Nobel Prize Postprints in the Era of Big Science

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Abstract

[Purpose/Significance] To foster a scientific and technological environment capable of cultivating Nobel Prize laureates, China must clearly understand the profound impact of the Big Science era on the Nobel Prize, thereby enabling targeted policy support. [Method/Process] The author examines relevant theoretical cases and data to investigate the influence of the Big Science era on the Nobel Prize. [Results/Conclusion] The impacts manifest in three primary aspects: First, scientific research organizations have become increasingly complex and large-scale, resulting in escalating controversies regarding scientists' awards; second, science is no longer merely scientists' personal interest-driven research, but increasingly depends on social support, with governments playing a pivotal role in the award process; third, science and technology have become inseparable, with numerous laureates receiving awards through applied research. The award controversies surrounding scientists such as Tu Youyou, the Japanese government' s Nobel Prize promotion initiative, and the substantial number of awards for semiconductor research in the twentieth century respectively provide compelling evidence for these three major impacts.

Full Text

The Nobel Prize in the Era of Big Science

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Abstract

[**Purpose/Significance**] To cultivate a scientific environment capable of nurturing Nobel laureates, China must clearly understand how the era of big science has profoundly influenced the Nobel Prize, thereby enabling targeted policy support. [**Method/Process**] This paper examines relevant theoretical frameworks, case studies, and data to explore the impact of the big science era on the Nobel Prize. [**Result/Conclusion**] The impact manifests in three principal aspects:

First, scientific research organizations have become increasingly complex and large-scale, leading to growing controversies over prize attribution. Second, science is no longer merely the pursuit of individual scientists' interests but relies heavily on social support, with governments playing crucial roles in scientists' path to the prize. Third, science and technology have become inseparable, with numerous laureates receiving awards for applied research. The award controversy surrounding Tu Youyou, Japan' s Nobel Prize revitalization plan, and the numerous prizes awarded for semiconductor research in the twentieth century respectively illustrate these three major influences.

Keywords: big science; Nobel Prize; influence
Classification Number: G321.9

Since the establishment of the Nobel Science Prizes in 1901, the landscape of science has undergone tremendous transformation, with the most significant change being the transition from the era of small science to the era of big science.

The concept of "big science" was first proposed by D. Price of Yale University in 1962. Big science primarily emerged from national research systems during World War II and took shape after the war (following the successful implementation of the "Manhattan Project" during World War II, science gradually transitioned from the era of "little science" to the era of "big science," representing what Price called a "mutation" [1]). In the small science era, research projects were typically conducted by individual scientists or small groups who formulated questions, executed research independently, and explored solutions, guided by the pursuit of scientific truth and working primarily within single disciplines. Big science, in contrast to small science, refers to large-scale scientific research activities that are technically challenging, require complex experimental equipment and numerous scientific personnel, and involve substantial research funding. By 1996, UNESCO had already adopted the term "big science" in its annual reports, and the concept has since become widely accepted. This paper discusses three major changes in scientific research in the big science era compared to the small science era and examines how these changes have influenced the Nobel Prize.

1. From the Era of Small Science to the Era of Big Science

In the small science era, research topics were not overly difficult, did not require many sophisticated and expensive instruments, and science was not highly socialized. However, in the big science era, the reality of how science operates has changed dramatically. Against the backdrop of explosive growth in both scientists and scientific achievements, scientific activities have been restructured through increasing specialization and professionalization of scientists. This transition has produced three 标志性 changes relative to the small science era, each exerting profound influence on the Nobel Prize.

1.1 The Complexification of Internal Relations within the Scientific Community

When the Nobel Prize was first established in 1901, the organization and division of labor in research were far less complex than today. As more personnel became involved in scientific research, the scientific community has exhibited new characteristics. On one hand, the collective and cooperative nature of the scientific community has become more pronounced, primarily due to the deepening and integration of modern science, along with further disciplinary differentiation and technological specialization. In a research project, each person is often only responsible for one specific aspect. On the other hand, social stratification exists within the scientific community, and because science has become a profession and a means of livelihood for some scientists, relationships among members are no longer simple and objective in the evaluation of scientific achievements and the awarding of scientific prizes, instead displaying certain complexities and subtleties. This internal stratification also means that "the greater a person' s power in the group, the more outstanding students they can select and the more funding they can mobilize." The new forms of research organization and power structures in the big science era have laid the groundwork for certain controversies in Nobel Prize awards.

