Scientometrics (2023) 128:6129–6145
https://doi.org/10.1007/s11192-023-04831-1

Mapping the scientific and technological landscape: an analysis of Nobel Prize-producing institutions

Lingche Zhang[1,2] **· Qiuju Zhang**[1]

Received: 17 March 2023 / Accepted: 3 September 2023 / Published online: 20 September 2023

Abstract
As a prestigious international accolade in science and technology, the Nobel Prize laureates gain significant attention from researchers. Scholars strive to distill patterns and insights from various aspects of this award. This article specifically examined the institutions generating Nobel Prize-winning work, discussed the distribution and mobility patterns of laureates among different types of institutions to roughly map the scientific and technological landscape. Our research findings indicate that universities are the primary generators of Nobel Prize-winning work, accounting for approximately 70% of the institutions, and demonstrate particular adeptness in "attracting" and "retaining" laureates in mobility analysis. The remaining 30% of institutions include governmental research institutions, enterprises, and non-profit organizations. Notably, North America and Europe lead the count with over 300 counts of prize-producing institutions each, establishing themselves as major centers for Nobel Prize production. However, over the past decade, there has been a slight decline in the aggregation effect of the distribution of these institutions.

Keywords Nobel Prize · Prize-producing institution · Types of institution · Mobility pattern · Aggregation effect · Scientific strategies

Introduction

Since its inception in 1901, the Nobel Prize Committee has awarded the Nobel Prize in Physics 116 times, in Chemistry 114 times, and in Physiology or Medicine 113 times. As the most prestigious international prize in science and technology, the number of Nobel Prizes is considered a crucial indicator for measuring a country's strength in scientific and technological innovation. Nobel laureates, as pioneers and trailblazers in their respective fields, represent the foremost component of a country's human resources in science and technology. With the escalating prominence of the Nobel Prize, scholarly inquiries

✉ Qiuju Zhang
zhangqiuju@casisd.cn

Lingche Zhang
lingche21@mails.ucas.ac.cn

[1] University of Chinese Academy of Sciences, Beijing, China

[2] Institute of Science and Development, Chinese Academy of Sciences, Beijing, China

pertaining to this prestigious award have increasingly surfaced within the academic sphere. Columbia University sociology professor Harriet Zuckerman is one of the first researchers to study Nobel laureates, she analyzed the patterns of productivity, collaboration, and authorship among laureates (Zuckerman, 1967) and the stratification system within the scientific community (Zuckerman, 1977). Later studies could be broadly categorized into three areas: Nobel laureates, prize-winning works, and awarding periods. Research on Nobel laureates has focused on their ages, nationalities, educational backgrounds, collaborating patterns and mentoring relationships. For example, Jin and Liu (2006) found that 88.5% of Nobel laureates did their prize-winning work between the ages of 28–52. Xu and Yuan (2004) analyzed the nationalities of laureates in Physics and identified a geographical transitional phenomenon in physics research. Cai and Chen (2012) analyzed data from 1901 to 2011 and reported that 94.57% of Nobel laureates had a doctoral degree, while 2.09% and 2.36% had master's and bachelor's degrees, respectively. Chan et al. (2015) found that Nobel laureates collaborate less with new coauthors after winning the prize, but show greater loyalty to pre-award collaborations, with the intensity and duration of pre-award cooperation increasing the likelihood of remaining in the coauthor network post-award, implying higher loyalty to the laureate. Chariker et al. (2017)found that some Nobel laureates have mentoring relationships with each other, forming high-level academic communities, such as those at Cambridge University in the late nineteenth century and Columbia University in the early twentieth century.

Studies on the prize-winning works have been categorized into major scientific discoveries, major theoretical breakthroughs, and major technological and methodological inventions (Yuan & Zhang, 2002). Moreover, scholars have carried out statistical analyses on the prize-winning works to explore the developmental laws of different disciplines and identify hot topics in frontier fields (Gao, 2003; Song & Shi, 2008; Zhang et al. 2001). Regarding the awarding period, relevant statistics show that the average research period of prize-winning works is 7.8 years(Jiang & Chen, 1994),while the average recognition period of the works is 16.7 years(Jin & Liu, 2006).

The official website of Nobel committee only records the affiliation institution of Nobel laureates, identifying the prize-producing institution is a crucial problem, and our review revealed a lack of research of prize-producing institution. Schlagberger et al. (2016) determined the institutions that produced Nobel Prize-winning achievements by searching for the papers of Nobel laureates and identifying the institutions to which the authors belonged, as recorded on the papers. Heinze and Fuchs (2022) used data from Nobel Foundation's website, enriched by American National Biography, Encyclopedia Britannica the American Institute of Physics etc. to analyze the distribution patterns of Nobel laureates among countries and institutions. While Schlagberger et al. limited their analysis to data from 1994 to 2014, and in the absence of Heinze's data (currently unavailable), our research seeks to amass a thorough dataset from 1901 to 2022, the methodology of which will be elaborated upon subsequently. Our objective is to juxtapose the institutions where the Nobel-recognized research took place against the institutions with which the laureates were affiliated when they received their accolades. For a nuanced understanding, we have categorized these institutions into universities, governmental research institutions, non-profit organizations, enterprises and others. Through this classification, we aim to shed light on the mobility patterns between these two stages across different institutional types and discern the shifts over four historical periods.

As researchers, it is incumbent upon us to acknowledge and address the limitations of our study. In this regard, it is essential to recognize that our analysis of the Nobel Prize is susceptible to significant biases, primarily due to the exclusion of critical fields and the limited scope

of the database employed. Consequently, the findings derived from our research should be interpreted with caution, as they represent a constrained examination of the vast and intricate scientific and technological landscape.

