"Technology Nation-Building" Strategy and the "Nobel Prize Plan" : Japan' s Path to Building a World Science and Technology Powerhouse (Postprint)

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Abstract

Since the inception of the Nobel Prize in 1901, Japan has produced a total of 22 Nobel laureates in the natural sciences, a phenomenon that has attracted widespread attention. This article takes Japan' s Nobel Prize achievements as a starting point, focusing its analysis on Japan' s science and technology policies and pathways since the 1970s—which laid a solid foundation for building Japan into a science and technology powerhouse—and summarizes the relevant experiences. Japan' s Nobel Prize "explosive phenomenon" reflects, from one perspective, the remarkable effectiveness of its science and technology strategies and policies in promoting the construction of a science and technology powerhouse.

Full Text

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Since the Nobel Prize was first awarded in 1901, Japan has produced 22 Nobel laureates in the natural sciences, a phenomenon that has attracted widespread attention. This article takes Japan' s Nobel Prize achievements as a starting

point, focusing on analyzing the science and technology policies and pathways since the 1970s that laid a solid foundation for Japan' s construction of a science and technology powerhouse, and summarizes relevant experiences. Japan' s "blowout phenomenon" of Nobel Prizes, to a certain extent, demonstrates the remarkable effectiveness of its science and technology strategies and policies in promoting the construction of a science and technology powerhouse.

Keywords: Japan, Nobel Prize, science and technology policy, science and technology powerhouse
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Japan' s Nobel Prize "Blowout Phenomenon" and Characteristics

The Nobel Prize in natural sciences represents one of the highest levels of international recognition and reward for basic research, and is widely regarded as the ultimate symbol of scientific achievement in contemporary society. The number of laureates has long been considered an important indicator of a nation' s scientific and technological level [1]. Since the Nobel Prize was first awarded in 1901, Japan has produced 22 Nobel laureates in the natural sciences (including Japanese-Americans, hereinafter collectively referred to as "Japanese scholars") (Table 1).

Overall, Japan' s Nobel Prize "blowout phenomenon" exhibits the following notable characteristics:

(1) Steady growth in total awards. Since the mid-20th century, Japanese scholars have won numerous Nobel Prizes in natural sciences, with a particularly significant increase in both number and frequency since 2000. Moreover, there have been many instances where multiple Japanese scholars won in the same year—for example, in 2008, four Japanese scholars received the prize simultaneously, far exceeding the pre-2000 pattern when each award year had at most one Japanese laureate.

(2) Awards concentrated in physics and chemistry. Among Japan' s 22 Nobel Prizes, physics accounts for 50% and chemistry for 32%.

(3) Concentrated time period for award-winning research outputs. The majority of Japan' s Nobel Prize-winning achievements are based on research conducted during the 1970s to 1990s.

(4) Rapid translation of award-winning research into practical applications with tangible results. Due to the forward-looking nature of basic research, its transformation into practical technologies typically requires a relatively long time—usually 20-30 years of development before commercialization. Notably, Japan' s proportion of translating cutting-edge basic research findings into practical technologies within a relatively short timeframe is significantly higher than that of other countries.

(5) Japanese enterprises possess unique vision and foresight in supporting basic research. It is commonly believed that Japanese corporate R&D focuses more on applied technology development than on basic research. However, this situation has been changing with the proposal and implementation of Japan' s "Science and Technology Innovation Nation" strategic objective. Companies such as Shimadzu Corporation and Sony have produced Nobel laureates. In an R&D environment where manufacturing enterprises emphasize applied technology, the fact that companies value and conduct basic research work, as evidenced by their research outputs, demonstrates that Japanese enterprises' competitiveness and sustained development momentum are closely related to their emphasis on and support for basic research while continuously developing and applying new technologies.

(6) Most award-winning scientists hold doctoral degrees from prestigious Japanese universities such as Kyoto University, the University of Tokyo, and Tokyo Institute of Technology. This fact demonstrates, to some extent, that these universities possess distinctive features and strengths in cultivating basic research talent.