1.2 Scientific Development' s Heavy Reliance on Social Support

Although the Nobel Prize was originally designed as an award for individual scientists, society today plays an increasingly significant role in science. A scientist' s research capability is only a necessary condition for winning the prize. In the small science era, scientists' pursuit of truth and intense curiosity about unknown fields were the internal driving forces of scientific development. However, the driving force for modern scientific development increasingly comes from external social needs. With its powerful capacity to transform society and nature, modern science has impacted every sphere of social life. Meanwhile, a nation' s scientific and technological strength ultimately determines its international competitiveness, and both the state and society are managing and guiding science in various ways. Scientists can no longer quietly pursue "science for science' s sake" free from external noise and interference. They exist not only as individuals but also play important roles as members of social communities, and individual freedom in scientific research has become increasingly weakened. "The scientist is merely a passive tool, like a dictionary consulted to provide correct answers to various demands." The foundation of the ideal of value-neutral pure science no longer exists, and the concept of "pure science" has been replaced by "basic science" as opposed to applied science. We find that in the big science era, the role of society behind Nobel-winning scientists has become increasingly significant.

1.3 The Increasing Inseparability of Science and Technology

The Nobel Prize is no longer merely a "pure science" award. Traditionally, science and technology have been qualitatively distinct. Science is a knowledge system about nature that reveals objective laws and seeks truth, while technology generally refers to various craft operation methods and skills developed from production practice experience and natural science principles. Science generally does not consider direct production applications, whereas technology is knowledge applied in production practice—knowledge about how to transform production factor inputs into outputs. Science is humanity' s means of understanding the world; technology is humanity's means of transforming it. However, these distinctions have gradually blurred in modern society. Modern science is science equipped with modern technology; technology has become an important component and element of scientific research—this is the trend of scientific technologization. Meanwhile, the scientification of technology refers, on one hand, to existing technologies being elevated to technical sciences that, guided by corresponding basic sciences, form systematic technical knowledge systems that in turn improve and enhance existing technologies. On the other hand, it means that technological inventions and creations are derived from existing basic scientific research achievements—that is, technological progress is guided by scientific progress. Modern science can no longer be pure science; it is inevitably closely linked with technology. For example, Shuji Nakamura, a 2014 Nobel laureate in Physics, did not even hold a doctoral degree; he was an engineer who developed LED technology in a company, a far cry from the traditional image of a scientist.

2. The "Insufficient" Nobel Prize: Award Controversies in the Era of Big Science

In the big science era, internal relations within the scientific community have become more complex, with obvious power structures, and Nobel Prize selections have been questioned for involving non-scientific factors. In plain terms, the Nobel Prize has become somewhat "insufficient" to distribute. The number of scientists and scientific achievements has grown dramatically in the big science era, and not all scientists who have made major contributions can receive this honor—some outstanding scientists inevitably fail to win. Moreover, as Nobel Prizes increasingly depend on collective cooperation, they cannot be awarded to research collectives, leaving some scientists feeling the system is unfair.

Both the number of scientific researchers and scientific achievements have risen sharply in the big science era. According to OECD statistics , the average number of researchers per thousand population in developed economies recognized for high levels of scientific and technological development, such as the United States and Japan, has remained stable with an upward trend, and the overall situation in OECD countries also shows stable growth. The situation is shown in Figure 1.

Figure 1 [Figure 1: see original paper] Trends in Researchers per Thousand Population in OECD Countries, the United States, and Japan

As can be seen, since the 1980s, the number of researchers per thousand population in the United States, Japan, and OECD countries overall has been on a significant upward trend.

