Postprint: Analysis of Selection and Identification of Key Science and Technology Areas in Major Countries

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Abstract

[Purpose/Significance] The planning and layout of national key scientific and technological (S&T) development fields influence a country's leadership in global scientific and technological innovation. Innovative intelligence research methods can provide reliable foundations for the selection and layout of national key S&T fields. This study explores a combined qualitative and quantitative approach to identify and select the key S&T development fields of major countries worldwide, providing support and reference for decision-making on China's key S&T development fields from a global perspective and through objective data analysis. [Method/Process] From the dimension of aligning with national strategic needs, this study qualitatively investigates national S&T plans and investments; from the dimension of solid theoretical research foundations, it quantitatively analyzes national research output. Based on comprehensive analysis indicators and weights for key national S&T development fields across three dimensions, the extreme value standardization method is employed for standardized calculation and ranking. [Results/Conclusion] The study identifies and selects the Top 10 key S&T development fields of major countries including the United States, the United Kingdom, Japan, South Korea, and the European Union. It identifies and analyzes the common and distinctive layouts of key S&T development fields across these countries, conducts a comparative analysis with China's layout of key S&T fields, and proposes recommendations that can serve as references.

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Full Text

Selection and Identification Analysis of Key Science and Technology Priority Fields in Major Countries of the World

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Abstract

[**Purpose/Significance**] Exploring innovative qualitative and quantitative methodologies can provide a reliable basis for the selection and identification of national science and technology priority fields. By combining qualitative investigation of national science and technology plans and investments with quantitative analysis of national research output from a global perspective and based on objective data analysis, this study provides support and reference for decision-making regarding China's science and technology priority fields.

[**Method/Process**] Three dimensions were established for identifying key fields: alignment with national strategic needs, solid theoretical research foundation, and comprehensive analysis indicators and weights across three dimensions. Qualitative surveys examined national science and technology plans and investments, while quantitative analysis assessed national research output. The extreme standardization method was used to normalize and rank the results.

[**Result/Conclusion**] The Top 10 priority fields for science and technology development in the United States, United Kingdom, Japan, South Korea, and major EU countries were identified and analyzed. The study examines common and distinctive layouts in these countries' priority fields and compares them with China's priorities, offering actionable recommendations for China's science and technology priority field planning.

Keywords: major countries of the world; research achievements; science and technology input; science and technology planning; priority fields; selection and identification analysis

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Introduction

In today's world, science and technology are developing rapidly, and economic globalization has significantly accelerated. Competition in scientific and technological strength has become the core and focus of competition in overall national comprehensive power. In the face of an environment of technological innovation and competition, national science and technology priority fields, as an important pathway to reflect national strategic objectives, integrate scientific and technological resources, and achieve leapfrog development in national scientific and technological innovation, are increasingly valued by major developed countries worldwide. The practice of scientific and technological innovation development in major developed countries demonstrates that strategic planning, investment deployment, and priority layout in national science and technology priority fields have become national strategies to achieve breakthroughs in science and technology and maintain global leadership in innovation development.

China is accelerating its progress from a major science and technology country to a science and technology powerhouse. To this end, the "National Innovation-Driven Development Strategy Outline" issued by the Central Committee of the Communist Party of China and the State Council in 2016 explicitly proposed implementing an innovation-driven science and technology development strategy, with the "three-step" goal of entering the ranks of innovative countries by 2020, becoming a front-runner among innovative countries by 2030, and building a world-leading science and technology innovation powerhouse by 2050. The "13th Five-Year National Science and Technology Innovation Plan" emphasizes adhering to a global perspective in planning and promoting China's scientific and technological development innovation, facing the forefront of world science and technology, the main battlefield of economic development, and major national strategic needs. China has launched 15 "Science and Technology Innovation 2030-Major Projects." Therefore, drawing on the science and technology priority fields of major countries worldwide and combining them with the needs of China's national economic development is particularly important for ensuring China's strategic interests and expanding its strategic priority fields.