Japan' s Nobel Prize "blowout phenomenon" is closely related to its science and technology strategies and policies, and to a certain extent reflects the remarkable effectiveness of Japan' s post-war scientific frontier level and environment for technological development.

Japan' s Policies and Pathways for Building a Science and Technology Powerhouse

"Technology Nation" : Establishing a Mechanism for Introduction, Digestion, Absorption, and Re-innovation

Following World War II, Japan' s series of reconstruction measures enabled it to accumulate substantial economic strength, human resources, and technological foundations. These conditions formed a solid basis for Japan' s Nobel Prize achievements. Japan' s technology introduction was integrated with its "Trade Nation" policy and foreign investment attraction. In 1949, Japan passed the Foreign Trade and Foreign Exchange Management Law, and in 1950 enacted the Foreign Capital Law, taking its first steps toward post-war technology introduction. Through the introduction, digestion, improvement, and utilization of foreign patented technologies and equipment, Japan' s economy recovered rapidly, achieving heavy chemical industrialization and economic takeoff. This not only established the economic conditions for Japan' s investment in science and technology, but also stimulated investment in education and the cultivation of science and engineering talent.

In the 1970s, Japan proposed the "Technology Nation" strategy, adopting comprehensive measures to shift its focus from introducing and imitating industrial technologies to strengthening independent basic research, with continuously increasing investment that enabled technological levels to improve steadily and placed Japan at the forefront of fields such as semiconductors. The government-led "Big Science" development model began to take shape, corporate R&D capabilities gradually strengthened, and university basic research also accumulated momentum—these became the highlights of scientific and technological development during this period. Important policy measures included four key aspects:

(1) Organizing technology foresight to systematically predict and identify key frontier fields. In 1971, Japan launched its first technology foresight initiative, aiming to grasp the trajectory of technological development over the next 30 years to provide a basis for science and technology planning and policy-making. A 1994 evaluation of Japan' s first technology foresight showed that 28% of the predictions had been fully realized and 36% partially realized [2]. This fully demonstrates that technology foresight effectively enables Japan to accurately grasp global trends in science and technology development and supports the government in making timely plans. To date, Japan has conducted ten rounds of technology foresight, continuously adjusting its methodology during this process to adapt to new circumstances and improve accuracy.

(2) Increasing stable investment in basic research. In 1971, the Japanese government proposed a target to raise R&D expenditure to 3% of GDP during the 1970s. Although this was not achieved due to the impact of global economic downturn, Japan still reached 2.11% in 1975 after the first oil crisis, exceeding the combined R&D expenditure of Britain and France [3]. Meanwhile, funding for basic research also continued to increase, accounting for 14.5% of total R&D expenditure by 1987, with a trend of continued growth [4].

(3) Promoting the "Industry-University-Government"collaboration system. In 1981, Japan' s Science and Technology Agency launched the "Creative Science and Technology Promotion System," establishing research groups centered on academic leaders and composed of researchers from enterprises, universities, and national research institutes, creating a fluid and flexible research system. In the same year, the Ministry of International Trade and Industry introduced the "Next-Generation Industrial Basic Technology Research and Development System," focusing on supporting collaborative R&D in next-generation industrial basic technologies such as new materials, biological functions, and new functional components [5]. Additionally, the Science and Technology Conference budget newly established the Science and Technology Promotion Adjustment Fund to support "Industry-University-Government" collaboration in basic and cutting-edge technology research.