While the number of researchers per thousand has increased, so has national scientific and technological innovation capacity. The TPF (Triadic Patent Families) is the main indicator used by the OECD to measure a country' s scientific and technological innovation capacity. We can observe that since 1981, the number of TPFs in the United States, Japan, and Europe has generally shown a stable upward trend, as shown in Figure 2:

Figure 2 [Figure 2: see original paper] Trends in TPF Numbers in the United States, Japan, and the EU (28 countries)

In other words, as the number of scientific researchers has increased, science and technology have indeed continued to develop. If humanity is creating more and more valuable scientific achievements, then the Nobel Prize established in the small science era clearly cannot honor all sufficiently great successes. In the big science era, the number of scientific researchers is constantly increasing, and the quantity of scientific achievements is also continuously growing, which provides a macro-level explanation for controversies in current Nobel Prize awards: On one hand, humanity' s scientific and technological achievements are increasing, but the limited number of Nobel Prizes cannot cover all great "Nobel-level" achievements. On the other hand, achieving new scientific and technological breakthroughs requires more and more researchers, but the Nobel Prize can be awarded to a maximum of only three recipients.

Statistics on all Nobel Science Prize laureates (including Physics, Chemistry, and Physiology or Medicine) from the prize' s establishment through 2016 show a total of 590 individuals over 116 years, averaging five laureates per year. When we visualize the data by counting laureates in five-year intervals, we can clearly see that the number of Nobel laureates shows an obvious upward trend, with significantly more laureates in the post-war big science era than before the war, and recent years showing high numbers hovering at elevated levels, as shown in Figure 3 [Figure 3: see original paper].

Figure 3 [Figure 3: see original paper] Trends in the Number of Nobel Prize Winners

We can see that the number of Nobel laureates has indeed increased with the rising number of scientific researchers in the big science era, but the Nobel Prize can be awarded to a maximum of only three recipients. Faced with the growing number of scientific researchers in the big science era, the Nobel Prize has become "insufficient." This inevitably generates controversy in prize awards.

Comparing the number of world scientific papers published between 2003 and 2013 makes the "insufficiency" of the Nobel Prize even more apparent. From 2003 to 2013, Nobel Prize awards approached their maximum of three recipients without significant growth. However, in terms of scientific paper publication—a key indicator of a country's scientific level—major countries maintained relatively high growth rates. Over the decade, world papers grew at an average annual rate of 7%, and even the United States, with its large base, maintained an average annual growth rate of 3.2% in paper publications.

In the big science era, science is developing rapidly, but the number of Nobel Prize recipients remains relatively limited. Therefore, it is highly questionable whether the limited Nobel Prize can serve as a measure for science with unlimited growth potential. Meanwhile, because the Nobel Prize does not have a collective award category, the work of some scientists has been overlooked.

In 2015, Chinese scientist Tu Youyou received the Nobel Prize in Physiology or Medicine, the first time a Chinese scientist had won a Nobel Science Prize. While receiving praise, Tu Youyou also faced criticism. She has been a controversial figure in Chinese academia, considered by many as "insufficiently indifferent to fame and fortune" and "stubborn in personality." In 2003, when Tu Youyou won the Mahidol Award, she had some conflicts with relevant departments [2]. The antimalarial drug research project, code-named "Project 523," lasted thirteen years with over a thousand participants, completing multiple essential steps including drug screening, separation and purification, structural identification, chemical synthesis, formulation, and clinical trials. "The debate over the attribution of artemisinin achievements has a long history, being intense even before Tu Youyou received the Lasker Award, and continuing after she received the Nobel Prize. The controversy seems to focus on whether the award should be given to a collective or several individuals, or should be given to Tu Youyou alone [3]."

In fact, this is not an award controversy unique to China with its deep collectivist tradition. In the big science era, the issue of individual versus collective attribution in Nobel Prize awards is a universal problem. Research projects such as the Superconducting Super Collider (SSC) in physics, the Hubble Space Telescope program in astronomy, the Human Genome Project (HGP) in bioscience, and the Ocean Drilling Program (ODP) in earth science are all multinational scientific projects requiring massive investment. Such scientific research cannot be completed by individuals alone, and how to award contributors presents a major challenge.

