Prospective Research on Science and Technology Information Policy

Authors: Gu Liping

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Abstract

As a national initiative that connects industrial conditions, competitive advantages, and innovation culture, foresight research constitutes the primary driving force for advanced countries to achieve technological leapfrogging. Through bibliometric analysis and literature review, this paper systematically presents a comprehensive panorama of foresight research and elaborates on its concept, history, and development trends. Based on an analysis of the operational mechanisms of foresight research in Germany, Japan, and Taiwan, this study formulates practical steps for applying foresight research in the field of science and technology information policy.

Full Text

Preamble

Title: Foresight Research on Science and Technology Information Policy

Author: Gu Liping
Affiliation: National Science Library, Chinese Academy of Sciences, Beijing 100190

Abstract: As a national project that articulates industrial conditions, competitive advantages, and innovation culture, foresight research serves as the primary driver for advanced countries to achieve technological leaps. Through bibliometric analysis and literature review, this paper systematically presents a panoramic view of foresight research and discusses its concepts, history, and development trends. Based on an analysis of foresight research operational mechanisms in Germany, Japan, and Taiwan, this study formulates practical steps for applying foresight research in the field of science and technology information policy.

Keywords: Strategy Foresight; Policy Foresight; Foresight Methods; Scientific and Technology Information; Decision Intelligence; Technology Foresight

1. Introduction: Foresight Research as an Instrument of National Will

At the turn of the century, Western countries faced a significant dilemma when undertaking genetic engineering projects. Because transgenic engineering required substantial investment across various technical branches while bearing the risk of failure, policymakers needed to consider not only technical feasibility but also assess future markets that could sustain long-term development of key technologies through profitable returns. While some scientists advocated for the frontier nature, feasibility, market potential, and scientific value of genetic engineering, others questioned their overly optimistic views on medical applications and their neglect of various risks. Moreover, the Western public particularly questioned whether such research violated traditional religious beliefs, social ethics, and legal systems. As science and technology policy decision-makers, how should they decide? Whom should they listen to—scientists, engineers, stockbrokers, lobbyists, politicians, or priests and the Pope?

Policy research following rigorous social science methods can explore the development path of such bioengineering technologies, gathering stakeholder views from a neutral third-party perspective to form a comprehensive understanding of the issues (see [1]). However, from the perspective of policy decision support, mere horizontal surveys are insufficient to resolve most policy problems. This is because science and technology policy research operates in two modes: looking backward (hindsight) and looking forward (foresight). The backward-looking approach serves two purposes: first, establishing a technological roadmap for rapid catch-up, and second, building simulation models for future projection. The forward-looking approach is more complex, involving various concepts with similar meanings but distinct implications, such as technology futures, anticipation, forecasting, and futures studies (see [2]).

Pioneers in China' s information science field have accumulated profound practical experience and systematic research on Technology Foresight (see [3-13]), achieving a series of important results. However, Technology Foresight has an obvious limitation: while it can map technological roadmaps from the past to the present and project possible future developments of existing technologies, it is unsuitable for describing visions or changing the future. Since the Technology Foresight system matured before foresight research, it is not surprising that it can only envision the visible future of already-existing technologies. However, when placed within the framework of foresight research, Technology Foresight can enrich its extension and connotation (from projection to vision) and establish its position in policy research (from technology to public affairs), thereby integrating foresight research into the ranks of China' s information science discipline.

Compared with Technology Foresight, Strategy Foresight emphasizes the condi-

tions that shape technology to explore how to develop technologies that have never existed before. It focuses on the supporting measures and innovative cultural environment for creating new technologies, rather than the industrial foundations, evolution, development, and changes—the implementation methods and hardware/software conditions required to develop a new technology.

In terms of practical origins, Technology Foresight derives from operations research in the U.S. military-industrial complex, while Strategy Foresight originates from critical thinking in French policy formulation. The French word *intuition* implies various possible futures, while *la prospective* in French includes the behavioral processes and outcomes adopted toward these possible futures. French scholars emphasize uncovering people' s taken-for-granted experiences and knowledge, breaking conventions to create change. Traditional American Strategy Foresight scholars have focused more on operational planning, which has little to do with strategy itself, viewing foresight not as result-oriented but as a preparatory stage for decision-making. Despite these different traditions, both outline two facts: (1) people want to change or influence the future; and (2) the capacity for foresight thinking can create subsequent work paths and their legitimacy (see [14]).