(4) State-led and supported Big Science projects. To promote breakthroughs in frontier and major fields and support the enhancement of industrial competitiveness, the Japanese government has led numerous large-scale

industrial technology R&D projects since the 1970s, with the Very Large Scale Integration (VLSI) project as a typical representative. In 1976, the Ministry of International Trade and Industry organized five major companies—Fujitsu, Hitachi, Mitsubishi, NEC, and Toshiba—together with two national research institutes, the Electronic Technology Research Institute and the Computer Research Institute of the Agency of Industrial Science and Technology, to form a research consortium to jointly implement the project. By 1979, the Japanese government and enterprises had invested a total of 72 billion yen (with the government covering 40% and enterprises 60%), yielding over 1,000 patents and successfully enhancing Japan' s industrial competitiveness in the semiconductor sector. By 1989, Japan had captured 53% of the world' s memory chip market, far exceeding the United States' 37% [6].

"Science and Technology Innovation Nation" : Leaping Toward an Innovative Country

Since the 1990s, with the end of the Cold War, the global competitive landscape has changed. Competition and technological protectionism from Europe, America, and other countries toward Japan have intensified, leading Japan to recognize that basic research is the true source of long-term technological and industrial competitiveness. The year 1995 marked an important turning point in Japan' s science and technology development history. In November 1995, the Japanese Diet passed the Science and Technology Basic Law, explicitly proposing the "Science and Technology Innovation Nation" strategy, shifting from a technology-heavy approach to balanced development of both science and technology, with all major fields advancing in unison.

(1) Continuously formulating science and technology basic plans and adjusting the direction of S&T development. Based on the Science and Technology Basic Law, Japan has issued a Science and Technology Basic Plan every five years since 1996 as a stage-specific S&T planning document. Each Basic Plan analyzes the challenges faced at the time, clarifies development goals, and identifies priority development fields (Table 2); simultaneously, each plan strongly emphasizes the importance of basic research and promotes its development comprehensively through funding, talent cultivation, education and research center construction, international cooperation, and other aspects. In the 2nd Science and Technology Basic Plan of 2001, Japan proposed the goal of winning 30 Nobel Prizes within 50 years—the "Nobel Prize Plan"—and introduced numerous specific policy measures around this objective [7].

Table 2: Priority Fields Identified in Japan' s Science and Technology Basic Plans

Science and Technology Basic Plan	Priority Fields Layout
1st	Life sciences, information science, environmental science, nanotechnology and materials
2nd	Life sciences, information and communications, environmental science, nanotechnology and materials science, energy, manufacturing technology, social infrastructure, scientific frontiers
3rd	Green innovation (low-carbon energy, energy efficiency improvement, greening of social infrastructure, etc.), life sciences innovation (disease prevention, early diagnosis, safe and effective treatment, improving quality of life for elderly and disabled persons, etc.)
4th	Technologies necessary for building a "super-smart society" (cybersecurity, IoT, big data analytics, artificial intelligence, etc.), core technologies for promoting new value creation (robotics, sensors, biotechnology, materials nanotechnology, quantum optics, etc.)

(2) Reforming the R&D system to accelerate the transfer and commercialization of research results. In the 1980s, Japan began reforming its R&D system to break down the closed and rigid nature of existing research organizations and stimulate researchers' subjective initiative and creativity. Reform of the science and technology system represents a deeper level of change. In 1997, Japan' s national research institutions and 17 national universities successively introduced a "tenure track system" to promote researchers' creative capabilities and cultivate young scientists. To stimulate the vitality of research institutions and universities, the Japanese government enacted laws in the 1990s allowing university professors and national research personnel to flow between positions, vigorously promoting the creation of new industries from basic research through industry-

university collaboration. In 2004, Japan began implementing the "National University Corporation" system, ensuring universities' independent and autonomous operational efficiency in budget utilization and organizational management. The civil servant status was reformed, introducing competitive systems. Collaboration with enterprises was strengthened, and technology transfer organizations and entrepreneurship centers were established to facilitate the smooth transfer and commercialization of research results [8].