In 2012, CERN discovered the Higgs boson, popularly known as the "God particle." The following year, Peter Higgs and François Englert shared the Nobel Prize in Physics for predicting the Higgs boson. However, more than 6,000 scientists at CERN participated in this work. Higgs' s theoretical contribution to the discovery of the Higgs boson has also been questioned, considered pioneering but incomplete. Many scientists believe experimental physicists at CERN made greater contributions. After all, this great research lasted nearly 40 years and consumed the efforts of a generation of scientists. If left unrewarded, it would likely demoralize scientists. Particle physics research represents the trend of scientific research globalization and has formed a mature international cooperation mechanism. Particle physics represents the most cutting-edge basic research in humanity' s quest for scientific understanding of the world, with experimental equipment becoming increasingly large-scale. The technology, funding, manpower, and materials required to build and maintain experimental equipment far exceed what any single country can afford, so scientists from various countries must and can only unite to conduct research. If such experimental physics is merely considered work that will not receive the highest honors, it is clearly unfair to the vast number of experimental physicists who work diligently [4].

Gunnar von Heijne, Chairman of the Nobel Committee for Chemistry, addressed the issue of individual versus collective awards in the big science era: "If the number of laureates becomes four, five, or more, it still doesn' t solve the problem. You always need to draw a line, and above that line, there will always be people with close contributions. Every year, someone questions whether the right people were selected, and we don' t make decisions about who wins lightly. We discuss continuously, a process that may last for several years [5]." Objectively speaking, as the highest award in natural science, the Nobel Prize indeed struggles to address team contributions in the big science era. Von Heijne also believes: "Perhaps in the future, awards will be given to organizations" [5]. Of course, the Nobel Prize Committee has rigorous procedures for selecting laureates from among many outstanding scientists. However, this phenomenon demonstrates that the Nobel Prize' s award rules, established in the small science era, are somewhat ill-suited to the big science era, as they struggle to honor collectives that have made tremendous contributions to science, and the relatively limited number of awards cannot satisfy the increasingly large scientific community.

3. Government and the Nobel Prize: Japan' s Nobel Prize Revitalization Plan

In the big science era, the interaction between society and science has become increasingly frequent. Society is actively influencing science, and science is no longer just the cause of scientists alone—the Nobel Prize is no exception. Domestic R&D investment can well reflect society' s support for scientific research. R&D funding in a country or region mainly comes from government, enterprise, and non-governmental social support. Let' s examine the data for the United States, Japan, OECD countries, and the EU 28 countries, as shown in Figure 4 [Figure 4: see original paper]:

Figure 4 [Figure 4: see original paper] Trends in Domestic R&D Investment in the United States, Japan, EU (28 countries), and OECD Countries

We can see that domestic R&D investment in Japan, the United States, the EU, and OECD countries has remained relatively stable at high levels. Japan' s investment far exceeds that of other developed countries, which may be a key factor causing its Nobel Prize "explosion." Massive social investment is not a sufficient condition for scientists to win Nobel Prizes, but it is a necessary condition. In the big science era with sharply rising research costs, without social support, scientific research becomes extremely difficult. The more research funding a society can provide and the better the research conditions, the greater the probability of producing Nobel Prizes. It would also defy common sense if Nobel Prizes frequently went to countries with small scientific and technological investment that do not emphasize research. In other words, if a country develops a culture that values scientific research in order to win the honor of the Nobel Prize, then to some extent, the purpose of establishing the Nobel Prize has been achieved.

When the Nobel Prize was first established, it was only an award for individual scientists, and scientific development in the small science era relied more on the self-organization of the scientific community. However, with the arrival of the big science era, scientific strength has gradually become an important indicator for evaluating comprehensive national power. The Nobel Prize is one of the ways human society evaluates and rewards the highest levels of intellectual activity. Although there are awards in the scientific community with longer histories and richer prizes than the Nobel Prize, the Nobel Prize remains the universally recognized supreme symbol of scientific achievement. The number of Nobel Prizes a country has won has become a recognized important indicator for measuring a country' s scientific and technological level and policy success or failure. Therefore, in the big science era, countries around the world follow their Nobel Prize situations with great enthusiasm, take pride in winning Nobel Prizes, and actively formulate corresponding laws and regulations in hopes of winning as many Nobel Prizes as possible.