Methodology

Data collection

The official website of the Nobel Prize Committee (https://www.nobelprize.org/) provides information on the institutions with which Nobel laureates are affiliated at the time they receive the prize. By examining the work description available on the website, we can determine the period during which the prize-winning works were produced and then use this information to identify the institutions where the laureates were employed based on their work history. In cases the official website lacks information on the production time and academic history of some Nobel laureates, we search for information on Wikipedia (https://www.wikipedia.org/) and the Encyclopedia Britannica (https://www.britannica.com/) to supplement the missing data.

Data process

Institutions are categorized as universities, governmental research institutions, non-profit organizations, enterprises and others based on their attributes. Some institutions have undergone name changes throughout history, so we merge different names of the same institution into a single entity, such as merging Kaiser-Wilhelm-Society into Max Planck Society, the Rockefeller Institute for Medical Research into Rockefeller University, and the Soviet Academy of Sciences into the Russian Academy of Sciences.

Multiple head count

When counting institutions and countries, certain principles are followed: first, if a prize-winning work was produced in multiple institutions, and a Nobel laureate was affiliated with more than one institution, each institution is counted once. Second, the property "country" is assigned according to the country to which the institution belongs. Third, if multiple Nobel prize-producing institutions of a laureate belong to different countries, each country is counted once, but if the institutions belong to the same country, that country is counted only once. Fourth, for multinational enterprises such as the International Business Machines Corporation, which has its headquarters in the United States but produces a prize-winning work at its Zurich research laboratory, both the United States and Switzerland are recorded. Fifth, if multiple individuals share the same award in a year, all prize-producing institutions related to them are recorded. As a result of these principles, the number of Nobel prize-producing institutions, affiliated institutions, and countries is greater than that of actual Nobel Prize awards.

Data analysis

This section presents a descriptive analysis of the data collected, aiming to give an overall depiction of Nobel prize in natural sciences. We introduce the awarding situation in the

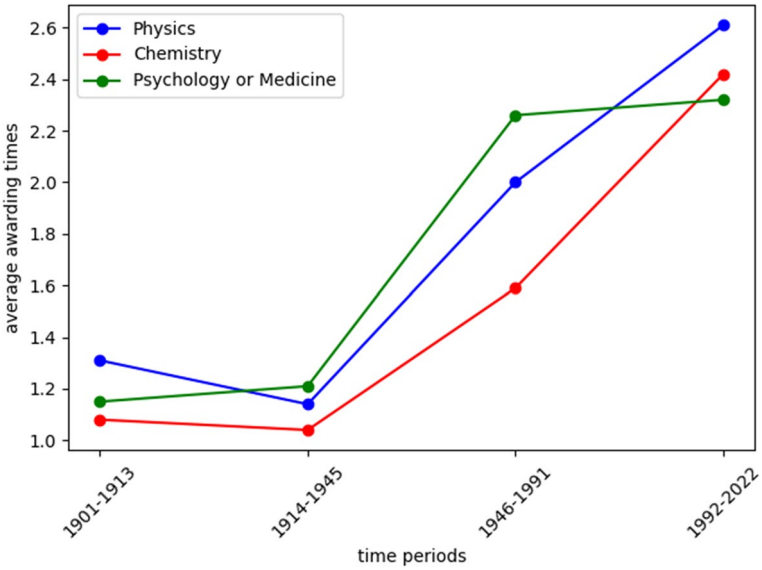

Fig. 1 Average Awarding times of Nobel prize in physics, chemistry, and psychology or medicine in four periods

first part, the distribution patterns in the second part, the variation trend in the third part and the mobility patterns in the fourth part.

Awarding situation of Nobel Prize in natural sciences

The Nobel Prize in natural sciences has been awarded 222 times in physics, 191 times in chemistry, and 225 times in physiology or medicine. Analyzing the distribution of the prizes over time can provide insights into the evolving trends within these disciplines. Notably, we observed that as time progresses, it has become increasingly common for multiple individuals to share the same Nobel Prize.

We divided the Nobel awarding time span into four periods, taking into account significant historical events. Before World War I, the average frequency of Nobel Prize awards remained below 1.4 in all disciplines, with a slight decline observed during the two wars. Subsequently, there was a notable increase in award frequency during the two post-war periods. The data indicates that before the Second World War, Nobel prizes were primarily awarded to single individuals in each discipline. However, the situation changed significantly afterward, with a shift towards more individuals sharing the same prize in that year. Particularly during the fourth period, the average awarding times exceeded 2.2 times in all three disciplines, with physics having the highest average awarding time, reaching 2.6 times (Fig. 1).

The shifting trend in Nobel Prize awards may be indicative of the rise of the big science era, leading to increased complexity and challenges in scientific research. This has resulted in a greater emphasis on collective efforts within the scientific community. However, the Nobel Prize's traditional focus on honoring individual achievements may not fully align with the current context of collaborative scientific endeavors. As scientific progress

Table 1 Count of different types of prize-producing institutions and the most productive ones

Type	Count	Most productive one	Count
University	481	Harvard university	35
Governmental research institution	102	National laboratories of DOE Max Planck Society	18
Enterprise	49	Bell Labs	14
Non-profit institution	36	Institute Pasteur	9
Others	20	/	/
Total	688	/	/

Table 2 Most productive institutions in three disciplines

Discipline	Name	Count
Physics	National laboratories of DOE	17
Chemistry	Harvard University	10
Physiology or Medicine	Harvard University	15

relies more on teamwork and collective contributions, the Nobel Prize may appear somewhat limited in acknowledging the full scope of modern scientific accomplishments (Pan & Zhou, 2016).