(3) Building national strategic S&T forces to continuously play a leading role in frontier fields. In 2015, Japan introduced the National Research and Development Agency system, granting certain national research institutions the status of "Designated National Research and Development Agency," enabling them to fully function as national strategic S&T forces, actively deploy in major frontier fields, and promote the implementation of national S&T strategies. The RIKEN (Institute of Physical and Chemical Research) serves as a typical example—in its 2018-2025 medium- to long-term plan, the institute clearly identified key research fields including innovative intelligent integration, mathematical creation, life medicine, life functions, neuroscience, quantum optics engineering, and accelerator science, with stable national support for their implementation [9].

Experiences in Building Japan' s Science and Technology Powerhouse

"Industry-University-Government" Collaboration Produces Major Achievements

The "Technology Nation" strategy since the 1970s has generally been characterized by economic development as the driving force, technology development as the goal, and basic research as the prerequisite. An examination of the output process of Japan' s Nobel Prize achievements from the 1970s to 1990s reveals that a considerable portion benefited from the vigorous "Industry-University-Government" collaborative research activities of that era. Application-driven collaborative research, multi-party cooperation, and the philosophy of enlightened enterprises contributing to science are all closely linked to Nobel Prize achievements. For example, Ryoji Noyori, a professor at Nagoya University who won the Nobel Prize in Chemistry in 2001, benefited to some extent from collaboration with industry partners such as Takasago International Corporation and Teijin Limited. Masatoshi Koshiba, a professor at the University of Tokyo who won the Nobel Prize in Physics in 2002 for his work in astrophysics, received not only "Special Research Grants" from the government but also free equipment and experimental facilities from Mitsui Mining & Smelting Co., which provided crucial technical support for instrumentation with its robust technological and processing capabilities. In 2002, Koichi Tanaka won the Nobel Prize in Chemistry as a corporate researcher, highlighting the role of Japanese enterprises in basic research [10].

Japan' s "Industry-University-Government" collaboration system launched after the 1980s, including the "Creative Science and Technology Promotion System," "Next-Generation Industrial Basic Technology Research and Development System," and "Science and Technology Promotion Adjustment Fund," effectively promoted collaboration and enhanced Japan' s basic research capabilities. On the one hand, these systems diversified research funding sources, with enterprises becoming an important funding source for basic research in addition to government investment. A 1989 survey showed that half of the R&D expenditure of major private enterprises was used for basic research [11]. On the other hand, the flexible collaboration system facilitated personnel exchange and knowledge diffusion, promoting talent cultivation and enhancing corporate research capabilities.

International Collaboration Incubates Original Innovation

To compensate for domestic shortages in talent and research facilities and enhance innovation capabilities in frontier fields, Japan initiated a series of international joint R&D projects in the mid-1980s, including the Human Frontier Science Program (HFSP) in 1987, the Supersonic/Hypersonic Technology Project and the Intelligent Manufacturing Systems (IMS) Project in 1989, actively collaborating with research institutions and enterprises in developed Western countries and regions such as the United States, the European Community/European Union, and Canada [12].

After 1995, Japan proposed the "Science and Technology Innovation Nation" strategy, expanding its development focus from technology development to comprehensive advancement in both science and technology. "Grounded in reality, oriented toward the frontier, dynamically adjusted, and consolidating the foundation" became the distinctive features of the new strategy, which were reflected to some extent in the Nobel Prize achievements since the 1990s. These achievements include application-oriented advanced technologies based on international collaboration such as the "high-brightness blue light-emitting diode," frontier explorations such as research on neutrino oscillation phenomena, and studies like autophagy mechanisms and induced pluripotent stem cells that possess both clear application value and strong frontier characteristics. These achievements combine applicability and cutting-edge nature, include both internationally collaborative and domestically produced results, and demonstrate a diversified pattern across fields such as energy, materials, space, and life sciences.