As an important manifestation of scientific strength, the Nobel Prize has also received high attention from governments, with winning Nobel Prizes even becoming a goal of government science and technology policy. Since the Meiji Restoration, Japan' s scientific and technological development has always kept pace with Europe and the United States, implementing a catch-up strategy, which has also made Japan' s basic research relatively weak. However, insightful people in Japanese political circles were not satisfied with immediate technological advantages and also hoped to "surpass Britain and catch up with the United States" in scientific originality [6]. The Japanese government proposed in its "Second Science and Technology Basic Plan" in 2000 the goal of "producing about 30 Nobel laureates within 50 years." Between 2000 and 2016, 17 Japanese (Japanese nationals and people of Japanese descent) have won Nobel Prizes . In the nearly 100 years before the Japanese government proposed this plan, only five Japanese had won Nobel Prizes. The Nobel Prize "explosion" phenomenon is the product of accumulated efforts, but we must not ignore the policy influence behind all this. In March 2001, the Japanese Cabinet passed the second "Science and Technology Basic Plan." The plan, implemented from April 2001, 预定投入 GDP 的 1% in government research and development funding, totaling 24 trillion yen, representing a 40% increase in research investment compared to the first five-year plan [7]. In 2007, the Japanese government launched the "World Premier International Research Center Initiative" (WPI), whose two most prominent features are stable financial support and internationalization. In 2007, the Ministry of Education, Culture, Sports, Science and Technology selected six research institutions in Japan' s basic research advantage fields to implement ten years of stable support, with 1.3 billion yen (approximately 110 million RMB) per institution per year, with the possibility of extension to 15 years for outstanding performers. The initiative aims to create a research environment close to that of Europe and the United States to attract global talent to conduct scientific research in Japan, trying to overcome cultural disadvantages in talent attraction. These six institutions all represent Japan' s highest research level in their respective fields [8]. In 2009, to counter the impact of the global financial crisis triggered by the U.S. subprime mortgage crisis, the Japanese government launched an even larger-scale science and technology investment plan, the most eye-catching being the "Funding Program for World-Leading Innovative R&D on Science and Technology." The Ministry of Education, Culture, Sports, Science and Technology organized experts to select 30 research teams and leading scientists likely to achieve world-class levels within 3 to 5 years, investing 200 billion yen (approximately 16 billion RMB) [8].

In addition to these measures, the "Second Science and Technology Basic Plan" also proposed that Japan should have more research hubs attractive to overseas talent and provide convenient working conditions for outstanding overseas talent to make Japan a gathering place for talent from Asia and around the world. The International Institute for Management Development (IMD) World Talent Report shows that although Japan' s comprehensive competitiveness has continuously declined from its 1990s high of first place, its science and technology 单项实力 has consistently ranked second only to the United States [7]. Among Japan' s many myths, science and technology is the only myth that has not been shattered, enabling Japan' s manufacturing technology and production efficiency to maintain world leadership.

In the big science era where science and society are inseparable, governments consciously support scientific development for the better development of their nations. Catch-up countries like Japan even formulate science and technology policies with the goal of winning Nobel Science Prizes. This must be said to be a major change relative to the self-organized flourishing of the small science era. It should be said that in the big science era, Nobel Science Prizes can only be born in scientifically powerful nations that invest heavily in research; it is almost impossible for scientists without strong social support to win Nobel Prizes. Countries like Hungary that shone brightly in the small science era have become dimmer in the big science era due to serious insufficiency in social investment.

4. The Inseparability of Science and Technology: From Semiconductor Applied Research to the Nobel Prize

In traditional Western understanding, science and technology are dichotomous. Science is considered a sacred metaphysical enterprise, while technology is a material production capacity. Science is a form of human activity through which increasingly perfect and accurate knowledge can be obtained to understand natural phenomena past, present, and future, increasing humanity' s ability to adapt to and change the environment and human characteristics. Technology, through designing and manufacturing various artificial things, aims to control nature, transform the world, increase social wealth, and improve human welfare. The author has counted the cases of technology winning the Nobel Prize in Physics since 1901 . The criterion for distinguishing technological awards is whether keywords such as "invent" or "technology" are explicitly mentioned in the English citation.