Distribution of prize-producing institutions

Through multi-dimensional analysis, we observed an aggregation effect within prize-producing institutions, evident in their type and geographical distribution. Universities emerged as the primary producers of Nobel Prizes, with a significant concentration of prize-producing institutions located in North America and Europe.

From 1901 to 2022, a total of 638 Nobel Prizes in natural sciences were awarded, with a count of 688 prize-producing institutions. Among them, universities stood out as the most productive type, followed by governmental research institutions, enterprises, and non-profit organizations. Harvard University ranked as the most prolific institution overall (Table 1), and it also led in two specific disciplines: chemistry and physiology or medicine (Table 2). The most productive governmental research institutions were the National Laboratories of the Department of Energy (DOE) in the US and the Max Planck Society in Germany. Bell Labs of Lucent Technologies excelled as the most productive enterprise, and the Institute Pasteur in France emerged as the most productive non-profit institution.

In physics, aside from universities (66%), governmental research institutions (19%) and enterprises (11%) also make significant contributions. Governmental institutions, often majorly funded by government departments, align with strategic national needs, generating ground-breaking achievements. Enterprises, focused on application research, foster the transformation of these achievements into practical use. Bell Labs, Lucent Technologies' R&D division, has contributed to 15 physics Nobel Prizes.

In chemistry, except for universities (72%), the governmental research institutions (16%) are the main birthplace of prize-winning works. The MRC Laboratory of Molecular

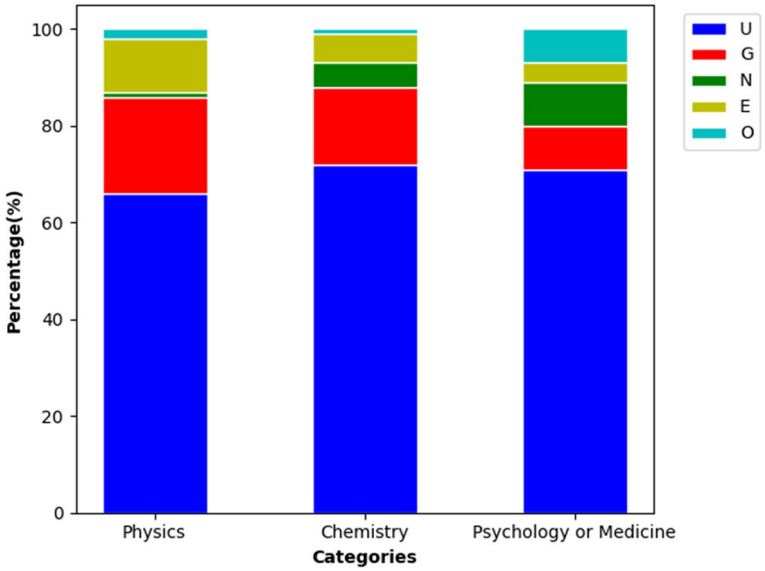

Fig. 2 The proportion of different types of prize-producing institutions in three disciplines. Note: U,G,N,E,O are the first letters of the five types of institutions, and represent them respectively

Biology in UK and the Max Planck Society in Germany are the most representative governmental research institutions. Both of them have produced 9 Nobel Prize achievements in chemistry.

In physiology or medicine, aside from universities (71%), the distribution of other institutions is relatively balanced. Non-profit organizations and governmental institutions each account for 9%, while others (6%) exceed enterprises (4%). This field, vital to human health, draws extensive attention, prompting various types of institutions to prioritize pertinent basic research (Fig. 2).

The continents of North America and Europe are home to the majority of institutions that produce Nobel laureates. With the exception of Antarctica, all other continents boast Nobel prize-awarded institutions, although North America and Europe are the predominant leaders in this respect.

North America institutions accounts for 315 in total. The United States holds a prominent position with 306 count, while Canada contributes 9 to this total. Europe's prize-producing institutions' count is led by the United Kingdom with 92, followed by Germany with 70, and France with 37, among other nations.

Turning our attention to Asia, Japan stands out as the continent's most prolific country in terms of prize-producing institutions, accounting 20 in total. In Oceania, Australia and New Zealand have 7 and 1 prize-producing institutions recorded respectively. In South America, Argentina has 2 prize-producing institutions. Finally, representing the continent of Africa, South Africa has 1 count.

This overview provides insight into the geographical distribution of prize-producing institutions and highlights the leading role North America and Europe play in producing esteemed award-winning research and innovation (Fig. 3).

Among these countries, we have chosen six leading countries for further analysis regarding the composition of their Nobel Prize-producing institutions. This selection

