Knowledge Structuring of Major Scientific Discoveries and Their Value Realization Pathways: A Case Study of Patents by Japanese Nobel Laureates in Physiology or Medicine (Postprint)

Authors: Zhelin Zhu, Liu Haibo, Permission

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Abstract

[Purpose/Significance] Major scientific discoveries are of great significance for promoting scientific and technological progress and enhancing influence. Exploring the fundamental pathways for knowledge structuration and value realization of major scientific discoveries can provide important insights for deepening the reform of the scientific research system in China.

[Method/Process] This study examines invention patents for which Japanese Nobel laureates in Physiology or Medicine serve as inventors or right holders. By analyzing data on patent application time, application quantity, maintenance duration, number of inventors, and ownership status, it reveals the patterns and characteristics of how scientists achieve major scientific discoveries through their research work.

[Result/Conclusion] The formation of major scientific discoveries represents the unity of continuity and discontinuity, the unity of quantitative and qualitative change, and the unity of technological accumulation and technological revolution. The open nature of patents can facilitate the structuration, publicization, and socialization of knowledge represented by major scientific discoveries, thereby feeding back into the advancement of the entire disciplinary field and the enhancement of public welfare.

Full Text

Research on Knowledge Structuring and Value Realization Path of Major Scientific Discoveries: Taking Patents of Japanese Nobel Laureates in Physiology or Medicine as an Example

Zhu Zhelin[1], **Liu Haibo**[2,3], **Xu Ke**[4] [1] School of Marxism, Renmin University of China, Beijing 100872 [2] Institute of Science and Development, Chinese Academy of Sciences, Beijing 100190 [3] School of Public Policy and Management, University of Chinese Academy of Sciences, Beijing 100049 [4] School of Innovation and Entrepreneurship, Shandong University, Qingdao 266237

Abstract: [Purpose/Significance] Major scientific discoveries are of great significance in promoting scientific and technological progress and enhancing influence. Exploring the knowledge structuring and basic pathways for value realization of major scientific discoveries can provide important insights for deepening China's scientific research system reform. [Method/Process] This study examines invention patents with Japanese Nobel laureates in Physiology or Medicine as inventors or rights holders, analyzing data on patent application timing, quantity, maintenance duration, number of inventors, and ownership status to reveal the regular characteristics of scientists' research work leading to major scientific discoveries. [Result/Conclusion] The formation of major scientific discoveries represents the unity of continuity and discontinuity, the unity of quantitative and qualitative change, and the unity of technological accumulation and technological revolution. The open nature of patents can promote the structuring, publicization, and socialization of knowledge represented by major scientific discoveries, feeding back into the entire discipline field and the improvement of social public welfare.

Keywords: Nobel Prize; scientific discovery; social value; patent

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The Nobel Science Prize is widely recognized as the highest honor in contemporary natural science and an important symbol of human original innovation [1]. In recent years, in addition to academic value, the Nobel Prize evaluation criteria have increasingly focused on the social value of award-winning research. Particularly for the Nobel Prize in Physiology or Medicine, which is most closely related to human survival and aims to recognize important discoveries or inventions in physiology or medicine, its award-winning achievements have profoundly influenced humanity's exploration of life and health and even the direction of civilization. The transformed achievements have become urgently needed drugs or treatment methods to help humanity overcome once-incurable diseases, advancing the cause of public health.

Some scholars have revealed the relationship between patent data analysis and major scientific discoveries. For example, using patent data of Nobel Science Prize laureates since the 21st century, they have explored the scientific nature of Nobel achievements and proposed that although physics, chemistry, and physiology themselves belong to basic sciences, their trends of differentiation, intersection, and expansion have intensified, resulting in more and broader new fields and achievements extending and transforming toward technical science and engineering technology [7]. Other scholars have taken Nobel Prize winners as examples to explore the paths and models for transforming scientific discoveries into products [8], while still others have inferred why a very small number of scientists with original creativity in the biomedical scientific community become Nobel laureates in Physiology or Medicine by analyzing scientists' output [9].