The selection of national science and technology priority fields reflects national science and technology development goals and strategies, playing an important role in obtaining opportunities for major scientific innovation breakthroughs, finding the intersection between scientific development goals and national economic and social development goals, and guiding and supporting basic and strategic scientific research. From the perspective of current practical operations and research literature in various countries, there is no unified paradigm for selecting national science and technology priority fields. The main intelligence collection and analysis methods include: (1) Expert survey methods (also known as expert consultation methods, such as the Delphi method). For example, the UK Government Office for Science and the Science and Innovation Group jointly organized scientists from different fields from institutions such as the UK Research Councils, government chief scientific advisors, and business representatives to propose priority areas for science and technology planning development based on investigation, analysis, and evaluation of world science and technology development trends, the current state of domestic science and technology development, and science and technology information from different types of countries. (2) Bibliometric analysis methods. For instance, Japan's National Institute of Science and Technology Policy identifies research fields through document co-citation and cluster analysis based on globally top scientific papers and their citations indexed in the Essential Science Indicators (ESI) database, and identifies hot research fields through text mining and expert knowledge. Domestic and international progress has also been made in research frontier detection methods, mostly based on citation analysis and keyword analysis using bibliometric characteristics for content analysis of scientific research fields.

However, since the selection of national science and technology priority fields reflects a country's scientific and technological goals and comprehensive strategies for a certain period, bibliometric analysis of research achievements reflects research that has already been conducted and cannot reflect current national science and technology investment and future science and technology development layout. Additionally, the disciplinary classification used in bibliometric analysis cannot completely correspond to the classification of national science and technology priority fields. How to more scientifically and rationally use multiple information sources to identify and discover national science and technology priority fields has become one of the urgent intelligence research problems to be solved.

This study addresses this gap by using three dimensions to select and study national science and technology priority fields: papers indexed in the authoritative Web of Science™ Core Collection database, science and technology project funding investment, and national science and technology strategic planning. These correspond to priority fields that have been carried out, are currently being conducted, and are planned for the future. The study designs multi-dimensional comprehensive analysis indicators and weights, taking the United States, United Kingdom, Japan, South Korea, and major EU countries as research objects, and explores the use of multi-source information combined with quantitative analysis and qualitative investigation to identify the Top 10 priority fields in science and technology development in major countries worldwide. The study analyzes the common and distinctive layouts of these countries' science and technology priority fields and conducts a comparative analysis with China's science and technology priority fields, aiming to provide an objective and systematic global perspective for planning and layout of China's science and technology priority fields.

2. Data Sources and Research Methods

2.1 Data Sources **Dimension 1—Research Achievements:** The Web of Science™ Core Collection authoritative database (Science Citation Index Expanded (SCI-Expanded), 1900-present) was used to collect journal papers from the United States, United Kingdom, Japan, South Korea, and the EU (France, Germany, Italy, Spain, Portugal, Netherlands, Denmark, Finland, Greece, Austria, Belgium, Sweden, Switzerland) published between 2010-2014. Bibliometric analysis methods and tools were employed for quantitative analysis according to Web of Science subject categories, ESI average citation rates, and expert judgment. Quantitative analysis can objectively reflect the core research achievements output in various fields that countries have already carried out, serving as an indicator for selecting fields that countries have already developed.

Dimension 2—Research Input: Qualitative surveys were conducted on science and technology projects funded at the national and major institutional levels in the United States, United Kingdom, Japan, South Korea, and major EU countries. Funding agencies surveyed included the U.S. National Science Foundation (NSF), U.S. Department of Energy (DOE), U.S. Department of Health and Human Services (HHS), U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), U.S. Air Force Office of Scientific Research (AFOSR), U.S. Environmental Protection Agency (EPA), U.S. National Institutes of Health (NIH), U.S. National Oceanic and Atmospheric Administration (NOAA), Japan Society for the Promotion of Science (JSPS) and Japan's Strategic Innovation Program, UK Research Councils (RCUK), South Korea's National Research Foundation (NRF) and Ministry of Science, ICT and Future Planning, and the EU Horizon 2020 program. Qualitative investigation and analysis of research fields funded by these agencies in 2014 were conducted as indicators for selecting currently funded priority fields.