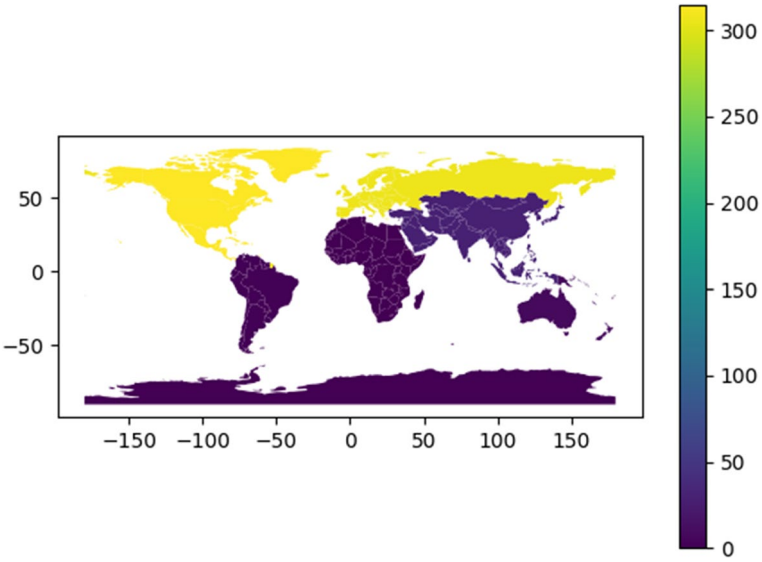

Fig. 3 The distribution density of Prize-producing institutions among continents

will provide some insight into the structural characteristics of the research entities in these countries. Our investigation reveals that, with the exception of Russia, universities overwhelmingly dominate as the principal institutions to produce prize-winning achievements in these selected countries.

In the U.S., the research output is shaped by universities (72%), government institutions (11%), and enterprises (11%).

In Britain and Germany, universities and governmental research institutions dominate research, with British universities at 76%, governmental research institutions at 17%. And German universities 57%, governmental research institutions at 31%.

In France, universities (61%), governmental research institutions (11%), and nonprofit organizations (21%) all play significant roles.

In Japan, universities, holding 80% of research contributions, and enterprises (20%) shape research output.

In Russia, governmental research institutions (100%) produce all prize-winning works, with the Russian Academy of Sciences being a major contributor. This reflects Russia's historical state system (Fig. 4).

Above are the most productive institutions in these countries. The most productive institution of the United States accounts for the lowest proportion among all prize-producing institutions within this country (11%), while that of Russia was the highest (92%). The United Kingdom, Germany, France and Japan were relatively similar, hovering around 25%. This suggests that advanced countries have a lower degree of institutional aggregation, which could be attributed to the fact that they have more top institutions. This phenomenon could be described as "a hundred flowers blooming together" in domestic settings. Conversely, countries with lower scientific and technological strengths have fewer top institutions, resulting in a phenomenon where "one outshines others." (Table 3).

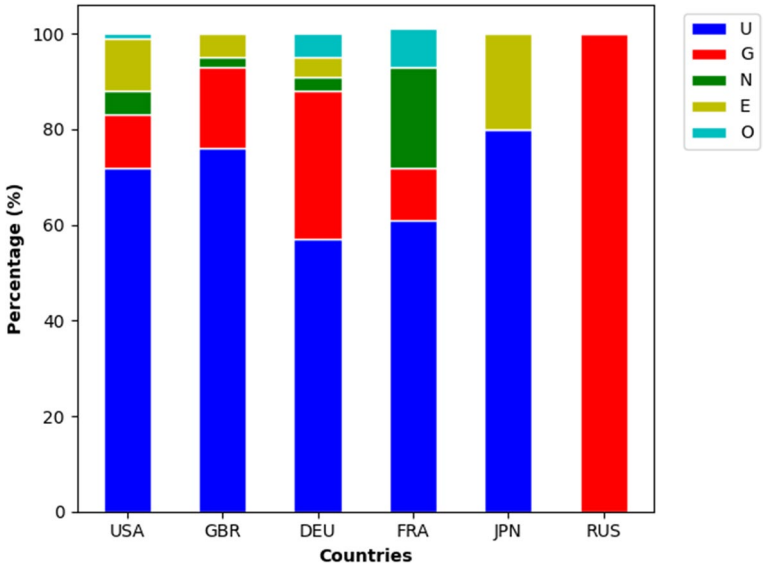

Fig. 4 The composition of different types of prize-producing institutions in leading countries. Note: all abbreviations of countries are followed by OECD

Variation trend of prize-producing institutions

In different periods, the structural characteristics of the types and geographical distribution showed differently. The proportion of universities remained consistently high throughout different periods. Governmental research institutions experienced a significant increase after World War II. Non-profit organizations showed a slight decrease after the Cold War, while enterprises demonstrated a rising trend. European countries were home to most prize-producing institutions before the World War II, after which the US makes a stunning debut, taking a leading position with a majority advantage. While within the near decade, the aggregation effect sees a slight decline.

The prevalence of university research peaked between the World Wars II (83%), dipped post World War II (67%), then kept the same post-Cold War (67%). Since the first modern university-Humboldt University of Berlin,[1] was established, the orientation of universities in major Western countries has been settled to educate students and carry out scientific research, Universities' dual role aims at providing highly educated workers for the society an increasing social knowledge stock through independent research(Shao, 2002)which fosters an open, relaxed atmosphere, and this may aid in the production of numerous Nobel-worthy works.

Government research institution contributions rose between the end of World War II and the Cold War, driven by the US "Whole Nation System" and Cold War competition, a large number of researchers were mobilized to work together with sufficient budget expenditure,

[1] The university's name was changed from Friedrich-Wilhelms-Universität to Humboldt-Universität in 1949 to honor the Humboldt brothers, Wilhelm and Alexander, and to symbolize a recommitment to their pioneering ideas in academia.

