Postprint of Strategic Choices for China's Future Industrial Technology Development

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Date: 2023-12-03T00:00:00+00:00

Abstract

Future industries, oriented toward new demands and new scenarios in economic and social development, significantly depend on breakthroughs in disruptive frontier technologies. There is an urgent need to research China's strategic choices for future industry technology development from the perspective of the demands of future industry technology development and management. Research findings indicate that the momentum for future industry technology development is manifested in three aspects: technology element supply, cultivation of technology scenarios, and technology policy guarantee. The development direction depends on breakthroughs in emerging and major frontier science and technologies, as well as major technology demands from economic and social development. This article examines the needs in four areas: macro layout of technology development for future industries, frontier technology breakthroughs, supply of technology innovation elements, and construction of technology innovation ecosystems. It summarizes the technology development layouts of typical countries for future industries and reviews the current situation and challenges of China's future industry technology development. Finally, it proposes optimizing China's future industry technology development layout from four aspects: strengthening the macro layout of future industry technology development, enhancing scenario-driven development of future industry technology, expanding the supply of elements for future industry technology development, and constructing an innovation ecosystem for future industry technology development.

Full Text

Strategy Choices for Science and Technology Development of China's Industries of the Future

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Abstract

Industries of the future (IOF) that cater to new economic and social demands and scenarios significantly rely on breakthroughs in disruptive cutting-edge technologies. This makes it crucial to study the demands of future industrial technology development and management in order to make strategic choices for technology development. This study finds that the impetus for IOF science and technology development is reflected in three aspects: the supply of scientific and technological elements, the cultivation of scientific and technological scenarios, and the assurance of scientific and technological policies. The development direction depends on breakthroughs in emerging and major frontier technologies, as well as the major technological demands of economic and social development. This paper examines the needs of IOF in four areas: macro-level layout of science and technology development, breakthroughs in frontier technologies, supply of innovation elements, and construction of an innovation ecosystem. It summarizes the science and technology development strategic layouts of typical countries and analyzes the current situation and challenges facing China's IOF development. Based on this analysis, the paper proposes optimizing China's IOF science and technology development layout through four approaches: strengthening macro-level layout, enhancing scenario-driven development, expanding the supply of innovation elements, and constructing an innovation ecosystem.

Keywords: industries of the future (IOF), science and technology development, strategy choices

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1. Drivers and Directions of Future Industry Technology Development

Future industries, oriented toward new economic and social development needs and scenarios, significantly depend on disruptive breakthroughs in frontier technologies. They exhibit strong forward-looking characteristics and high uncertainty. Understanding the drivers and directions of future industry technology development is essential for grasping development trends and supporting strategic decision-making.

1.1 Drivers of Future Industry Technology Development

Technology push and demand pull represent important drivers of industrial technology development. Technological breakthroughs spawn new products and ser-

vices, promoting innovative economic and social development, while scenario demands generate innovation momentum that drives technology to meet practical application needs. Additionally, because future industry technology development relies on disruptive frontier breakthroughs and carries high uncertainty and risk, government support and guidance play a crucial role. Thus, the drivers of future industry technology development are systemic, requiring synergy among "technology push," "scenario pull," and "policy assurance."

First, frontier technology breakthroughs propel future industry technology development. Disruptive frontier technological breakthroughs constitute a primary source of future industry technology supply. Current breakthroughs in new materials, new energy, next-generation artificial intelligence, and biotechnology are transforming existing industrial structures and competition patterns. For example, breakthroughs in brain-inspired intelligence technology have spawned new products such as brain-inspired chips and brain-inspired robots, significantly advancing general artificial intelligence technology and accelerating the formation of new business forms, models, and industries. Generative AI technologies, exemplified by ChatGPT, have created new human-computer interaction paradigms, driving demand for algorithms, computing power, and data, thereby bringing new opportunities for future industry development.