Dimension 3—Science and Technology Planning: National-level science and technology strategic plans from the United States, United Kingdom, South Korea, Japan, and EU countries were surveyed. Plans analyzed included the U.S. Technology Competitiveness Program, U.S. Innovation Strategy, and plans released by the White House, technology committees, and research institutes; Japan's Science and Technology Basic Plan (2011-2015) and Innovation 25 Strategy; UK's Emerging Technology Industry Strategic Plan (2014-2018) and UK Research Councils' plans; South Korea's Third Science and Technology Basic Plan; EU Horizon 2020 program, Germany's High-Tech Strategy 2020, and France's 2020 Strategic Agenda. Qualitative investigation and analysis of priority areas in these plans released by 2014 were conducted as indicators for selecting current and future priority fields.

2.2 Analysis Methods Since qualitative investigation and quantitative analysis draw from extensive data sources including disciplinary fields of journal papers, research fields of funded projects, and priority fields of strategic plans, the three dimensions have different field classifications, making unified classification a challenge in priority field selection. Therefore, during the research implementation process, multiple expert review and consultation meetings in relevant national fields were held. Based on expert recommendations, a comprehensive analysis framework for national science and technology priority fields was designed, determining analysis indicators, weights, and dimensional rankings from the three dimensions of research achievements, research input, and science and technology planning. The Top 10 ranking was then calculated using the extreme standardization method.

2.2.1 Comprehensive Analysis Indicators and Weights: The three dimensions of research achievements, research input, and science and technology planning correspond to three first-level indicators, including seven second-level indicators: discipline scale, discipline influence, expert judgment, project quantity, funding amount, current planning, and future planning. The indicator weights are detailed in Table 1 .

2.2.2 Weight Calculation Principles: The principles include:

1. **Research Achievements:** (1) Discipline Scale: Ranking of paper quantity in disciplinary fields, maximum 10 points, minimum 1 point; (2) Discipline Influence: ESI total citation ranking, maximum 12.5 points, minimum 1 point; (3) Expert Judgment: Expert interpretation of priority fields, maximum 2.5 points, minimum 0.5 points.
2. **Research Funding:** (1) Project Quantity: Number of funded projects, maximum 15 points, minimum 1 point; (2) Funding Amount: Project funding amount, maximum 20 points, minimum 1 point.
3. **Science and Technology Planning:** (1) Current Planning: Inclusion of priority fields, maximum 25 points, minimum 1 point; (2) Future Planning: Inclusion of priority fields, maximum 15 points, minimum 1 point.

2.2.3 Extreme Standardization Method Calculation: Based on the above indicators and weights, the total ranking of priority fields across the three dimensions for the United States, United Kingdom, Japan, South Korea, and major EU countries was calculated. The Min-Max standardization extreme value method was then used to map all values to the [0,1] interval. The standardization formula is Y_{standardized} = (MaxY - Y) / (MaxY - MinY). The closer the standardized value is to 1, the more important the field. The top 10 fields by standardized value were identified as the Top 10 priority fields for national science and technology development.

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3. Research Results

3.1 Selection of Top 10 Priority Fields in the United States, United Kingdom, Japan, South Korea, and Major EU Countries Through quantitative analysis of research achievements and qualitative investigation of science and technology input and planning in the United States, United Kingdom, Japan, South Korea, and the EU, and based on the comprehensive analysis framework indicators and weights, the Top 10 priority fields for science and technology development were selected according to the standardized values of the total rankings across the three dimensions. The results are shown in Table 2 .

3.2 Comparison of Top 10 Priority Fields in the United States, United Kingdom, Japan, South Korea, and Major EU Countries Comparing the Top 10 priority fields for science and technology development in the United States, United Kingdom, Japan, South Korea, and EU selected in Table 2, it was found that these countries/regions collectively involve 25 science and technology priority fields, as shown in Table 3 .