Table 3 Most productive institution and their proportion in selected countries

Country	Name	Count	Proportion (%)
USA	Harvard University	35	11
GBR	University of Cambridge	28	29
DEU	Max Planck Society	18	24
FRA	Institute Pasteur	8	22
JPN	Kyoto University	5	25
RUS	Russian Academy of Sciences	11	92

the proportion represents the percentage of the most productive institutions within a country among all the Nobel Prize-producing institutions within that country

thus increasing the scale of its national laboratories (Fang et al. 2021) Such institutions produced a majority of their Nobel-winning works during this period, signifying governmental support's significance. During that period, the DOE national laboratories produced 12 prize-winning works, which accounted for 67% of all prize-winning works produced by it. To compete with the United States, the Soviet Academy of Sciences (later Russian Academy of Sciences) produced 8 prize-winning works. We can conclude that the strong support from the government was an important reason for the abundant achievements from the governmental research institutions in this period.

Enterprises, while not primary contributors, showed a gradually increasing trend. Nonprofit organizations consistently contributed minimally, peaking during the Cold War before declining. Their respective applied research orientation and public-welfare focus imply that they are not primary sources of Nobel-winning achievements (Fig. 5).

During different periods, the proportions of different countries exhibit different characteristics. Further analysis may explore the scientific strength and changing trends among selected countries.

Before World War I, Germany and France had a relatively high proportion. Between 1901 and 1913, Germany and France were neck to neck, both accounting for 24% of the total during that period. During this time, the United Kingdom had a low proportion, only accounting for 7%, while the United States and Russia had even lower proportions, accounting for 4% and 2% respectively.

During the two World Wars, Germany had a higher proportion, while the United States and the United Kingdom were showing a catching-up trend. Between 1914 and 1945, Germany's advantage increased slightly, with its percentage rising by 1%, while France's percentage dropped significantly, from the previous 24% to 7%. Meanwhile, the United States and the United Kingdom both had significant increases in their proportions during this period, with the United Kingdom rising from 7 to 20%, and the United States rising from 4 to 16%. However, neither Japan nor Russia won any Nobel Prizes during this period.

After World War II and during the Cold War period, the United States' advantage continued to expand, while the proportions of the United Kingdom, Germany, and France declined. Japan began to emerge as a new winner, and Russia achieved its highest proportion in history. During this time, the United States' advantage rapidly expanded, accounting for over 50% of the total prizes. However, the proportion of Germany, France, and the United Kingdom all declined significantly, with Germany experiencing the most significant decline, dropping from 25% during World War II to 8%. Russia's proportion during this period was 3%, its highest in history, while Japan began to emerge, accounting for 1%.

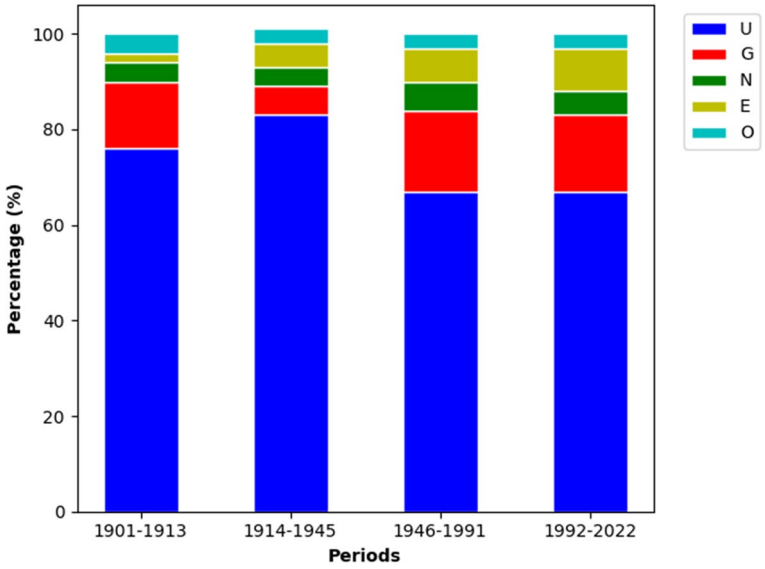

Fig. 5 The proportion of different types of prize-producing institutions in four periods

After the end of the Cold War, the United States' advantage continued to expand, while the proportion of the other three countries (Germany, France, and the United Kingdom) further declined, except for Japan, which saw its advantage increase. After the disintegration of the Soviet Union, the United States became the only superpower, and its advantage expanded further, rising from 54% during the Cold War to 59%. The percentages of the United Kingdom and Germany continued to decline, while France's percentage remained stable compared to the previous period. Russia's percentage decreased to only 1%. Japan's advantage expanded, surpassing both France and Germany, and reaching 7% (Fig. 6).

In the near decade, the overall structural characteristics keeps the same, but we can see a slight sign that the aggregation phenomenon is declining. From the type dimension, the proportion of university decrease, from 67 to 65%, while that of non-profit organization increase, from 5 to 8%. From nation dimension, the proportion of the US declines, from 59 to 52%, while that of the total proportion of other countries increases (Fig. 7).

The mobility pattern of Nobel laureates

Mobility among institutions is a noticeable trend among Nobel laureates. After completing their prize-winning work, they often move to different institutions rather than staying in the same one. Among the 638 Nobel laureates studied, 315 are considered mobile laureates, while 323 are stable laureates. The mobile laureates show inter-institutional mobility, with 152 transitioning to institutions of the same type, 136 moving to institutions of a different type, and 9 being associated with two different types of institutions (working for more than one institution when awarded the Nobel Prize).