Table 6 Technologies Awarded the Nobel Prize in Physics Over the Years

Year	Technology
1908	Invention of color photography reproduction
1909	Invention of wireless telegraphy technology
1912	Invention of automatic lighthouse regulator
1939	Invention of the cyclotron
1953	Invention of the phase-contrast microscope
1956	Research on semiconductors and invention of the transistor
1960	Invention of the bubble chamber
1961	Invention and research of optical techniques for Hertz resonance in atoms
1968	Hydrogen bubble chamber and its analysis technology, discovery of resonance states
1971	Invention of holography
1978	Basic inventions and discoveries in low-temperature physics
1981	Development of high-resolution electron spectroscopy
1981	Development of laser spectroscopy
1986	Development of the scanning tunneling microscope
1989	Development of the separated oscillatory fields method and its use in hydrogen masers and other atomic clocks
1989	Development of ion trap techniques
1992	Invention and development of particle detectors, particularly the multiwire proportional chamber
2000	Invention of the integrated circuit
2005	Contributions to the development of laser-based precision spectroscopy, including optical frequency comb technology
2009	Breakthrough achievements in "the transmission of light in fibers for optical communication"
2009	Invention of semiconductor imaging devices—charge-coupled devices

Year	Technology
2010	Outstanding experiments on graphene that can be used to develop new materials and produce innovative electronic products
2014	Invention of blue light-emitting diodes (LEDs), enabling a new energy-saving light source

By examining the technological awards of the Nobel Prize from its establishment in 1901 through 2016, we can see that a total of 26 inventions have been awarded the Nobel Prize in Physics. If we analyze this in 50-year spans, we find that between 1901-1950, only four inventions received the Nobel Prize in Physics, while between 1951-2000, there were 14 such awards, and since 2000, there have already been five awards. Clearly, in the second 50-year period representing the big science era, numerous Nobel Prizes in Physics have been awarded to inventions. Physics is the model that all sciences emulate and has a deep tradition of theoretical research. In the past, there was considerable controversy when inventions like the automatic lighthouse regulator won awards. However, in the post-war big science era, many inventions have received the Nobel Prize in Physics.

Nevertheless, since the Nobel Prize has always been regarded as the highest achievement in scientific awards and has consistently adhered to science' s own evaluation standards, the increase in technological awards should be seen not as the technologization of the prize, but rather as a necessary adjustment made by the Nobel Prize in response to the increasingly blurred boundaries between science and technology in the big science era. The recognition of technological awards both acknowledges the scientific nature of technological achievements and adapts to the demands of the times. The technologization of the Nobel Prize precisely reflects the technologization of science and the scientification of technology.

The continuous awarding of Nobel Prizes for semiconductor applied research after the war provides excellent confirmation of this trend.

In July 1945, Bell Labs in the United States established a solid-state physics group led by Shockley to conduct transistor-related research. Shockley and his colleagues focused on semiconductor materials such as silicon and germanium, exploring the possibility of using semiconductor materials to create amplification devices, and finally succeeded in manufacturing the first "PN transistor" in 1950. Shockley, Bardeen, and Brattain won the Nobel Prize in Physics in 1956 for inventing the transistor [9]. The invention of the transistor opened a new era in semiconductor science and technology development. For more than half a century, semiconductor science and technology has integrated materials, physics, devices, and processes, becoming an excellent example of coordinated development through the intersection and penetration of science and technology.

However, we must be 清醒地意识到 that Shockley from Bell Labs was actually conducting applied research, with the ultimate goal of manufacturing commercially valuable transistors rather than creating knowledge.