Analysis of the Top 10 priority fields in Table 3 reveals the following common layouts:

1. Common to the United States, United Kingdom, Japan, and EU: nanomaterials and nanotechnology, renewable energy and efficient utilization, green/new energy, and energy-saving technologies.
2. Common to the United States, United Kingdom, South Korea, and EU: materials genome, emerging engineering materials, and advanced materials.
3. Common to the United States, United Kingdom, and South Korea: high-performance computing, big data analysis and big data applications.
4. Common to the United States, South Korea, and EU: intelligent/advanced manufacturing and 3D printing.
5. Common to the United Kingdom, Japan, and South Korea: artificial intelligence and robotics.
6. Common to the United Kingdom, South Korea, and EU: environmental science and climate/environmental change response.
7. Common to the United Kingdom, Japan, and EU: information and communication technology and digital networks.
8. Common to the United States and Japan: transgenic technology.
9. Common to the United States and South Korea: gene medicine, disease prediction, and biomedical healthcare.
10. Common to the United States and EU: safe and effective drugs, and medical health.
11. Common to the United Kingdom and EU: space technology and biotechnology.

The distinctive layouts are:

1. Unique to the United States: new quantum devices and quantum information security technology, health information technology.
2. Unique to the United Kingdom: synthetic biology.
3. Unique to Japan: tumor prevention and treatment, biomedical engineering and biomaterials, disaster prediction technology, and electronic/electrical

engineering materials and equipment.

4. Unique to South Korea: environment-friendly automobiles, brain and cognitive science, smart grid, and agricultural/livestock/aquatic disease prevention and control.
5. Unique to the EU: food safety.

3.3 Comparison Between China and the Priority Fields of the United States, Japan, United Kingdom, South Korea, and EU The 25 priority fields identified for the United States, United Kingdom, Japan, South Korea, and EU were compared with the priority fields, priority themes, and strategic frontier major scientific issues deployed in China's science and technology strategic planning. The comparison included the "13th Five-Year National Science and Technology Innovation Plan" (13th Five-Year Plan), the "National Medium- and Long-Term Science and Technology Development Plan Outline (2006-2020)" (Medium- and Long-Term Plan Outline), and the "13th Five-Year Plan Outline of National Economic and Social Development of the People's Republic of China" (13th Five-Year Plan Outline). The results are shown in Table 4 .

The comparison reveals that among the 25 priority fields, China has explicitly deployed 23 fields that completely align with those of the United States, United Kingdom, Japan, South Korea, and EU. Only two fields—U.S. health information technology and Japan's disaster prediction technology—have not been explicitly included in China's science and technology priority fields.

U.S. health information technology involves comprehensive management of healthcare through computer systems, focusing on biomedical information technology, healthcare information technology, electronic medical records, mobile technology applications in healthcare, and sensors for monitoring chronic diseases. It stores, extracts, shares, and uses medical information, data, and knowledge to facilitate communication and decision-making, and significantly improves the overall quality, safety, and effectiveness of healthcare service systems. China's medical informatization started relatively late, and the current 13th Five-Year Plan is promoting digital healthcare and health service technologies. Therefore, the U.S. prioritization of health information technology as a Top 10 field offers important insights for future development in a populous country like China.

Japan's disaster prediction technology mainly includes disaster observation and prediction, risk assessment of environmental pollution and hazardous substances, advanced prediction technologies for natural disasters such as earthquakes and tsunamis, disaster information networks, and disaster information communication systems. It focuses more on predicting disasters before they occur. Currently, China's key research focuses on monitoring, early warning, and comprehensive risk analysis and assessment of earthquakes, typhoons, storms, floods, and geological disasters—more on post-formation disaster alarms. Therefore, Japan's disaster prediction technology in its Top 10 priority fields is ahead of China's and offers valuable lessons for China's priority field research and innovation development.

This study conducted quantitative analysis of research achievements in major countries worldwide, qualitative investigation of research input and science and technology planning across three dimensions, and used comprehensive indicators, weight ranking, and extreme standardization methods to select the Top 10 priority fields for science and technology development in the United States, Japan, United Kingdom, South Korea, and EU. It compared and analyzed the 25 science and technology priority fields identified for major countries with those deployed in China. Although this study's selection and identification analysis has undergone expert review, further empirical research is needed. The authors believe that the selection of national science and technology priority fields reflects a country's scientific and technological goals and comprehensive strategies for a certain period. Regular and dynamic conduct of broader intelligence research, such as world science and technology development forecasting and emerging technology foresight, based on changes in international science and technology development and domestic socio-economic development, can better support and serve national science and technology development strategic goals and strategic interests.