To visually represent these patterns, we present the overall count of institutions and countries to exhibit the mobility patterns of Nobel laureates, shedding light on their career

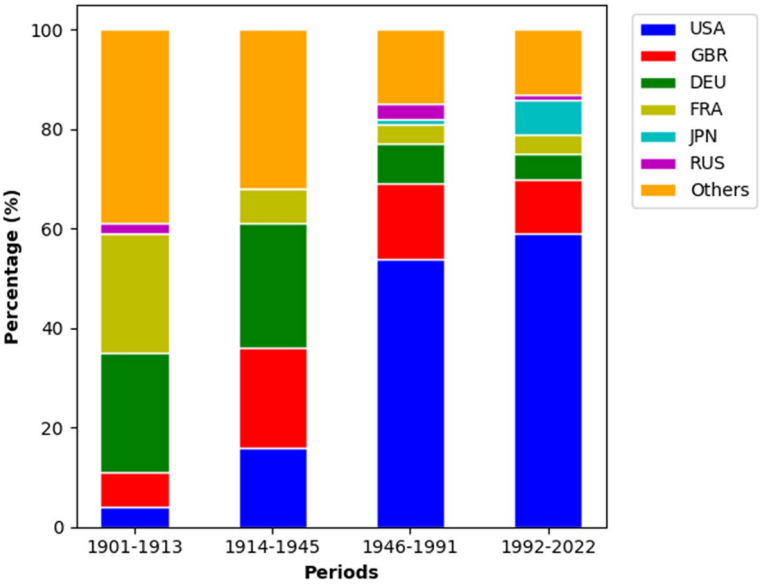

Fig. 6 The proportion of different countries in four periods

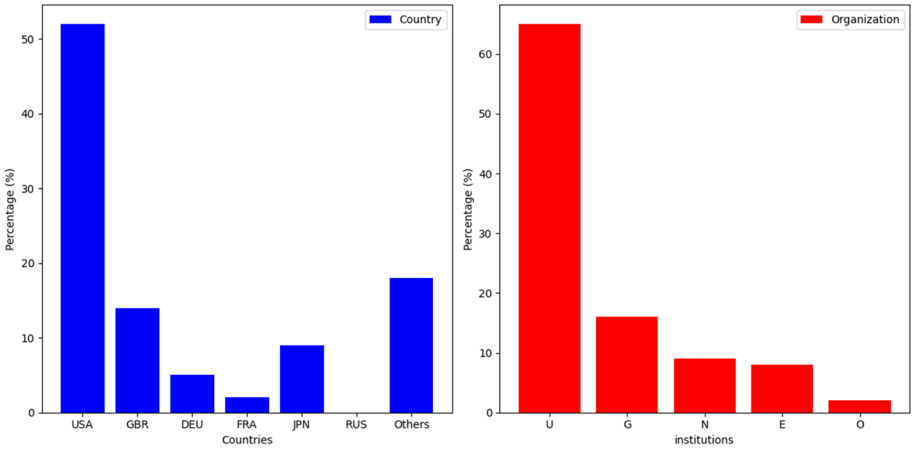

Fig. 7 Proportion of different types of institutions and selected countries in the near decade

trajectories and the diversity of institutions and countries they have been affiliated with during their Nobel Prize journey.

Out of the 315 mobile laureates and 323 stable laureates, the distribution among different types of institutions is shown in the graph below (Fig. 8). It is noteworthy that, except for universities, the other types of institutions have a lower count of stable laureates, indicating that they have "lost" more laureates than they have "attracted." This suggests that Nobel laureates who conducted their prize-winning work in universities were more inclined to remain at the same university.

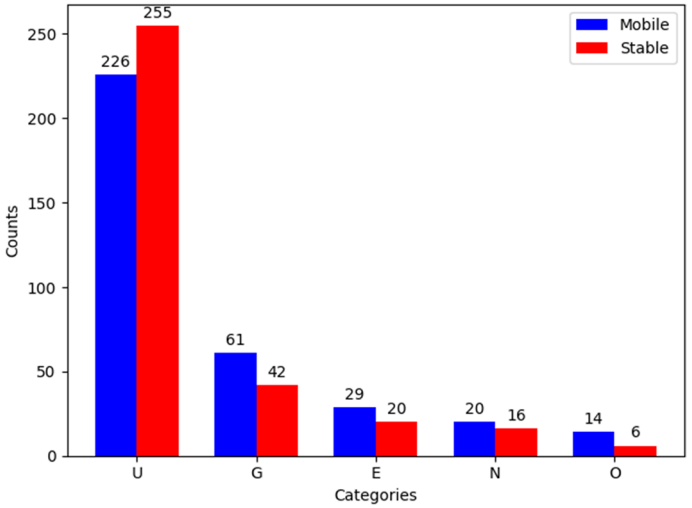

Fig. 8 The count of mobile and stable laureates in different types of institutions

Table 4 Top 5 universities that have most stable Nobel laureates

Name	Stable	Total	Proportion of stability (%)
Harvard university (US-America)	24	35	69
University of Cambridge (UK)	14	28	50
Rockefeller University (US-America)	12	14	86
California Institute of Technology (Caltech) (US-America)	12	13	92
Columbia University (US-America)	9	14	64
Cornell University (US-America)	8	10	80
University of California, Berkeley (US-America)	8	13	62

Further analyzing the top five universities with stable Nobel laureates, as shown in Table 4, reveals that Caltech has the highest percentage of stable laureates, followed closely by Rockefeller University and Cornell University. Interestingly, all of the top five universities, except Cambridge University, are based in the United States. This observation highlights the strong retention of Nobel laureates in US-American universities, indicating their attractiveness as long-term research and academic destinations.

Among the 315 mobile laureates, their inter-institutional mobility patterns are depicted in the diagram below (Fig. 9). The left column represents the types of prize-producing institutions and the right column shows the types of institutions with which the laureates were affiliated when they were awarded the prizes. The length of each type of institution signifies its count.