Overall, current research using patent data remains limited in quantity and can be expanded in two aspects: First, due to institutional changes, rapid technological progress, and social development in recent years, all of which have certain impacts on major scientific discoveries, it is necessary to supplement data from recent years to reflect the latest development trends. Second, most existing research is universal and fails to distinguish key differential factors such as the nationality of winners and award categories, making it necessary to conduct typical studies on specific countries and fields.

Therefore, to more clearly summarize the basic pathways through which the patent system organizes knowledge and realizes commercial value from major scientific discoveries, this paper selects invention patents with Japanese Nobel laureates in Physiology or Medicine as inventors or rights holders as typical samples. By analyzing the years, quantity, and ownership of patent applications, it reveals the regular characteristics of scientists' research work leading to major scientific discoveries and proposes relevant countermeasures and suggestions, aiming to provide reflection and decision-making support for the country to promote basic scientific research and innovation development in science and technology.

1 Overview of Research Achievements and Their Value of Japanese Nobel Laureates in Physiology or Medicine

As the most authoritative, prestigious, and influential award in the contemporary field of natural science, the Nobel Prize in Natural Sciences not only highly recognizes scientists and their research achievements but is also regarded as an important indicator reflecting a country's strength and status in science and technology. The main reasons for selecting Japan as a research sample are: First, existing Nobel Prize research typically focuses on Europe and America, with insufficient attention to Asia-Pacific countries. Japan is China's neighbor. Although its legal and institutional systems differ from China's national conditions, compared with Europe and America, Japan, also part of Asia, shares certain cultural similarities with China, making experience borrowing more feasible. Second, Japan's scientific and technological achievements are obvious to all. Data shows that as of 2019, a total of 27 Japanese individuals (including two Japanese-Americans) have won the Nobel Prize, including 24 in natural sciences, ranking second only to the United States and marking Japan's entry into the ranks of world-leading scientific and technological nations, thus providing a relatively sufficient sample for research [10]. Since the 21st century, four Japanese scientists—Shinya Yamanaka, Satoshi Ōmura, Yoshinori Ohsumi, and Tasuku Honjo—have won the Nobel Prize in this field.

The research achievements and their social value of the three scientists selected for this study are summarized as follows:

Shinya Yamanaka, winner in 2012, is one of the founders of induced pluripotent stem cells (iPS cells). In 2007, his research team discovered a method to induce human epidermal cells to exhibit embryonic stem cell activity characteristics through experiments on mice. This method can transform stem cells into heart and nerve cells, providing tremendous assistance for researching treatments for currently incurable cardiovascular diseases [11]. iPS cells have many advantages that embryonic stem cells lack. iPS cells derived from the patient's own body and re-implanted after in vitro operations will greatly reduce immune reactions [12].

Satoshi Ōmura, winner in 2015, established many original methods for screening natural active substances and discovered more than 130 structural types and 330 new active compounds [13]. The Avermectin discovered by Ōmura is hailed as one of the most significant inventions for humanity since penicillin in the 20th century. According to a World Health Organization report, in 1997 alone, 33 million people were saved from blindness. Subsequently, the WHO included Ivermectin in the global elimination program for onchocerciasis [14].

Tasuku Honjo, winner in 2018, first discovered the PD-1 protein present on the surface of T cells by applying subtraction hybridization technology in mouse apoptotic cell hybridomas, thus opening the prelude to research on the PD-1 target. This research made outstanding contributions to inhibiting substances that suppress human immune capacity and clarifying their mechanisms, developing the cancer drug Opdivo (Nivolumab), and establishing "cancer immunotherapy." Tumor immune checkpoint therapy is also regarded as one of the most promising tumor treatment methods in the future, as it can effectively overcome the drug resistance problems of existing tumor targeted therapy drugs (including targeted monoclonal antibodies) [15].