In 2007, Japan's Ministry of Education, Culture, Sports, Science and Technology established the "World Premier International Research Center Initiative" (WPI), creating an excellent research environment through focused and concentrated support to attract and gather world-class frontline researchers, forming world-leading research hubs centered on high-level researchers [13], hoping thereby to enhance Japan' s basic research capabilities and national innovation capacity. In

2012, Japan' s largest basic research funding agency—the Japan Society for the Promotion of Science (JSPS)—launched the "Core-to-Core Program," aiming to strengthen collaboration between Japanese universities and research institutions and 15 developed countries or regions including the United States, Canada, Australia, and Europe in scientific frontier fields. By establishing and strengthening research networks between Japan and these countries or regions, the program seeks to maintain and enhance Japan' s universities' and research institutions' collaboration levels with other scientifically advanced countries or regions over a long period, and support short-term collaborations for their domestic and international researchers to build domestic and international collaborative research networks [14].

Continuously Strengthening Basic Research Investment to Enhance Original Innovation Capability

Under the new science and technology policy system constructed by the "Science and Technology Innovation Nation" strategy, Japan has not only proposed policy approaches to enhance basic research capabilities in each Science and Technology Basic Plan, but has also actively implemented various policy measures to win more Nobel Prizes.

(1) Continuously increasing funding to ensure support for basic research and strengthen support for large-scale scientific facilities. By 2016, Japan' s research and development (R&D) expenditure had reached 3.42% of its gross domestic product (GDP) [15], with the 5th Science and Technology Basic Plan further proposing to achieve a target of 4% during the plan period [16]. Among this, funding for basic research accounts for 14.5% of total expenditure (exceeding China' s 5.1%) [17]. Moreover, Japan has continued to increase funding for the operation of large-scale scientific facilities, enacting the Law on the Promotion of Shared Use of Specific Cutting-Edge Large-Scale Research Facilities to provide stable financial support from the state for major facilities such as the large synchrotron radiation facility Spring-8, the X-ray free electron laser facility SACLA, the supercomputer "K," and the high-intensity proton accelerator facility J-PARC.

(2) Continuously increasing researcher density, strengthening youth talent cultivation, and building a researcher support system. In 2015, Japan' s total number of researchers was approximately 660,000, far lower than China' s 1.619 million and the United States' 1.352 million (2014 figures). However, its density of R&D personnel per 10,000 economically active population reached 103.5, higher than China' s 19.1 (2014) and the United States' 86.7 (2014), and continues to show an increasing trend [17]. In 2002, Japan launched the "21st Century Center of Excellence Program" (COE), providing focused funding in several cutting-edge disciplines at major national, public, and private universities to establish world-class research bases and cultivate creative young researchers. In 2007, the "Global Cen-

ter of Excellence Program" (GCOE) was introduced to further cultivate internationally competitive young talent based on the COE program [18]. In 2010, Japan released the Long-Term Policy for Strengthening Basic Research, proposing to increase cultivation of young talent oriented toward basic research, including establishing a new hiring system for young talent, providing independent research environments for young researchers, and ensuring an annual salary system for young talent; simultaneously, it proposed building a research support system by increasing the number of assistants assigned to researchers, enabling them to concentrate on their research work [19].

After more than 60 years of accumulation since World War II, marked by Japanese scientists winning Nobel Prizes successively in the early 21st century, Japan' s basic research has begun to bear fruitful results, attracting worldwide attention. Japan' s experiences in building a science and technology powerhouse after World War II—vigorously raising innovation awareness, creating an academic atmosphere conducive to innovation, establishing mechanisms that facilitate innovation, providing relatively stable funding and environment, and strengthening international exchanges—offer valuable insights for consideration.

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"Constructing Nation via S&T Strategy" and "Nobel Prizes Planning" —Japanese Way to World S&T Power

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Abstract: Since Nobel Prize was first assigned in 1901, 22 Japanese scientists have achieved this honor, which has led wide interests over the world. This article, beginning from this phenomenon, focuses on analyzing Japanese S&T policies and development path since 1970s, which set significant foundation for the country to be an S&T great power, and summarizes some important experience. Japan' s great achievement in Nobel Prizes indicates that those policies are apparently effective in consolidating Japan' s S&T abilities.

Keywords: Japan, Nobel Prizes, S&T policies, S&T great power

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