Universities are shown to attract the majority of Nobel laureates from other types of institutions, indicating that many laureates moved to universities after conducting their prize-winning work. This suggests that universities play a crucial role in fostering scientific excellence and promoting collaboration.

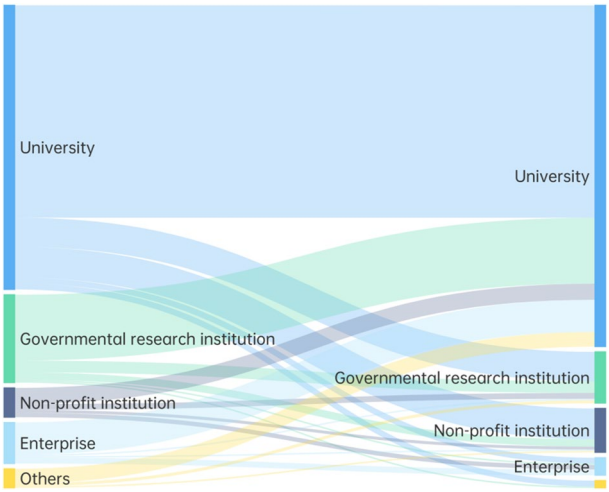

Fig. 9 Inter-institutional mobility pattern of Nobel laureates

Non-profit organizations are also significant in attracting Nobel laureates, underscoring their role in providing an environment for independent research and exploration.

On the other hand, governmental research institutions and enterprises exhibit a net loss of laureates, which could possibly be attributed to a less flexible environment in governmental institutions and a focus on stability within enterprises. This highlights the influence of institutional culture and structure on the career paths of Nobel laureates.

Overall, the mobility of Nobel laureates across different types of institutions highlights the importance of collaboration and exchange of ideas in scientific research. It also underscores the need for institutions to provide an environment that fosters creativity, innovation, and academic freedom, in order to attract and retain the best and brightest minds in science.

Of the 315 laureates who have flowed between institutions, 75 of them have crossed countries. The period between 1901 and 1913 witnessed 6 Nobel laureates flowing transnationally, accounting for 13% of all laureates in that period. From 1914 to 1945, a total of 8 laureates flowed transnationally, accounting for 8% of the total number of laureates in this period. From 1946 to 1991, a total of 29 laureates flowed transnationally, accounting for 11% of the total number of laureates in this period. From 1992 to 2021, a total of 31 laureates flowed transnationally, accounting for 14% of the total number of laureates in this period (Fig. 10).

Before World War I, Nobel Prize laureates primarily went to Britain (3), Germany (2), France (1), for they were the old centers in science and technology at that time. During the two world wars, there was a shift towards the United States (15) as a destination for Nobel Prize laureates. After World War II, the United States became the most important destination for Nobel Prize winners, attracting (16).

The two world wars were primarily fought in Europe, while the United States focused on recuperation and development during these periods. Its economy and technology experienced significant growth, which attracted a large number of Nobel Prize winners and helped establish the US as a superpower. During the Cold War, most Nobel Prize laureates went to the United States, while the attractiveness of the United Kingdom, Germany and France to Nobel Prize laureates decreased.

After the end of the Cold War, the United States became the main destination for Nobel Prize laureates, particularly in the field of physics. German Nobel laureate (5) in physics

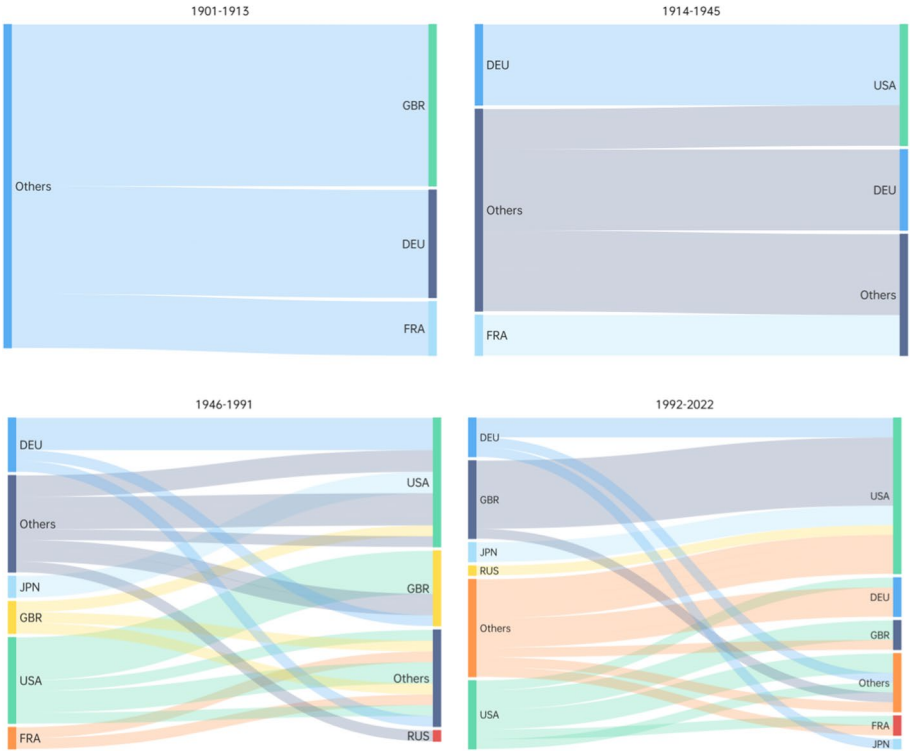

Fig. 10 Transnational mobility patterns of Nobel laureates in four historical periods

have been attracted to the United States the most, followed by those from Japan (3) and the United Kingdom (2). In the field of chemistry, the United States has attracted the most Nobel laureates from the United Kingdom (4), while American Nobel laureates have mainly flowed to the United Kingdom (2) and Switzerland (1). Germany is also an attractive destination for Nobel laureates in chemistry, attracting laureates from Sweden (2), Finland (1), Latvia (1), and the Netherlands (1). In the discipline of physiology or medicine, the United States has attracted laureates from numerous countries, notably the United Kingdom (2). However, the United Kingdom is also a preferred destination for US laureates in this field, with a larger number of US laureates (3) migrating there (Fig. 10).