2 Patent Status and Characteristics of Japanese Nobel Laureates in Physiology or Medicine

As an important system for protecting and promoting innovation, patents are a crucial pathway for integrating and summarizing innovative knowledge generated from scientific research into technically structured solutions with commercial application value. Patents can systematize scattered knowledge into well-structured, closely related, and significantly valuable knowledge systems, featuring both openness and private rights. This system can not only bring economic benefits to inventors and their teams but also facilitate knowledge disclosure and dissemination, enhancing overall social public welfare.

Using the “InnoJoy” global patent search platform, this study searched for U.S. authorized patents using the English names of the four scientists mentioned above as keywords and “inventor” or “applicant (rights holder)” as search conditions. The results showed that Yoshinori Ohsumi had zero patent data as an inventor or applicant, providing no researchable patent samples. Therefore, this paper selected three scientists—Shinya Yamanaka, Satoshi Ōmura, and Tasuku Honjo—as research objects. By analyzing specific data on patent application timing, quantity, maintenance duration, number of inventors, and ownership status, this study explores the development patterns of innovative activities conducted by Nobel laureates.

2.1 Distribution of Patent Application Timing and Quantity

Patent application timing and quantity are important indicators for analyzing and evaluating scientists’ research cycles and output efficiency. The distribution of patent application timing and quantity in the United States for the three scientists is shown in Figure 1 [Figure 1: see original paper].

2.1.1 Patent Quantity and Award Cycle Ōmura first applied for a patent in 1981 and won the award in 2015, a span of 33 years, while his continuous patent application activity as an inventor or rights holder in the United States lasted 37 years. Between 1982 and 2017, Ōmura participated in 67 invention patents that were applied for and granted. Honjo first applied for a patent in 1986 and won the award in 2018, a span of 32 years, with continuous patent application activity lasting 31 years. Between 1986 and 2016, Honjo accumulated 39 invention patents as an inventor or rights holder. Yamanaka first applied for a patent in 2003 and won the award in 2012, a span of nearly 10 years. As an inventor or rights holder, he continuously applied for patents over 16 years from 2003 to 2018, obtaining 36 invention patents.

2.1.2 Temporal Fluctuation in Innovation Output The patent output of the three Nobel scientists shows obvious fluctuations, with years of zero patent applications being common, presenting two trend types: (1) Relatively stable type of patent application quantity change. Honjo had no patent applications for six consecutive years from 1988 to 1993, but over the 30 years up to 2016, he basically maintained an application rate of 2-3 patents every other year. (2) Explosive fluctuation type of patent application quantity change. Ōmura had seven years without patent applications during his 37-year span from 1981 to 2017, and only 10 patents were applied for during the 15-year period from 1986 to 2001. However, between 2002 and 2015, he applied for 39 patents, with application peaks appearing between 2002 and 2004. Yamanaka had four years without patent applications during his 16-year span from 2003 to 2018, but his patent applications increased significantly between 2008 and 2014, with 29 patents applied for during these five years, though this growth trend did not continue afterward.

It can be found that from their first patent application to winning the award, they experienced a long-term, continuous but unstable process, reflecting the unity of slow development and leapfrog development [16]. Specifically, two characteristics are presented: (1) Long-term nature. Some scholars have proposed the concept of "discovery period," referring to the time Nobel laureates in natural sciences experience from beginning their award-winning research to achieving award-winning results [17]. Existing research has found that Honjo's discovery period from focusing on molecular immunology research to publishing results in *Immunology* was 28 years. The patent data in this study reflects a discovery period of 32 years. Considering the time interval from patent application to authorization, the "discovery period" reflected by patents and papers shows similarity in specific timing, indicating a certain correlation between patent data and major discoveries and demonstrating that using patent data to explore major scientific discoveries has scientific validity. (2) Continuity. Nobel scientists have continuous patent applications, but they seem unstable. The continuity of patent applications aligns with the continuity of scientific research. Nobel scientists' exploration of certain fields is continuous, but this continuity does not need to be measured by indicators like "patent applications every year." Such quantity fluctuations align with the uncertainty of scientific research output, and patents, as one form of scientific research output, have application fluctuations that conform to scientific research, especially the characteristics of major scientific research activities.