Today, the National Foresight Process promoted by Germany' s Federal Ministry of Education and Research (BMBF) integrates the respective advantages of Technology Foresight and Strategy Foresight, forming a "Policy Foresight" method for science and technology information, decision intelligence, and organizational transformation (see [15]). Policy Foresight includes four core components: (1) identification of new focuses in research and technology, (2) designation of areas for cross-cutting activities, (3) exploration of fields for strategic partnerships, and (4) derivation of priority activity lines for R&D policy.

Notably, Germany' s Policy Foresight operational mechanism employs many "housekeeping skills" of library and information scientists: (1) quantitative bibliometrics, (2) qualitative workshops, (3) expert interviews, and (4) internet and literature searches.

Systematically reviewing foresight research can expand related research themes in China and introduce them into China' s library and information science enterprise, particularly in the emerging field of science and technology information policy research and consultation, which can draw upon its theoretical and practical content.

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2. Panoramic Observation of Foresight Research

To comprehensively trace the origins and development of foresight research, this study employs bibliometric methods to select key terms and conduct a full-domain literature search. After reading each paper, we classified the literature to outline research hotspots and connections, gradually revealing the development

trajectory of foresight research.

A search of the Web of Science database using "foresight" as a keyword in titles, abstracts, and topics yielded 1,318 papers (data collection date: August 16, 2011; final verification date: September 22, 2012). After rapid reading, 731 relevant documents were identified. The main journal sources include: *Futures* (117 papers), *Technological Forecasting & Social Change* (99 papers), and others such as *Journal of Economic Dynamics and Control*, *Technology Analysis & Strategic Management*, *Journal of Economic Theory*, *International Journal of Technology Management*, *Economics Letters*, *Journal of Public Economics*, *International Economic Review*, *Long Range Planning*, and *The Futurist*.

Based on the bibliographic data, we mapped a keyword atlas of foresight research (Figure 1 [FIGURE:1]). The vocabulary from this keyword atlas served as filtering criteria for a second expanded literature search (not limited to the single WOS database). We referenced the literature search and selection approach of Martin B.R.' s foresight team at the University of Manchester when establishing "science and technology foresight policy" recommendations:

(1) Do not only look at high-impact-factor articles, as they do not necessarily reflect political influence.

(2) Preliminary work: list 600 scholars, 80 journals, and keywords.

(3) Screening work: identify 200 works cited more than 250 times, summarized into 20 latest developments.

He explained that SSCI represents partially academically theorized information, while the focus of foresight research lies in its research objects rather than theoretical construction. Therefore, various types of information should be broadly collected, including monographs, anthologies, conference announcements, conference papers, report white papers, government news, business reports, and even blog posts or advertising materials [16].

Consequently, the scope of our second search encompassed SSCI papers, important papers, and research reports. After the second SSCI literature search and further analysis based on themes and abstracts, foresight research can be roughly categorized into ten types: Technology Foresight, Strategy Foresight, Policy Foresight, Sustainable Foresight, Foresight Campaigns, Decision Systems, Regional Studies, Methods and Methodology, Foresight Concepts, and Organizational Foresight. An eleventh category, "Non-foresight Research," refers to papers that mention foresight but are not actually foresight studies, instead using the term "foresight" as an adjective or adverb.

In the analysis of important papers and research reports, research themes can be divided into: EU science and technology policy, UK innovation policy and strategy, government foresight, distribution of foresight research, relationship between foresight and knowledge society, foresight policy research models, types of foresight thinking, diamond model of foresight research, foresight policy in

intergovernmental organizations, role of experts in foresight policy, forecasting techniques, foresight attitudes and behaviors, strategy theory and organization theory, strategy foresight in public policy, Technology Foresight literature, development predictions of foresight research, foresight-scenario analysis, etc. (Figure 2 [FIGURE:2]).

Based on the above, although there are 28 literature categories and research themes, continuity and connections can still be vaguely discerned between individual documents and themes. Therefore, clarifying the definitions of related concepts and sorting out the development history of foresight research can help us understand trends and summarize key points for guiding practical work. We have summarized the above results into three parts: conceptual definitions, historical evolution, and development trends.

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3. Concepts, History, and Development Trends of Foresight

3.1 Conceptual Definitions

Martin B.R., a British scholar who has engaged in science and technology policy research and consultation for over thirty years and was also one of the earliest researchers in foresight, integrated UK government policy research with Chinese intelligence studies to propose that foresight is Anticipatory Intelligence [17]. He explained that in the context of policy research, "foresight" as an actual action rather than an adjective means various involvement activities before an event occurs. To accurately define and explain the concept of "foresight," he pointed out that the French term *la prospective* means not only looking into the future but also shaping and constructing the future we choose.