The invention of the transistor was an epoch-making great invention, and the birth of the integrated circuit was a technologically innovative milestone of scientific significance. In the early 1950s, driven by requirements for high reliability and miniaturization of electronic equipment, people began research on circuit integration of discrete semiconductor devices. Jack Kilby of Texas Instruments (TI) proposed a solution for the full solid-state circuitization of discrete semiconductor devices. He attempted to fabricate passive components such as resistors and capacitors together with active devices on the same semiconductor substrate, and finally completed the first demonstration experiment of an integrated circuit oscillator in the laboratory in September 1958, marking the birth of the integrated circuit [10]. Subsequently, a series of new process technologies including epitaxy, oxidation, diffusion, and photolithography established the silicon planar transistor process, opening the prelude to integrated circuit development centered on silicon planar devices. For this historically significant innovative work, Kilby was awarded the Nobel Prize in Physics in 2000. The integrated circuit not only led to the emergence of microelectronics technology and promoted the development of information science and technology, but also transformed human life dramatically. Judging from the enormous impact integrated circuits have had on human civilization and social progress and the huge economic benefits they have brought, making them worthy of the Nobel Prize in Physics seems well-deserved. But ultimately, this research was too technological. From 1958 to 2000, it took a full 42 years to win the award, far longer than the waiting time for other semiconductor research awards. One possible reason is that at the time, the integrated circuit was indeed an important technological innovation rather than a major scientific discovery. However, this invention that profoundly changed the face of human life eventually received the Nobel Prize in Physics.

In the 1980s, Isamu Akasaki and Hiroshi Amano, working at Nagoya University in Japan, chose gallium nitride materials to challenge the world problem of blue light-emitting diodes. In 1986, the two first produced high-quality gallium nitride crystals, and in 1989, they successfully developed blue LEDs for the first time. Starting in 1988, Shuji Nakamura, then working at Nichia Corporation, also began developing blue LEDs. Like his Japanese colleagues, he chose gallium nitride materials, but his technical approach was different. In the early 1990s, Nakamura also developed blue light-emitting diodes [11]. This invention benefits all humanity by creating white light sources in a completely new way. When Nakamura invented the blue LED, he was merely a company employee without a doctoral degree, but this did not diminish the greatness of this technology.

All these Nobel Prizes were obtained during the research and development of semiconductor materials. In fact, this fully complies with Nobel' s will: "to reward those who have made outstanding contributions to mankind in the previous year."Objectively speaking, these are all technological studies that seemingly should receive some engineering award rather than a Nobel Science Prize. In the small science era, we could not find Nobel Prizes in Physics with such a strong "technological flavor," but in the big science era where the boundaries between science and technology are increasingly difficult to draw, such Nobel Science Prizes have become extremely common.

The big science era has had a tremendous impact on the Nobel Science Prize. Scientists can no longer be heroes independent of groups, science can no longer be separated from and indeed depends on social support, and science and technology can no longer be clearly dichotomized. The transformation of scientific eras has given Price food for thought about changes in scientists' responsibilities and spirits. As the supreme symbol of scientific awards, the Nobel Prize must complete its self-transformation and adjustment in the revolution and transition of scientific eras. Scientific activities under group research, research behavior under social influence, and the current state of technology-oriented science all urgently require the Nobel Prize to reestablish its evaluation philosophy and value system in the new era. In the big science era, how the Nobel Prize maintains its independence amidst its close connections with society, and how it continues to uphold the neutrality and objectivity of scientific value amid widely permeated values, deserves even more attention. It is believed that with historical development, the Nobel Science Prize in the new era will undergo new changes, but two basic elements will remain unchanged: the truth-seeking spirit as the core of scientific spirit will not change, and the principle in Nobel' s will of rewarding those who have made the most outstanding contributions to mankind will not change.

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Notes: To ensure uniform sources and avoid errors caused by different statistical departments' survey methods and data sources, unless otherwise specified, this paper uses data from the OECD database (Organization for Economic Co-operation and Development). Its survey objects cover 34 market economy countries and numerous intergovernmental international economic organizations worldwide, and its data well includes control variables such as R&D investment needed for this study. This paper mainly uses OECD survey data from 1981 to 2012. Because statistical data before 1981 is scarce, objective comparison is difficult. The problems illustrated in this study can already be explained using data from 1981 to 2012.

The average number of scientific researchers per 1,000 people in a country or region.

Patents protected in the European Union, the United States, and Japan.

Referenced from https://www.nsf.gov/statistics/2016/nsb20161/#/data. NSF currently publishes statistics up to 2013.

R&D investment as a percentage of a country or region' s GDP.

Referenced from http://www.nobelprize.org/.

Referenced from https://knoema.com/IMDWTR2016/imd-world-talent-report-2015?location=1000260-japan.

Referenced from http://www.nobelprize.org/.

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

Source: ChinaXiv —Machine translation. Verify with original.