References

[1] Xu Ye, Cheng Jiayu, Meng Hong, et al. Research on the selection of key tasks for China's "Twelfth Five-Year" science and technology [J]. Science Research Management, 2012, 30(1): 35-37.

[2] Li Liya, Li Ying. Evolution of national science and technology planning system and its management [J]. China Science and Technology Forum, 2008(8): 6-11.

[3] Cheng Ruyan, Cui Shengjun. Analysis and enlightenment of future science and technology development plans in major countries [J]. China Science and Technology Forum, 2014(3): 5-10.

[4] National Innovation-Driven Development Strategy Outline [EB/OL]. [2018-02-06]. http://www.gov.cn/zhengce/2016-05/19/content_{5074812}.htm.

[5] "13th Five-Year National Science and Technology Innovation Plan" [EB/OL]. [2018-02-06]. http://www.gov.cn/zhengce/content/2016-08/08/content_{5098072}.htm.

[6] Wu Tong, Li Zhengfeng, Zeng Guoping. Basic research evaluation and national objectives [J]. Science Research, 2002(4): 343-347.

[7] Science & Innovation Investment Framework 2004-2014 [EB/OL]. [2018-02-06]. http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/spending_{{{sr04}}_{{tech}}}.htm.

[8] National Institute of Science and Technology Policy. Science and technology foresight [EB/OL]. [2018-02-06]. http://www.nistep.go.jp/en/?page_{id}=56#target01.

[9] Bai Rujiang, Leng Fuhai, Liao Junhua. Comparison of important methods for detecting scientific research frontiers [J]. Information Studies: Theory & Application, 2017, 40(5): 33-37.

[10] Tan Zongying. Research methods and practice of disciplinary strategic intelligence [J]. Library and Information Service, 2006, 50(5): 14-18.

[11] Zhao Fan. Comparative study on strategic intelligence analysis methods of foreign consulting intelligence agencies [J]. Intelligence Magazine, 2008(3): 132-134, 141.

[12] U.S. Innovation Strategy [EB/OL]. [2018-02-06]. http://www.whitehouse.gov/issues/technology.

[13] Interpretation of Japan's 4th Science and Technology Basic Plan (V) [EB/OL]. [2018-02-06]. http://www.istis.sh.cn/list/list.aspx?id=9269.

[14] UK Research Councils (RCUK) [EB/OL]. [2018-02-06]. http://www.rcuk.ac.uk/.

[15] Gao Fang, Zhao Zhiyun, Zhao Kexin, et al. Interpretation of South Korea's ICT R&D medium- and long-term strategy (2013-2017) [J]. Science and Technology Management Research, 2015(8): 21-25.

[16] Zhang Lijuan, Liu Runsheng, Song Wei. South Korea's Third Science and Technology Basic Plan [J]. Scientific Chinese, 2014(2): 7-9.

[17] Horizon 2020 [EB/OL]. [2018-02-06]. http://ec.europa.eu/programmes/horizon2020/.

[18] Outline of the National Medium- and Long-Term Science and Technology Development Plan (2006-2020) [A]. Gazette of the State Council of the People's Republic of China, 2006(9): 7-37.

[19] Outline of the 13th Five-Year Plan for National Economic and Social Development of the People's Republic of China [EB/OL]. [2018-02-06]. http://www.gov.cn/xinwen/2016-03/17/content_{5054992}.htm.

[20] U.S. Healthcare Information Technology [EB/OL]. [2018-02-06]. http://naisscience.englu.blog.163.com/blog/static/13427637920115252133722/.

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Wu Ming: Responsible for research framework and dimension methodology design, paper writing.
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Jin Qian: Responsible for revision of research framework and content.

Yang Xiaowei: Responsible for investigation and analysis of science and technology development fields in the United Kingdom and EU.
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Note: Figure translations are in progress. See original paper for figures.