The Role of Systems Analysis in Science and Technology Strategy Research (Postprint)

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Abstract

Research on science and technology strategy under the new situation should adopt two broad perspectives: on the one hand, it must address the new requirements arising from domestic economic and social development; on the other hand, it must respond to emerging trends in international science and technology development. This constitutes a formidable undertaking characterized by systematicity, foresight, and robustness. The scientific application of systems analysis tools facilitates accurate assessment of global science and technology development trends and comprehension of economic and social development needs; it aids in systematically resolving prominent issues in science and technology development, thereby enabling science and technology to fulfill its supportive and leading role in the functioning of economic and social systems; and it assists in deliberating on robustness issues in science and technology development strategy, exploring bottleneck factors in science and technology deployment under conditions of uncertainty. Moreover, the employment of management approaches can provide support for the successful implementation of science and technology strategy through organizational models, policy safeguards, and mechanism construction.

Full Text

The Role of System Analysis in Science and Technology Strategy Research

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Abstract

Under new circumstances, science and technology (S&T) strategy research must possess two broad perspectives: one that recognizes new demands arising from

domestic economic and social development, and another that discerns emerging trends in global S&T advancement. This constitutes a formidable task requiring systematic, forward-looking, and robust approaches. The scientific application of system analysis tools facilitates accurate assessment of global S&T development trends and helps grasp the needs of economic and social development. It aids in systematically addressing prominent issues in S&T development and enables science and technology to play a supportive and leading role in the operation of economic and social systems. Furthermore, it promotes reflection on the robustness of S&T development strategies and exploration of bottleneck factors in S&T deployment under uncertain conditions. Additionally, the application of management methods provides support for the smooth implementation of S&T strategies through organizational models, policy safeguards, and mechanism construction.

Keywords: science and technology strategy, systematic nature, forward-looking nature, robustness, system analysis
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On November 3, 2015, at the Fifth Plenary Session of the 18th CPC Central Committee, President Xi Jinping explained the proposals for the 13th Five-Year Plan. Regarding scientific and technological innovation, he stated: "To implement the innovation-driven development strategy, we must place scientific and technological innovation in key areas in a more prominent position." When analyzing the current S&T innovation situation, Xi noted: "China' s scientific and technological innovation has entered a new stage, shifting from primarily following others to running alongside and even leading in certain areas. There is an urgent need to orient ourselves toward national goals and strategic demands, target the international S&T frontier, and deploy a number of larger-scale, interdisciplinary, and comprehensively integrated national laboratories, optimizing the allocation of human, financial, and material resources to form a new pattern of collaborative innovation."Discussing future drivers of development, he emphasized that "development impetus should shift from relying mainly on resources and low-cost labor inputs to innovation-driven growth."

A deep understanding of President Xi' s speech reveals that S&T strategy research under new circumstances requires two broad perspectives. First, a perspective that recognizes new demands from domestic economic and social development. Bottlenecks in energy, resources, and the environment; population aging; and unbalanced, uncoordinated, and unsustainable development all place more urgent demands on S&T innovation. S&T strategy research must shoulder multiple missions: promoting industrial technological revolution, safeguarding national economic security, fostering innovation in S&T policy, and serving scientific and democratic decision-making. Second, a perspective that recognizes new trends in international S&T development. S&T strategy research must focus on the deployment of core and key technologies and adapt to the competitive landscape of international S&T resources. This includes not only research and deployment of core and key technologies such as networking and informa-

tion technology, energy conservation and environmental protection, new energy, marine development, and space observation, but also securing S&T innovation talent and seizing the initiative in strategic emerging industries.

1. Characteristics of Science and Technology Strategy Research

The acceleration of economic globalization and the development of a global S&T landscape mean that nations face an environment full of uncertain factors. S&T strategy research must cover S&T development issues over several years and consider both internal and external factors that significantly influence strategy formulation, implementation, and control, such as economic and social development needs, technology maturity, and the social benefits of scientific progress—all of which exhibit characteristics of uncertainty. As Qian Xuesen pointed out regarding large-scale social systems, there are two key features: "First, the system' s components are hierarchical and regional, meaning that in a small locality, direct constraints and coordination are possible. On this basis, mutual constraints and coordination can be achieved at the next higher level formed by several small localities, and there are even larger organizational levels above that. This is called a multi-level structure. The second feature is that when the system is large, its effects cannot be instantaneous and one-time, but must be considered in multiple stages. Therefore, general planning theory alone is insufficient for long-term planning; dynamic planning must be developed." Consequently, S&T strategy research must possess characteristics of systematic nature, forward-looking nature, and robustness that facilitates flexible adjustment.

1.1 Systematic Nature

S&T strategy research focuses on the international development frontier and competitive landscape of S&T systems, addresses the dilemmas in China' s sustainable economic and social development, and determines the strategic direction and objectives of China' s S&T development based on scientific analysis of future social needs, prospects for new technology applications, and resource utilization. It then integrates multiple factors including society, economy, resources, and talent to set strategic priorities and plan S&T deployment. S&T strategic layout and key tasks must ultimately be implemented along the innovation chain and extended to the industrial chain of socio-economic development. Unblocking bottlenecks in China' s innovation chain—from basic research to applied development, pilot testing, commercialization, and industrialization—and clarifying upstream-downstream relationships and value exchange in the industrial chain constitute systematic work.