Second, future scenario demands pull future industry technology development. Scenarios represent the integrated convergence of social demand and technology supply, serving as the carrier for technological innovation and industrial development under evolving innovation paradigms. The deepening trends of intelligent, healthy, and green development in economic society generate powerful market demands that further drive breakthroughs in future industry technologies. To achieve iterative upgrades of AI technologies and rapid industrial growth, China's Ministry of Science and Technology and five other departments issued the "Guiding Opinions on Accelerating Scenario Innovation to Promote High-Quality Economic Development through High-Level AI Applications," aiming to strengthen scenario innovation to drive AI technology development and high-level application.

Third, policy support and assurance drive future industry technology development. Due to the high uncertainty and risk associated with future industry technology development, science and technology policies related to investment, actors, transformation, and conditions profoundly affect the pace and direction of development. Fiscal, financial, investment, and trade policies also significantly influence prospects for future industry technology development, making policy assurance crucial. To accelerate development, governments worldwide employ fiscal subsidies, investment planning, and other guidance mechanisms. Building upon fiscal and monetary policy tools, they further introduce innovation policies and industrial policies tailored to future industry technology development.

1.2 Directions of Future Industry Technology Development

The direction of future industry technology development depends on both emerging and major frontier technology breakthroughs and major technological demands from economic and social development.

First, the direction depends on emerging and major frontier technology breakthroughs, characterized by obvious digitalization and intelligence features and presenting a pattern of multiple-point group breakthroughs. Frontier technology breakthroughs increasingly rely on cross-disciplinary knowledge integration. The new round of scientific and technological revolution exhibits characteristics of continuous cross-fusion of multidisciplinary and multi-domain knowledge, along with a trend of group breakthroughs at multiple points. As this revolution deepens, it will inevitably trigger breakthroughs in future industry technologies. Meanwhile, breakthroughs in some peripheral technologies may also significantly impact the future technology system, bringing about technological revolutions and industrial transformations that guide development directions. Japan's 11th Technology Foresight Survey identified big data systems, robotics technology, and artificial intelligence as important future technology fields.

Second, the direction depends on major technological demands from economic and social development, characterized by obvious health and green features that highlight the social attributes of technology development. Current technology development increasingly relies on the demands of economic and social development. An aging society has created "silver demand"—to meet future elderly care and medical needs, information technology, materials technology, and biotechnology continue to merge, potentially spawning future industries. The UN Sustainable Development Goals emphasize that caring for human society's sustainability while developing technology is a common global goal. The greening of technology development will inevitably become an important trend, with clean transportation technology and green hydrogen energy becoming key focus areas for future industry technology development.

2. Development and Management Needs of Future Industry Technology

The uncertainty, breakthrough potential, and disruptive nature of future industry technologies significantly increase development complexity, posing major challenges for effective management. Promoting future industry technology development requires reform of institutional mechanisms and research organization approaches, creating new demands in four areas: macro-level layout, frontier technology breakthroughs, innovation element supply, and innovation ecosystem construction.

2.1 Strengthening Macro-Level Layout and Strategic Planning

The dual uncertainties of frontier technology breakthroughs and future industry development demands necessitate strengthened strategic guidance. For example, brain-inspired intelligence, quantum information, gene technology, and future networks represent important directions for future industries, but the key technologies supporting their transformative development remain under exploration. Strengthening forward-looking judgment of critical technology development directions and identifying more new technologies to meet market demands during the processes of technology maturation, industrialization, and product commercialization are essential for strengthening future industries. This urgently requires national-level top-level design and strategic planning to strengthen policy guidance for future industry technology development.

2.2 Strengthening Frontier Technology Breakthroughs to Support Scenario Applications

Future industry technologies exhibit strong permeability and traction across various industries and sectors. By driving paradigm transformations in technology and economic society, they support scenario development across industries and systematically meet the needs of economic and social development evolution. Consequently, they have high technological thresholds and barriers requiring systematic breakthroughs. For instance, quantum technology represents a major disruptive innovation that impacts and reconstructs traditional technology systems. How to effectively achieve breakthroughs has become a globally recognized challenge, with major countries deploying research initiatives. Therefore, promoting future industry technology development must focus on strengthening technology breakthroughs in key areas.