2.2 Distribution of Patent Citations and Maintenance Duration

Patent citations and maintenance duration are important indicators for evaluating patent quality and can also be used to evaluate the market value or technical influence of research output.

2.2.1 Patent Citation Status Scholars have already noted the relationship between the academic influence of research output and the possibility of winning the Nobel Prize, finding that among Nobel candidates, the higher the single highest citation frequency, the greater the probability of winning the Nobel Prize [18]. Compared with papers, patents are also a form of knowledge expression, and the process of scientists applying for patents can also be viewed as a process of knowledge accumulation. To highlight the overall citation status of patents, this study accumulated the citation status of patents applied for by the three scientists in the same year, calculating the total citations of their annual patent applications. The data shows (see Figure 2 [Figure 2: see original paper]) that patents with the three scientists as inventors all have records of single or single-year patents cited more than 100 times. Among them, Honjo had eight years where the cumulative citations of applied patents exceeded 100 times. Ōmura's patents applied for in 2002 had a cumulative citation count of 238 times. Yamanaka had four years where the cumulative citations of applied patents exceeded 100 times, with the cumulative citations of patents applied for in 2005, 2006, and 2009 all exceeding 250 times, and approaching 350 times in two of those years.

2.2.2 Patent Maintenance Duration Numerous studies have shown that patent maintenance duration (patent age) is positively correlated with patent quality [19-20]. On the one hand, patent maintenance requires certain fees, so the longer the maintenance time within the statutory protection period, the higher the patent's quality and market value [21]. On the other hand, patent maintenance duration also determines the time period during which patents generate economic benefits [22]. High-quality patents also indirectly indicate that the research results themselves have certain social attention and broad commercial prospects. Analyzing the patent maintenance duration of the three Nobel scientists shows that as of July 2021, among Honjo's cumulative 39 invention patents, 20 patents have become "invalid." However, among these 20 expired patents, 12 expired due to the expiration of the statutory protection period, meaning that 60% of the expired patents are high-quality or long-duration patents that became "passively invalid." Among Ōmura's cumulative 67 invention patents, 53 patents have become invalid, of which 9 expired due to the expiration of the statutory protection period, indicating that 15% of patents can be maintained until the statutory protection period expires, while the existing 14 valid patents also have a high possibility of continued maintenance. All 36 of Yamanaka's invention patents remain "valid," including patents applied for as early as 2003. Combined with patent application quantities, the patent maintenance duration of the three Nobel scientists reflects high patent quality, and patent quality can reflect innovation quality [23], which fully demonstrates that innovation quality may be one of the important evaluation criteria for the Nobel Prize.

2.3 Inventor Status

The number of patent inventors is not only an important indicator reflecting the scale of scientific research teams but can also directly reflect the size of scientists' core research teams.

(1) Based on the analysis of patent citations and maintenance duration, the relevant patents of the three scientists were screened again to further explore the characteristics of high-quality R&D results. Specifically, using a single patent citation count exceeding 50 times as the screening standard, the results showed that 17 high-citation patents had citation counts exceeding 50 times, with an average of 129.5 times. Among them, Yamanaka had 6, Honjo had 9, and Ōmura had 2. These patents were all team outputs, with an average of 4 inventors, fully demonstrating that high-quality results that may win the Nobel Prize are almost impossible to achieve through "solo efforts." High-level research teams have become

the basic unit of scientific research activities, and team collaboration is an important guarantee for high-quality innovation.

(2) Using patent maintenance duration reaching the statutory protection period expiration as the basis to screen long-duration patents, the study further explored the team size issue in high-quality innovation. The results showed that there were 21 long-duration patents, of which Honjo had 12 and Ōmura had 9, all of which expired due to the expiration of the statutory protection period. The average number of claims was 11, and the average number of inventors was 3. As of July 2021, Yamanaka's patents applied for in the United States as an inventor have not yet reached the statutory protection period expiration, with an average of 13 claims and an average of 4 inventors. It is worth noting that there is no positive correlation between innovation level and research team size in this study. On the contrary, "small but refined" inventor teams are the most significant commonality of high-quality patents, reflecting that the scale of scientists' core R&D teams has a "miniaturization" characteristic. Therefore, in basic research fields, it is necessary to dialectically view the relationship between research team size and research capability level, avoiding using research team size as the sole criterion for measuring or judging research capability level and attempting to improve research capability through simply expanding research team size.