Although he opposed the "academicization" of foresight research, his articles are highly condensed, concise, and profound. Another scholar, Rafael Popper, writes more accessible articles because he was a staff member of former U.S. Vice President Al Gore, making his language more plain while encompassing foresight research types across six world regions (see [18]). Additionally, we note some foresight research surrounding economic issues (e.g., [19]) attempts to explain how foresight research guides various policy implementations from the perspective of "how to predict markets for new product development in business."

The establishment of a discipline requires countless reasonable questions and public challenges. Some have questioned whether "so-called foresight research" should become an independent discipline, arguing that foresight researchers usually discuss well-established policy issues in short-term management, making it merely a branch of futurism [20]. However, we note that most foresight research actually discusses methods and activities for supporting long-term planning, involving but not limited to futures studies. For example, Strategy Foresight is a technology for forecasting and controlling design and implementation under

growing complexity and dynamics, and decision-making in uncertain environments (see [21]). The academic term referred to as foresight today denotes a comprehensive, holistic activity encompassing long-term strategy, medium-term tactics, and short-term operations.

Under this meaning, foresight research on science and technology information policy aims to detect, formulate, plan, and shape various information support mechanisms related to future science and technology.

3.2 Historical Evolution

The term foresight has a long history, representing a human capacity since ancient times. Its etymology was recorded in *Love for Love* (1694) during the Western Renaissance. In the industrial era, H.G. Wells used foresight in *Anticipations of the Reactions of Mechanical and Scientific Progress upon Human Life and Thought* (1901) to describe technology' s impact on the future. More relevant to current discussions is the systematic establishment of technology foresight mechanisms in the United States beginning in 1937. For example, the National Resources Committee report *Technological Trends and National Policy Including the Social Implications of New Inventions* mentioned the significant social impact of technological inventions and developments over the next thirty years. At that time, "forecasting" and "prediction" appeared multiple times in the report, while "foresight" appeared only twice and was often omitted as a substitute for other terms. In American society, compared with terms like futures studies, futures research, futurology, futuristics, futurics, forecasting, and prognostics, foresight was more often used to describe government governance behaviors. For example, in Bezold's book *Anticipatory Democracy* (1978), foresight meant systematic looking ahead. The Office of Technology Assessment (OTA), established in 1972, produced 700 reports for the U.S. Congress, in which long-term analysis of technological change was called foresight/forecasting. The 1982 report discussed modeling work and government foresight. Subsequently, in European countries, it gradually evolved from Technology Foresight to Policy Foresight, such as the UK' s National Key Science Review System under the TFP in 1995 (see [22]).

According to Linstone H.A.' s research [23], science and technology policy has three distinct stages. In the first two stages, there was no distinction between foresight and forecasting, but the third stage represents a major paradigm shift. He explained that the first stage was the modernization process, mainly including (1) Taylor' s "Scientific Management Principles" in 1911, (2) mathematical methods and operations research during World War II, (3) many quantitative methods developed by the U.S. Department of Defense and manufacturers in the 1950s and 1960s, (4) "non-military" industrial policy during the Cold War era of the 1970s, and (5) the 1969 launch of *Technological Forecasting and Social Change* as representative. The second stage primarily involved the comprehensive development of the information industry, following the railway age, steel age, and oil age—the fourth wave information age and fifth wave biotechnology

age. The United States had various studies from the RAND Corporation, while the Soviet Union had studies surrounding the TRIZ method. Their common characteristic was the complex science and multiple dimensions of technology, organization, and individuals (T-O-P). The third stage is the "data-driven innovation" era, facing: (1) interdisciplinary fields (biology, chemistry, physics, computer science), (2) integrated disciplines (information technology, nanotechnology, biotechnology, cognitive science), and (3) cutting-edge special applications (human mind and body engineering). Since then, relying solely on technology forecasting cannot produce technological revolutions; Technology Foresight and Policy Foresight play important roles.

Recent developments in foresight concepts have shifted from technology tracking and forecasting to include indicators of constantly changing trends and developments, qualitative and quantitative means, and monitoring clues for policy impact analysis. The research team emphasizes that foresight assists policymakers and implementers in facing future needs and opportunities. Although it cannot completely replace government policy definition, it can facilitate the process to make policy implementation conditions more appropriate, flexible, and adaptable to changing times and environments.