2.3 Increasing Innovation Resource Supply and Optimizing Element Allocation

The complexity of future industry technology development increases the complexity ratio of integrating innovation resources, placing higher demands on the supply, allocation, and utilization of innovation elements. For example, digital technologies such as future networks are key technologies supporting future industry development, but advancing them requires strengthening the supply of data resources, digital technologies, digital platforms, and digital infrastructure. Moreover, future industries typically have long return cycles, requiring early guidance and support. Innovation resource allocation methods must be optimized according to different development stages to efficiently cycle various innovation element resources.

2.4 Improving the Innovation System and Building a New Innovation Ecosystem

Cultivating an industrial innovation ecosystem is essential for promoting future industry development and technological breakthroughs. For example, large model technology is accelerating AI industry development, but involves heavy resource investment in big data, massive computing power, and strong algorithms. This requires deep cooperation among academia, industry, and government departments to jointly build an open-source and open-access ecosystem for AI, covering algorithm open-sourcing, data sharing, and computing infrastructure construction and usage rules. Therefore, promoting future industry technology development must mobilize the positive interaction among entrepreneurs, scientists, and venture capitalists to build an open innovation ecosystem conducive to technological breakthroughs.

3. International Experience in Future Industry Technology Development

3.1 Strengthening Macro-Level Layout of Future Industry Technology Development

Major countries are actively seizing future industry technology directions and development opportunities, seeking cooperation in fierce national technology competition while safeguarding national future technology security. First, they formulate forward-looking strategic plans to systematically build frameworks for future industry technology development. The United States released the "Future Industries Act" in 2020 to promote American leadership in future semiconductors, AI, advanced manufacturing, quantum computing, and next-generation wireless networks. Second, they promote international cooperation on future industry technologies to safeguard national security. In October 2022, the European Quantum Internet Alliance launched a seven-year plan to build a quantum internet ecosystem across Europe and promote collaborative R&D in quantum technology. Japan and the United States are strengthening cooperation in networks and aerospace.

3.2 Focusing on Frontier Technology Development Trends

Major countries actively identify future industry development trends to seize technological commanding heights and open new tracks for future industry technology development. First, focusing on the intelligent trend, they strengthen digital technology breakthroughs. The United States proposed the "National Quantum Initiative Act," deploying a ten-year national quantum action plan. The European Union's 2022 "European Chips Act" aims to boost Europe's semiconductor industry. Second, focusing on the green trend, they strengthen new energy technology breakthroughs. Germany introduced the world's first national hydrogen strategy in June 2020, focusing on hydrogen technology development and application, followed by the United States, United Kingdom, and EU re-

leasing hydrogen plans. Third, focusing on the health trend, they strengthen biotechnology breakthroughs. In September 2022, a U.S. executive order on "Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy" called for supporting and coordinating federal investment in key R&D areas of biotechnology and biomanufacturing.

3.3 Increasing Investment in Future Industry Innovation Resources

Major countries are increasing innovation resource supply for future industries, supporting development through funding and talent. First, they strengthen government funding to increase R&D investment. The U.S. "Future Industries Act" proposes increasing investment in future industries to $10 billion annually before FY2025. Germany established a €10 billion "Future Technology Investment Fund" to finance startups. Second, they expand professional talent supply to enhance development momentum. In September 2020, the EU released the "Digital Education Action Plan (2021-2027)," stating that people need the latest advanced digital skills to support digital and green transformation across society, public services, and the economy. The South Korean government announced a "Semiconductor Support Plan" in 2022, aiming to cultivate 150,000 professionals for the semiconductor industry by 2031.

Major countries are also strengthening innovation actor construction and promoting collaborative development to build an open ecosystem. First, they strengthen innovation actor construction and improve R&D platforms. In 2021, the U.S. President's Council of Advisors on Science and Technology (PCAST) recommended establishing future industry institutes to drive breakthroughs in technology commercialization and industrialization through organizational and operational management innovation. Second, they promote collaborative development among innovation actors to create open ecosystems. Germany has established a future research strategy system with the German Joint Science Conference (GWK) as the link, encouraging multi-actor collaboration among government, society, and research institutions. Japan launched the "Industry-Academia Collaboration Open Innovation Platform Program" to strengthen cooperation among 24 institutions including the University of Tokyo.