2.4 Research Entities

Based on patent ownership, according to China's current system, patent rights can belong to individuals or entities. When ownership belongs to an entity, it is usually a service invention. Analyzing from the perspective of patent ownership characteristics, the aforementioned 38 high-quality patents with high citation counts or long maintenance duration include only one patent each owned by Honjo and Ōmura personally, while the remaining 36 patents belong to service invention achievements, accounting for nearly 90%. This means that service inventions remain the most important channel for major scientific discoveries. From the perspective of legal entities, the rights holders of these service inventions belong to universities, research institutions, and enterprises.

Specifically, Yamanaka's high-citation patents as an inventor are all owned by Kyoto University. Honjo's high-citation patents as an inventor are all owned by Ono Pharmaceutical, while his long-duration patents belong to Kyoto University, Ono Pharmaceutical, and Asubio Pharma (a subsidiary of Daiichi Sankyo). Ōmura's high-citation and long-duration patents as an inventor are all owned by Kitasato Institute. On the one hand, the service invention system can have a positive impact on major scientific discoveries. Taking Ōmura's Avermectin-related technology as an example, Avermectin is the only biological pesticide with an annual output value reaching 3 billion yuan, generating enormous social and economic benefits. As a cooperative R&D partner for Avermectin, Merck & Co. obtained huge economic returns, while Kitasato Institute also received considerable dividends, which economically supported the development of Kitasato Institute, Kitasato Hospital, and Kitasato University, representing typical high-quality innovation by research institutions [24]. In recent years, many studies have questioned the service invention system, with some scholars pointing out that the ownership system of service inventions affects scientists' innovation enthusiasm and proposing to optimize the existing system through "mixed ownership" of service inventions [25]. However, Japan currently implements a "selective employer original ownership principle" for service inventions [26], and based on the patent ownership status of Japanese Nobel laureates, there seems to be no evidence that patent ownership inhibits innovation.

On the other hand, market entities such as enterprises can also play important roles in major scientific discoveries. During the incubation period of PD-1/PD-L1 technology, patent applications mainly came from Ono Pharmaceutical and Professor Tasuku Honjo of Kyoto University. Between 1996 and 2016, Ono Pharmaceutical and Professor Honjo jointly applied for 8 patents related to PD-1, PD-L1, or PD-L2. This indicates that high-quality patents can originate from different innovation entities. Re-examining the relationship between research "national teams" represented by universities and research institutions and market entities represented by enterprises should become an important issue in high-quality innovation development.

3 Patent Value Realization Path of Japanese Nobel Laureates in Physiology or Medicine

Based on the analysis of the distribution and characteristics of Japanese Nobel laureates' patents in Physiology or Medicine, several issues need to be recognized regarding major scientific discoveries and realizing related value through patents.

3.1 Uncertainty of Innovation Output and Long-term Nature of Research Support

Scientific innovation begins with questions and is nurtured through accumulation [27]. Analysis of the patents of Japanese Nobel laureates in Physiology or Medicine reveals that long-term, continuous but unstable patent applications are the most significant characteristic of the three scientists' research output. Therefore, the long duration, high cost of researchers' energy and effort, and likely long-term absence of outstanding results are common features of major scientific discoveries. Adequate funding and continuous investment in related resource guarantees are the cornerstones of ensuring high-quality innovation.

Moreover, compared with direct financial investment, it is important to recognize the significant role of government in strengthening institutional and policy guarantees. Research points out that Japanese scientists' frequent awards are due to many factors, among which the "Nobel Prize Plan" led by the Japanese government is considered one of the most powerful policy measures [28]. At the same time, Japan adheres to a "science and technology nation" development strategy, providing stable funding for universities and offering institutional and economic guarantees for innovation output. Since 1995, the Japanese government has also formulated the "Science and Technology Basic Plan" based on the "Science and Technology Basic Law," clarifying at the legislative level that the government should attach importance to and strengthen basic research, with institutional support in funding, talent cultivation, and infrastructure construction.