3.3 Development Trends

The trends and practices can be summarized into three key points: execution of scientific research, integration of democratic processes, and driving force of policy promotion. In other words, research drives discussion, multi-level experts and decision-making units reach consensus through discussion, and through relevant audits and promotion by various sectors, this structured method can ultimately deliver the important information refined from policy research completely and accurately to policymakers.

Taking Germany' s National Foresight Process as an example, the three stages of national policy formulation—(1) national expert workshops, (2) international workshops, and (3) final report conferences—are built upon eleven steps for theme selection and identification: (1) national expert interviews, (2) first report, (3) domestic and foreign data searches, (4) collecting opinions from relevant domestic decision-making units, (5) evaluating online questionnaires, (6) analyzing and describing twenty thematic areas, (7) second report, (8) clustering new dimensions and adding special structures, (9) workshops focusing on details of thematic areas, (10) third report, and (11) comprehensive release conference, allowing many institutions to obtain needed information [15]. It applies market forecasting and promotion methods to shape and implement national science and technology policy. This approach includes: (1) continuous forecasting and environmental scanning, (2) combined auditing, (3) continuous conceptualization, and (4) expert validation [24], representing a structured method from collecting, aggregating, and analyzing information to obtaining near-term forecasting results. Using prediction markets as a foresight research method can address the future, anticipate changes, enhance participation, reduce costs, and

manage complexity.

However, we note that foresight research has gradually shifted from focusing on "things" to focusing on "people," that is, toward building foresight communities and driving policy implementation. This is because the policy formulation process involves many stakeholders, and the process is not simply about researchers delivering recommendations to policymakers. Stakeholders between researchers and policymakers often play various positive and negative roles in information transmission, information shielding, information distortion, and information improvement. Foresight methods supplement and improve relevant information through multi-party discussions and anticipate and guide achievable directions.

Regarding foresight community building, there are six personality types in foresight policy formulation: Futurist, Activist, Opportunist, Flexist, Equilibrist, and Reactionist [25]. Their roles in organizations fall into four categories: Framer, Adapter, Tester, and Reactor [26]. Communities composed of these twenty-four types primarily aim to directly obtain expert advice and build consensus to indirectly promote policy implementation. This typology helps explain, consult, persuade, and communicate with stakeholders of different tasks, functions, purposes, and personalities.

Regarding the driving force of policy promotion, there are seven core elements [27]: (1) **Informative outcomes**: Using foresight processes and specialized methods to promote attention to current conditions and future challenges of innovation systems. Therefore, informative outcomes do not expect foresight activities that necessarily lead to concrete actions. (2) **Instrumental outcomes**: Not only producing information but also using foresight to support anticipated decision-making scenarios, such as resource allocation or forming strategic partnerships and joint actions. (3) **Consensual future perspectives**: Establishing priorities, relevant collaboration networks, and common understanding for future actions. (4) **Diverse future perspectives**: Developing and understanding different ideas, opinions, and priorities, identities and alternative paths, and competing alliances and value networks to explore alternative futures and comparable visions. (5) **Fixed management**: Characterized by centralized approaches where coordinators establish scope and methods and control the process from the beginning, often like Delphi. (6) **Autonomous management**: Conversely, a mediated process where coordinators facilitate continuous participation of leaders, such as continuous mediation in expert panel work. (7) **Stakeholder engagement**, including extensive stakeholder engagement and exclusive stakeholder engagement where participants are not extensive and therefore not open to all stakeholders. These seven elements outline the communication process among policy researchers, policymakers, and policy stakeholders in forming foresight policy.

Thus, in foresight science and technology policy, the focus is not only on people (political appointees, civil servants, grassroots personnel, stakeholders) but also on matters (laws, policies, technologies, markets, products), and ultimately integrating people and matters (what people do what things in what environments).

As Popper R. stated, the overall program includes pre-foresight, recruitment, generation, action, and renewal [28], representing a set of procedures that balance various opinions while maintaining effective policy formulation.

Since internal discussions and archival documents in the policy formulation process generally allow scholarly research but are not suitable for public publication, when studying the same decision-making process, scholars tend to analyze publicly available foreign government policy reports as a way to describe and explain how to conduct similar work. Foresight policy research in Germany, Japan, and Taiwan shows high similarity but operates in very different policy practice environments. Therefore, it is necessary to analyze and compare them to illustrate execution points and procedural steps for similar practical work.