4. Current Situation and Challenges of China's Future Industry Technology Development

4.1 Macro-Level Layout of Future Industry Technology Needs Improvement

Although China is vigorously promoting future industry development, its future industry technology development still lacks systematic layout. Building a mechanism for central-local and inter-departmental coordination with prioritized and categorized exploration faces challenges. First, regarding central-local coordination, since the 14th Five-Year Plan period, local governments have formulated future industry development strategies referencing the central govern-

ment, but there is cross-repetition in local strategic layouts. For example, more than ten provinces have explicitly mentioned "quantum information" or "quantum technology" as major future industry directions in their 14th Five-Year Plans. Second, regarding inter-departmental coordination, promoting future industry development is a systematic project involving multiple departments. While the Ministry of Industry and Information Technology, Ministry of Science and Technology, and Ministry of Education have launched pilot programs, overall coordination efficiency remains to be improved. Science and technology, education, industrial, fiscal, and financial policies have not yet been deployed from the perspective of promoting the entire chain of future industry technology breakthroughs, transfer, and application. Third, regarding organizational coordination, the synergistic role of innovation platforms such as national laboratories, national key laboratories, national manufacturing innovation centers, national industrial innovation centers, and national engineering research centers in advancing future industry technology development has not yet become prominent.

4.2 Shortcomings in Key Frontier Technologies for Future Industries

China's capabilities in future industry technology breakthroughs continue to improve, but some technologies in key areas such as information, energy, and biology still face "bottleneck" issues. The "Outline of the 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through 2035" identifies brain-inspired intelligence, quantum information, gene technology, future networks, deep-sea and space development, hydrogen energy, and energy storage as key future industry technology areas. However, the level of independent control over basic research and key frontier technologies in these areas is not high. The "Industrial Foundation Innovation Development Catalog (2021 Edition)" compiled by the National Industrial Foundation Expert Committee lists 1,047 industrial foundation products and technologies requiring vigorous development. Shortcomings in basic components, parts, and materials seriously constrain frontier technology breakthroughs, making it difficult to achieve independent control over key technologies for future industry development.

4.3 Insufficient Supply of Innovation Elements for Future Industry Technology

The in-depth implementation of the national innovation-driven development strategy has provided broad space for future industry technology development, but the supply capacity of technology elements remains insufficient, and effectively expanding investment channels and scale faces difficulties. First, regarding talent supply, China faces a significant gap in future industry technology talent. The cultivation cycle is long and requirements are high, making it challenging to cultivate sufficient talent quickly. For example, intelligent manufacturing, as an important future industry direction, has a huge talent gap. The "Intelligent Manufacturing Talent Demand Forecast Report" released in

2021 predicts that by 2025, intelligent manufacturing talent demand will reach 9 million, with a projected shortage of 4.5 million. Second, regarding funding supply, financial institutions lack adequate market identification and technology foresight for future industry technology cultivation, causing some promising and valuable future technologies to face financing constraints. This weakens the motivation of innovation actors to conduct R&D. Meanwhile, China's financial system for future industry technology development remains in the exploratory stage, making it difficult to build complete financing and financial service models quickly.

4.4 Future Industry Technology Development Ecosystem Needs Improvement

China's technology development ecosystem in some potential future industry areas remains inadequate, with ecosystem construction in some fields facing international blockades that seriously constrain China's future industry technology breakthroughs. Domestically, although China has a vast consumer market and complete industrial categories, infrastructure, technical standards, testing and certification systems, and regulatory systems for future industries are not well-developed. The country lacks unified strategic planning and top-level design, and an innovation ecosystem with "government-industry-academia-research-finance-service-application" collaboration has not yet formed. Internationally, global industrial and technological competition is intensifying. Developed countries, leveraging their first-mover advantages, have already established favorable positions in some technology fields and built industrial alliances. For example, ChatGPT is leading a new wave of AI development, with OpenAI, Microsoft, and NVIDIA providing algorithm, funding, and computing power support for large model training and application, forming a ChatGPT-based future industry technology ecosystem. However, China's large model ecosystem faces challenges such as difficulty in aggregating data resources, a shortage of AI chips, and an incomplete open-source system, making it difficult to catch up with international advanced levels.