In summary, major scientific discoveries require researchers to invest substantial research time, energy, and even a spirit of adventure, repeated trial and error, and even accumulation lasting 10, 20 years or more. They also include the accumulation of overall social scientific capabilities, scientific traditions, scientific ideas, and personal experiences. The formation of major scientific discoveries or pioneering cognitive frameworks is rooted in scientists' long-term, continuous scientific research activities on the one hand, and on the other hand, depends on scientific and reasonable, stable, and orderly research management by research institutions. Therefore, China's current scientific and technological innovation endeavors not only need to increase support for basic research and form a group of researchers engaged in long-term basic research but also need to solve the long-term and continuous problems of research investment in basic research through legislation. In research management, it is necessary to establish corresponding innovation systems and scientific management mechanisms to ensure major scientific and technological innovation breakthroughs and their promotion and application [29]. Basic research management must establish reasonable error-tolerant mechanisms, fully recognizing that the output of major scientific discoveries has fluctuating characteristics, eliminating quick success and instant benefits, encouraging "ten years to sharpen one sword," and forming a research management system more in line with the laws of scientific research.

3.2 Important Roles of Various Organizations in Innovation Output

3.2.1 Organizations (Entities) as Guarantees for Major Scientific Discoveries Although the Nobel Prize attributes honors to individuals, the study found that most patent rights of the three Nobel scientists belong to research groups or sponsoring entities, meaning most high-quality patents are service inventions. This fully demonstrates that the entities behind scientists play a collaborative and supportive role in major scientific discoveries. Scientists' "solo efforts" are not feasible and require strong support measures. Scientists' personal reputations and stable, high-quality research teams cooperate and coordinate with each other, jointly ensuring the high precision and professionalism of research projects. Entities can provide stability in research funding sources and various guarantees of human and material resources. The two parties cooperate for mutual benefit, achieving a 1+1>2 effect that facilitates continuous innovation and iteration of knowledge.

3.2.2 Diversification of Innovation Entities Favors Innovation Output

The study found that the patent rights of the three Nobel scientists belong to different innovation entities such as universities, research institutions, and enterprises, indicating that the entities of Japan's major scientific discoveries show a diversified development trend. In contrast, China's basic research investment entities are mainly the central government, with expenditure entities mainly being universities and research institutions. The relatively high proportion of research expenditures by China's universities and research institutions in the country's total basic research expenditures indicates that "national teams" represented by universities and research institutions remain the main force engaged in basic research, with market entities playing a limited role in basic research. China should also strive to achieve diversification of innovation entities. As pointed out by President Xi Jinping at the Academicians' Conference and the 10th National Congress of the China Association for Science and Technology, "National laboratories, national research institutions, high-level research universities, and leading technology enterprises are all important components of the national strategic scientific and technological force."

Therefore, it is necessary to re-examine the relationship between research institutions and universities representing the scientific research national team and market entities representing enterprises, promote the optimal allocation and resource sharing of research forces among research institutions, universities, and enterprises, promote diversification of basic research funding sources, and support and encourage enterprises and society to invest in targeted basic research [30].

3.3 Relationship Between Patent Private Rights and Social Public Interests

In modern society, knowledge production has become a visualization process based on experimental foundations, with scientific experiments replacing contemplation and speculation, collective witnessing replacing personal meditation, and scientific knowledge becoming a public product with public attributes [31]. Undoubtedly, patents are an efficient system that enables knowledge to be disseminated, acquired, maintained, and used by society for accumulation, recognition, and utilization. Although patents, as a form of knowledge structuring, have private rights attributes, they do not contradict the public attributes of scientific research as a knowledge production process.

