its authority in the field of S&T strategic research, but also cultivated and gathered a high-level strategic research expert team with strategic vision, national sentiment, and holistic perspective. CAS has enriched and innovated strategic research methods such as S&T development roadmaps, established mechanisms for continuously conducting in-depth strategic research, and formed a systematic research network that is driven by field demands, centered on strategic experts, connects frontline experts and research institutions, and combines S&T foresight and prediction with policy research. This has accumulated experience for CAS to leverage its "trinity" advantages and build a national high-level S&T think tank.

3. Layout and Priorities of S&T Development Strategic Research

In December 2015, CAS decided to establish the Institutes of Science and Development as a legal entity. The Institutes are the research and support organization for CAS's Academic Divisions to play their role as the nation's highest consulting body on S&T issues, and an important carrier and comprehensive integration platform for CAS to take the lead in building a national high-level S&T think tank. The Institutes will consolidate and integrate advantageous forces inside and outside CAS, both domestic and international, to build an innovation research institute. Its main tasks are to focus on promoting S&T development and think ahead about global S&T development trends from the perspective of S&T laws, and to focus on promoting development through S&T and study major domestic and international economic and social development issues from the perspective of S&T impacts and roles.

The Institutes have unique advantages in five domain directions: S&T development strategy research, S&T and innovation policy research, ecological civilization and sustainable development strategy research, quantitative forecasting and foresight analysis research, and S&T strategic intelligence research and data platform construction. Among them, the directions of S&T development strategic research are mainly S&T development trend research, S&T monitoring and evaluation research, and S&T governance system research.

First, **S&T development trend research** involves grasping global S&T development trends, combining national conditions and development stages, continuously conducting scientific foresight and technology foresight, judging the direction of new S&T and industrial revolutions, and continuously identifying major S&T issues and new frontier directions. Oriented toward 2050 and beyond, we should focus on priorities in the near term (5-10 years), identify directions in the medium term (10-20 years), and observe trends in the long term (20-30 years), forming successive strategic predictions for near, medium, and long terms. We should formulate and timely update roadmaps for important fields and key technologies at each stage to lead S&T development directions.

Second, **S&T monitoring and evaluation research** involves monitoring the development status of major countries and regions, important S&T fields, and various research organizations, comparing and analyzing competitive situations and core competitiveness, with a focus on comparative studies of development strategies, S&T layouts, priority directions, innovation management, S&T investment, and policy trends. By comparing with China's development situation, we can identify gaps and deficiencies, learn from and absorb advanced concepts and practices, and propose differentiated and asymmetric innovation strategies.

Third, **S&T governance system research** involves studying the evolution, patterns, and characteristics of S&T innovation activities, as well as major issues in S&T management systems, research organization systems, research management models, S&T legislation, S&T talent policies, S&T investment and

resource allocation, S&T evaluation, intellectual property management, S&T ethics, and scientific culture. The goal is to propose policy recommendations and solutions that are conducive to liberating and developing S&T productive forces, solving institutional and mechanism problems, and forming a modern S&T governance system.

4. Basic Requirements and Methods of S&T Development Strategic Research

S&T development strategic research is both a specialized research activity and a systematic organization and comprehensive integration effort. It must adhere to the principles of being ideological, constructive, scientific, forward-looking, and independent, establish value criteria for major outputs oriented toward impact and application effects, and innovate research methods to continuously improve research quality.

4.1 Adhering to the "Five Principles"

(1) Ideological. We must focus on the supporting and leading role of S&T, understand and grasp the interactive relationship between S&T and economic and social development, study major issues in economic and social development from the perspective of S&T, and identify major S&T issues from the demands of economic and social development. We must continuously propose new concepts, new ideas, new viewpoints, and new perspectives to provide high-quality consulting suggestions and evaluation opinions.

(2) Constructive. We must closely meet decision-making needs, accurately understand China's basic national conditions and phased characteristics, address current issues to solve hot and difficult problems affecting China's transformation and upgrading under the new normal, and look at the long term to address major global challenges and break through bottlenecks in China's modernization process. We must solve major problems in S&T development that are conducive to modernizing governance capabilities and systems, and propose "practical and effective" systematic solutions with depth, insight, and operability.

(3) Scientific. Based on professional knowledge and scientific evidence, we must establish standardized and rigorous research and consulting evaluation procedures, adopt scientific methods, develop quantitative analysis tools and platforms, ensure the authenticity and reliability of data sources, and combine qualitative understanding with quantitative analysis to comprehensively and systematically study and analyze problems and draw objective and fair research conclusions and arguments.

(4) Forward-looking. From both the perspective of S&T's own development and its potential impacts, we must foresee the direction of new S&T revolutions and the direction of human civilization, keenly predict development trends and frontier directions, be good at discovering regular, essential, and emerging

issues, understand new situations, new problems, and new characteristics, conduct forecasting and foresight, and provide policy recommendations for advance response and optimized layout.

(5) Independent. With a spirit of high responsibility to the Party and the country, we must objectively and independently propose scientific suggestions and frankly and sincerely provide consulting and evaluation opinions. We must follow objective laws, exclude interference from personal, group, and local interests, and ensure that the suggestions and opinions proposed can withstand the test of practice and history.

4.2 Establishing Value Criteria for Major Outputs

Measured by impact and contribution, S&T development strategic research outputs can be roughly divided into five aspects:

(1) Development concepts and strategies level. In research on major issues related to human civilization development and the overall and long-term development of the nation's economy and society, the new concepts, new ideas, new viewpoints, and strategic suggestions proposed become universal consensus, lead development trends or directions, or become important scientific foundations for national strategies.

(2) Regulations, planning, and methods level. Research results become the scientific basis for formulating or revising relevant provisions of national laws and regulations. Scientific suggestions and predictions are incorporated into national planning and task deployment. Developed research methods or tools are widely used by think tank peers.

(3) Institutional mechanisms level. Scientific suggestions proposed are adopted by the state or relevant departments and become important scientific foundations for institutional and mechanism reforms and improvements.

(4) Policy level. Research on key issues related to national economic and social development, national security, and S&T progress provides scientific suggestions and predictions that become research support for national policy formulation.

(5) Measures level. Systematic solutions proposed for major issues in reform and innovation development are adopted by relevant national departments and important regions and become important measures and actions for reform and development.

4.3 Innovating Research Methods

Methods such as the Delphi method, brainstorming, bibliometrics, scenario analysis, and social surveys have been widely used. We must fully apply information technology, big data technology, and the latest achievements in operations research, systems science, and complexity science research to develop and apply new models, tools, and methods for S&T development strategic research, such as

science structure maps and visual decision support platforms, to form methodological systems and improve the scientific nature and quality of research.

We must fully rely on S&T experts, policy experts, strategic intelligence experts, and management experts to establish mechanisms for conducting S&T development strategic research continuously at multiple levels, systematically, and with focus. We must establish and improve a strategic research network system composed of professional research institutions, experts from national macro-management departments, and strategic research teams and organizations in various fields.

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