1.2 Forward-looking Nature

S&T strategy research is future-oriented with a long decision-making time horizon, requiring scientific foresight of future scenarios. This includes assessing future domestic socio-economic development needs, future international competitive landscapes, and future S&T development levels, and on this basis, designing forward-looking S&T layouts and formulating China's S&T development roadmap. Traditional strategic planning methods that precisely depict future scenarios, identify the most likely outcomes, and formulate strategies accordingly can be effective in relatively stable environments but may fail or even become dangerous in highly uncertain environments. Therefore, S&T strategic layout must consider its robustness—its adaptive capacity and guiding significance in modern society characterized by rapid change and increasing uncertainty.

2. The Role of System Analysis

How to study S&T strategic layout from a systematic perspective, analyze the impact of relevant internal and external factors on S&T strategic layout, and assess how S&T strategic layout affects China's future economic and social development and international competitive environment—all these research questions require scientific and effective methodological tools. Some typical international S&T think tanks are continuously strengthening the application and development of quantitative analysis tools, with a growing number of relevant indicators and databases. System analysis involves treating the problem to be solved as a system, conducting comprehensive analysis of system elements, and identifying feasible solutions. Facing large-scale transnational flows and optimal reorganization of technology elements, S&T strategy research requires support from systematic analysis. Hua Luogeng once proposed that in national economic planning, we must "coordinate comprehensively and optimize broadly" and "build systems and strategize development." These ideas also apply to S&T strategy research: determining future S&T development goals based on current international and domestic environments, coordinating technology resources, deploying China' s S&T development roadmap from a large-system perspective, and using methods such as operations research, control theory, and mathematical statistics to promote roadmap implementation.

Systematic research on S&T strategy can be summarized as a closed loop of "description-assessment-diagnosis-improvement-tracking." "Description" refers to identifying key components of the studied system and their relationships to provide a systematic description of the research object. "Assessment" involves designing analytical methods for different types of research objects to evaluate their current status and main problems. "Diagnosis" refers to further analyzing the constraints causing these problems. "Improvement" involves designing targeted solutions based on assessment and diagnosis. "Tracking" refers to dynamically evaluating the implementation effects of think tank products and timely adjusting deficiencies in the solutions.

2.1 Systematic Research

S&T strategy research requires systematic analysis to address the complex interplay of factors. The innovation chain and industrial chain must be considered as integrated systems, with attention to bottlenecks at each stage. International S&T think tanks increasingly rely on quantitative tools and comprehensive databases to support their analysis. The systematic approach involves describing the system structure, assessing current conditions, diagnosing problems, improving solutions, and tracking implementation—forming a complete analytical cycle.

2.3 Robustness Research

As mentioned earlier, S&T strategic layout must consider uncertain factors such as economic and social development needs and technology maturity, thus requiring reference to robustness analysis theories and methods. Robustness, also known as stability or resilience, originates from robust design. Japanese quality management expert Genichi Taguchi established robust design in the 1970s, which involves adjusting design variables and controlling their tolerances to ensure product quality even when controllable and uncontrollable factors deviate from design values. Unlike traditional decision-making methods that provide optimal strategies for specific scenarios, robust S&T strategic layout requires systematically exploring bottleneck factors of different S&T strategic layouts under uncertain conditions to provide satisfactory strategies that remain stable across various conditions and scenarios.

Furthermore, S&T strategy research should fully leverage management functions to support the achievement of S&T development goals and ensure smooth strategy implementation through planning, organizing, commanding, coordinating, and controlling. S&T strategic layout involves organizational models, policy safeguards, and mechanism construction, requiring participation from S&T experts, strategy experts, management experts, intelligence experts, and other multidisciplinary professionals. How to organize these experts to leverage their wisdom at different stages of research and implementation warrants careful consideration. For S&T strategic layout work, it is also necessary to integrate social network strengths, break down barriers between government, industry, and research institutions, and unleash the potential of collaborative innovation mechanisms around research questions. Additionally, S&T strategy research and implementation require corresponding policies and mechanism safeguards in talent development and financial support.

3. Conclusion

S&T strategy research under new circumstances requires broad and systematic vision and forward-looking analysis to scientifically judge global S&T development trends and accurately grasp economic and social development needs. It must employ system analysis and management techniques, develop new theories

and methods, solve prominent problems in S&T development, and enable science and technology to support and lead the operation of economic and social systems. S&T strategic layout must also consider robustness, systematically exploring bottleneck factors of different S&T strategic layouts under uncertain conditions. Ultimately, the role of S&T strategy research manifests in its tangible contributions to China' s socio-economic development and international competitiveness, requiring management approaches that provide support through organizational models, policy safeguards, and mechanism construction to ensure steady strategy implementation.

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Author Biography

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