5. Recommendations for Optimizing China's Future Industry Technology Development Layout

Promoting China's future industry technology development requires forward-looking judgment and systematic layout. Optimization should focus on four aspects: macro-level layout, scenario-driven development, element supply, and innovation ecosystem construction.

5.1 Strengthening Macro-Level Layout of Future Industry Technology Development

First, conduct forward-looking foresight of future industry technologies. Regularly conduct strategic foresight based on technology development trends and

major economic and social demands to select priority directions. Establish a national strategic advisory committee for future industry technology development to guide resource allocation.

Second, build a future industry technology R&D system. Adhering to the entire-chain layout of future industry technology development, give full play to the coordinating role of the Central Science and Technology Commission. Deploy future industry technology development projects across the entire chain from basic research to applied research and development trials, mobilizing national laboratories, national research institutions, high-level research universities, and leading technology enterprises to conduct breakthroughs.

Third, create a collaborative innovation system for future industries. Considering national strategic needs, local resource characteristics, and development advantages, build a central-local and inter-departmentally linked future industry science and technology innovation system to promote joint breakthroughs among innovation actors.

5.2 Enhancing Scenario-Driven Future Industry Technology Development

First, cultivate application scenarios for future industry technologies. Focus on trends such as intelligent, healthy, and green production and lifestyles, and release catalogs of future industry technology scenarios based on major economic and social development needs.

Second, support collaborative scenario construction and sharing. Encourage enterprises, industry associations, and governments to jointly participate in scenario mining and cultivation. Support building frontier technology exhibition centers to showcase future industry technology scenarios.

Third, promote scenario application. Relying on leading enterprises in industrial chains, build "future industry brains" to promote technology application across upstream and downstream industrial chains and among large, medium, and small enterprises. Support the construction of benchmark demonstration projects to drive large-scale application of future industry technology scenarios.

5.3 Expanding the Supply of Elements for Future Industry Technology Development

First, build future industry technology innovation platforms. Support the construction of new R&D institutions and technology innovation consortia. Establish future technology colleges, future industry innovation centers, and future industry laboratories in key regions and fields to create sources of future industry technology.

Second, strengthen talent cultivation. Optimize university discipline and professional systems around important future industry technology directions, promoting new engineering, medical, and agricultural sciences. Encourage

"university-enterprise cooperation," "industry-education integration," and "industry-research integration" to cultivate talent.

Third, increase financial support. Use fiscal funds to stably support key future industry technology areas, optimize financial systems for future industry technology, and attract foreign and financial institution investment.

Fourth, layout major scientific and technological infrastructure. Build major scientific and technological infrastructure around key future technology fields to accelerate original innovation breakthroughs.

5.4 Building an Innovation Ecosystem for Future Industry Technology Development

First, improve multi-actor governance. Leverage the collaborative advantages of government, universities, research institutes, enterprises, and investment institutions in technological innovation, product development, and talent cultivation. Support the formation of a "basic research + technology breakthrough + industrialization + technology finance" cultivation chain, with multiple actors jointly participating in future industry technology governance.

Second, improve the technology transformation ecosystem. Support the establishment of future industry technology development alliances, and joint construction of pilot test bases and verification platforms by enterprises and research institutes. Improve service systems for industrial finance, technology consulting, and technology training to perfect the entire process from R&D to transformation, pilot testing, and mass production.

Third, strengthen international cooperation. Relying on international science and technology innovation centers such as Beijing, Shanghai, and the Guangdong-Hong Kong-Macao Greater Bay Area, strengthen cooperation with countries along the Belt and Road, RCEP members, and BRICS countries. Support the establishment of international science and technology organizations in key future industry technology fields and build international exchange platforms.

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