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4. Case Analysis and Comparison of Foresight Research in Germany, Japan, and Taiwan

In the dynamic field of future research intersecting science and technology expertise, Germany' s Federal Ministry of Education and Research (BMBF) launched a two-year foresight process in 2007 [15]. Aiming at four objectives—(1) identifying new focuses in research and technology, (2) designing cross-cutting activities, (3) exploring strategic partnerships across fields, and (4) deriving priority activity lines for R&D policy—the ministry commissioned the Fraunhofer Institute for Systems and Innovation Research and the Institute of Industrial Engineering. Participating institutions encompassed universities, companies, and government units, including the Technical University of Berlin, Nanotechnology of the Research Centre Karlsruhe, RWTH Aachen, Austrian Research Centers GmbH (ARC), and the Technology Policy Systems Research Department of the German Mechanical and Architects Association (VDMA). Through this process, foresight has gradually become a primary method for German science and technology departments, with some foresight research results directly integrated into national policy activities and others indirectly permeating innovation systems in specific sectors.

Japan began its first national foresight research in 1970, systematically conducting large-scale surveys on science and technology development and application trends every five years. However, while Western countries like Germany pioneered the use of foresight research results as references for R&D resource allocation and strategic planning across departments in the 1990s, Japan only began directly applying foresight research to its national innovation system as a reference for formulating science and technology basic plans in 2004 [29]. Using methods such as technology roadmapping, Japan mapped out industrial development blueprints and the "Innovation 25" long-term strategic guidelines [30] as important foundations for national scientific research and industrial development. Therefore, Japan frequently uses the realization accuracy rate of various branch plans, including complete and partial realization [31], as a basis for re-

view and direction correction. Notably, Japan' s national foresight research emphasizes Technology Foresight, with less involvement in Strategy Foresight and integrated Policy Foresight.

Taiwan' s foresight research is currently relatively scattered across various think tank reports, with main research members connected through the civil society group "Foresight Society." However, since 2008, a series of related studies and activities have begun, including the notable research project "Technology Foresight and Policy Formation Mechanism" that integrates industry, academia, and research [32]. This project analyzes foresight mechanisms in various countries and conducts foresight research projects on agricultural biotechnology. Compared with Japan, Taiwan' s voluntary societies focus more on Strategy Foresight, while the scale of Technology Foresight (also called technology foresight) is not large.

In summary, Germany conducts foresight research through ministry-commissioned think tanks, Japan through direct ministry implementation, and Taiwan through individual and group approaches. Although the institutional frameworks differ, their logical thinking in foresight research is largely similar and can serve as a reference for application in science and technology information policy fields.

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5. Practical Application in Science and Technology Information Policy

Based on the above, the author believes that various foresight approaches can be briefly divided into three dimensions: effectiveness, methods, and purposes:

(1) **Effectiveness**: Informing policy (clearly and explicitly explaining policies), promoting policy (making relevant personnel aware of, understand, and comprehend relevant policies), participating in decision-making (expanding knowledge, scope, and content needed for policy among relevant personnel), supporting policy (making relevant personnel actively assist and cooperate), resetting policy systems (based on practical experience), and performing symbolic functions (achieving spiritual encouragement of unity, harmony, and progress).

(2) **Methods**: Bibliometrics (comprehensive information collection and analysis through databases and network systems), questionnaires (addressing actual needs and broadly collecting public opinions), expert interviews (consulting professional insights and suggestions in different special fields), and conference organization (publicly releasing results and providing sufficient research and practical content).

(3) **Purposes**: Policy research mainly focuses on building consensus and optimizing resource utilization while maximizing public welfare. Unlike traditional scientific research that emphasizes discovering truth, policy research

more often revolves around how to apply or popularize academic research results, serving as a service rather than an esoteric pursuit.

Foresight research exists according to needs, is designed according to purposes, and is executed according to design. However, clear operational processes and steps can enhance efficiency and accelerate work. Therefore, we have mapped out specific operational methods as follows:

(1) Based on actual needs, determine the general direction and project scale; imagination can be exercised at this stage.

(2) Conduct bibliometrics and literature review to collect relevant materials and content, focusing on comprehension.

(3) After bibliometrics, invite relevant researchers to discuss, supplement missing information, and assist in judgment, thereby enhancing absorptive capacity.

(4) Design topics, particularly emphasizing detailed work division and potential problems and difficulties, to fully exercise planning capacity.

(5) After topic setting, design questionnaires to collect stakeholder opinions and jointly formulate policy implementation schedules, fully exercising execution capacity.