On the one hand, patents are a path for integrating, disseminating, and developing knowledge. In Nobel Natural Science Prizes that focus mainly on basic research, scientists' research and knowledge innovation principles and original intentions are often difficult for the public to understand and accept. Even for the Physiology or Medicine Prize, which is most closely related to life, its award-winning reasons still appear obscure to non-professional citizens. Patents' re-integration and summarization of knowledge innovation can be reflected in the exchange value of knowledge products. The patent layout of Nobel laureates enables these major scientific discoveries to enter commercial production as quickly as possible, making the public aware that this innovation may mean hope for saving their own or their relatives' lives. Patents enable scientists' inventions to obtain long-term, society-oriented disclosure through short-term commercial monopoly, creating and deriving new social demand content that even the designers may not have initially anticipated.

On the other hand, patents are a win-win in the contradiction between "monopoly" and "openness." The patent system is an institutional arrangement that conducts interest measurement, selection, and integration between the monopoly interests of patentees and social public interests to achieve dynamic balance. The key is the balance between the interests of patentees and the public interest and broader public welfare based on this. Essentially, patent law needs to promote the appropriate flow of innovation resources and fully guarantee the public's appropriate access to patented technology [32]. Scientists can also actively promote research results from the laboratory to the market through patent applications while directly facing social public interests and engaging in scientific research work, achieving a balance between personal interests and social public interests. When knowledge can be structured and used to produce more knowledge, at the social value level, the importance of knowledge dissemination is even greater than knowledge acquisition. It can be said that patents provide a pathway for knowledge marketization and maximize the public value of knowledge.

4 Conclusion and Outlook

4.1 Conclusion

After more than 40 years of effort, China's basic research has developed rapidly and made considerable progress. In 2021, China officially entered the ranks of innovative countries, and scientific and technological innovation under the leadership of the Communist Party of China has achieved remarkable accomplishments attracting worldwide attention [33]. However, compared with the long-term goals of ranking among the top innovative countries by 2035 and building a world science and technology power and a modern socialist power by 2050, and compared with the practical needs of implementing new development concepts, building a new development pattern, and effectively supporting high-quality economic and social development, there are still several key institutional and mechanism bottlenecks. In contrast, the rapid rise of Japanese scientists in winning Nobel Prizes has attracted high attention from the international academic community. Domestic researchers have also conducted extensive studies on this, linking it with the thought-provoking "Qian Xuesen's Question" and triggering various discussions and reflections in academic and social circles, which can provide enlightenment for China's current deepening of scientific research system reform [34].

Meanwhile, the formation of major scientific discoveries is also the unity of continuity and discontinuity, the unity of quantitative and qualitative change, and the unity of technological accumulation and technological revolution. While scientists engage in scientific research work oriented toward social public interests, actively promoting research results from the laboratory to the market through patent applications is a beneficial way to achieve a balance between personal interests and social public interests. The openness of patents can promote the efficient structuring, publicization, and socialization of knowledge represented by major scientific discoveries, thereby feeding back into their own and the entire discipline field and enhancing social public welfare.

4.2 Outlook

This study takes invention patents with Japanese Nobel laureates in Physiology or Medicine as inventors or rights holders as research objects to reveal the regular characteristics of scientists' research work and major scientific discoveries and proposes countermeasures and suggestions. The study has certain innovations in research perspective but still has aspects that can be further deepened and strengthened in future research: First, in terms of sample selection, among countries or regions with many Nobel Natural Science Prize winners, Japan is already the most similar to China's national conditions, but there are still many differences, and its experience cannot be "copied entirely." Future research can more meticulously explore the impact of institutional differences on major scientific discoveries to supplement this study. Second, selecting the Physiology or Medicine Prize as a sample mainly considers its huge social benefits from achievement transformation, but the sample size of Japanese winners in this category is still insufficient. Although the conclusions have certain scientific validity, their universality and generalizability still need to be further verified in future research through studies on relevant samples from more countries or regions.

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Liu Haibo: Responsible for initial topic selection and guidance;
Xu Ke: Responsible for partial initial draft writing, paper structure optimization, and revision.

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