(6) After schedule setting, interview experts to form conference agendas, fully respecting, absorbing, and understanding leadership guidance, and actively communicating and coordinating various relevant institutions to exercise collaborative capacity.

(7) After agenda setting, hold expert meetings. At this stage, based on "bibliometrics," "questionnaires," "expert interviews," and stakeholder opinions, assist various relevant units in a series of activities to support policy activities and enhance self-capability according to existing foundations. The overall goal is to achieve policy legitimacy, rationality, and desirability, fully exercising driving capacity.

(8) Produce fixed annual reports and build consensus, allowing the community to grow larger to achieve the goal of promoting foresight policy and exercising influence.

In summary, the process includes eight comprehensive capabilities: imagination, comprehension, absorption, planning, execution, collaboration, driving, and influence. Through continuous practice and coordination, team members can gradually enhance these eight capabilities for business, team, and personal growth.

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6. Continuous Development of Foresight Research

Currently, regardless of whether countries use the term "foresight research," there is a universal trend: adopting social science research methods to maximize knowledge exchange, thereby building consensus, reducing parochialism, eliminating decision-making uncertainty, and effectively promoting various policies. For example, the U.S. study "The Value and Performance of Libraries Participating in the Federal Depository Library Program" [33] used questionnaires and segmentation analysis to absorb valuable opinions from various libraries to improve policy planning. It then argued from an end-user perspective about what resources should be preserved, how to manage them, and how to access them, to persuade librarians and staff to participate in alliances, implement policies, publicize results, and attract more member libraries.

In other words, the first way to continuously develop foresight research is to integrate it closely with practical work. Through accumulating and summarizing practical experience, foresight research serves as a method to sort out work experience, enriching its connotation while enhancing theoretical capabilities.

The second way to continuously develop foresight research is to familiarize oneself with its main methods or techniques, such as: literature review, expert panels, scenarios, trend extrapolation, future workshops, interviews, brainstorming, questionnaires and surveys, SWOT analysis, Delphi, environmental scanning, essays, key technologies, technology road mapping, modeling and simulation, etc., but not limited to these methods. Furthermore, these methods can be combined with practical work to form an integrated foresight mechanism [34] (as shown in Figure 3

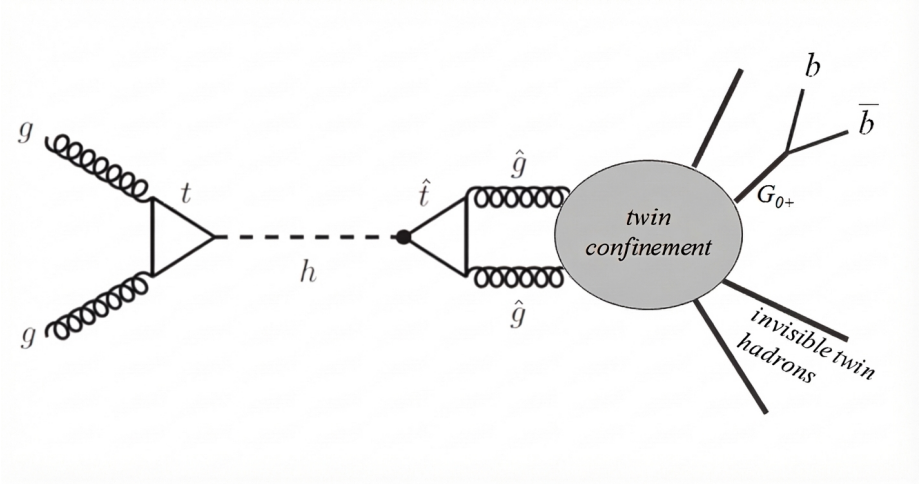

Figure 1: Figure 3

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The third way to continuously develop foresight research is to investigate foresight itself. Such research, based on practical experience, 提炼 and summarizes foresight talent capability enhancement and cultivation through self-reflection on deficiencies. As Professor Fuerth L.S. from the University of Washington pointed out, science and technology policy or government governance for the public has two key points: systematic thinking and continuous feedback. Moreover, foresight alone is insufficient for governance; it must also include hindsight, insight, topsight, prescience, and anticipation to achieve the goal of revitalizing the nation through science and technology [35].

Therefore, in the foreseeable future, as a new paradigm for science and technology information policy research, foresight research still has ample room for exploration and practical development. If the above three approaches advance simultaneously, they can continuously support science and technology innovation and stimulate social creativity in science and technology information policy work. This paper aims to serve as a modest spur to induce more valuable contributions.

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