Conclusion

Through our analysis, main findings are listed as follows:

(1) As time goes on, it has become increasingly common for multiple individuals to share the same Nobel Prize, especially in physics.
(2) The distribution of prize-producing institutions exhibits an aggregation effect, respectively in types and locations. Universities dominate as the most prolific type of institu-

tions, maintaining a significant lead both in total count and across the three disciplines. And institutions are predominantly located in North America and Europe.

(3) Throughout different periods, the types and geographical distribution of institutions showed varying characteristics. Universities consistently held a high proportion, governmental institutions saw a significant rise post World War II, non-profit organizations declined slightly post Cold War, and enterprises showed an upward trend. European countries hosted most prize-producing institutions before World War II, but the U.S. took the lead afterwards. However, in recent years, the U.S.'s dominance has slightly declined.

(4) Over a half laureates retain in the institution where they did the prize-wining achievements, while other half moved to other institutions. Universities are the leading attractors and retainers of Nobel laureates, with governmental institutions drawing most chemistry laureates and non-profits appealing to those in physiology or medicine. The early twentieth century saw laureates primarily in the UK, France, and Germany, reflecting their scientific dominance. Amid and post-World Wars, the US gained prominence, further cementing its global scientific leadership post-Cold War.

Discussion

This article provides an analysis of the prize-producing institutions. A key challenge in our study stems from the complexity of laureates' research trajectories, as some of them shifted institutions multiple times during their research career. This fact could potentially lead to incomplete or inaccurate recording of prize-producing institutions. However, we made exhaustive efforts to collate a comprehensive list of all Nobel Prize-producing institutions to recreate the true scenario as accurately as possible, which can roughly map the landscape of modern science. This is the main contribution of our research, particularly because full institutional data are often missing in Nobel Prize analyses. Additionally, our investigation into the types of prize-producing institutions provides valuable insights into the role different entities play in producing Nobel achievements, which is expected to offer guidance for governmental research investment strategies.

The descriptive analysis of the data provides a comprehensive depiction of the institutions that produce Nobel Prize-winning achievements, which is of certain significance for understanding the overall situation of the Nobel Prize. However, the study mainly reveals the phenomenon, lacking content analysis and causal exploration. Nobel Prize-winning achievements can be broadly classified into three categories: significant scientific discoveries, significant theoretical breakthroughs, and significant technological and methodological inventions. This paper does not show the distribution of different types of Nobel Prize-winning achievements in different types of institutions or changes over time. Additionally, a deep analysis of Nobel Prize-winning achievements in the fields of physics, chemistry, physiology or medicine can help understand the forefront and the internal laws of disciplinary development. The study does not cover these aspects, lacking content analysis of specific achievements. Moreover, the study does not provide an in-depth interpretation of the reasons for the distribution of prize-producing institutions. By conducting more comprehensive analyses using the available data, the research can attain greater depth and increased social significance.

Human resource in science and technology is the dominant factor in technological activities (Xu, 2001) and Nobel laureates in natural sciences are undoubtedly the most elite part

of this human resource pool. The Nobel Prize is largely determined by the individual abilities of scientists and has a certain degree of unpredictability, making it a major challenge to analyze the reasons behind the award. However, with the establishment of science and the rapid development of technology, independent research institutions, professional scientists and engineers have emerged, starting the process of institutionalization of science and technology in society. Especially with the advent of the "big science" era, the role of society behind Nobel Prize-winning scientists has become increasingly significant (Pan & Zhou, 2016), meaning that the role of research institutions in promoting scientific development is becoming more and more evident. Nobel Prize is very good documented and therefore can be an indicator of the scientific landscape. Therefore, in the modern semantic context, in-depth analysis of the social mechanisms behind the Nobel Prize's creation is expected to conduct, like why universities can generate the most prize-winning achievements or how a country's research entities work in its national innovation system, which is of great significance for a country to formulate strategies for science and technology development. Future research is expected to make breakthroughs in this area.

Funding Our research was founded by the Chinese Academy of Sciences through a project named Research on the Differentiated Positioning and Innovation Path of National Strategic Strength in Science and Technology with an award number E2X1161601.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

References

Cai, C., & Chen, B. (2012). The statistic analysis on educational background of Nobel Prize winners and its inspiring implications to graduate education in China. *China Higher Education Research*. https://doi.org/10.16298/j.cnki.1004-3667.2012.05.009

Chan, H. F., Önder, A. S., & Torgler, B. (2015). Do Nobel laureates change their patterns of collaboration following prize reception? *Scientometrics, 105*(3), 2215–2235. https://doi.org/10.1007/s11192-015-1738-8

Chariker, J. H., Zhang, Y., Pani, J. R., & Rouchka, E. C. (2017). Identification of successful mentoring communities using network-based analysis of mentor-mentee relationships across Nobel laureates. *Scientometrics, 111*(3), 1733–1749. https://doi.org/10.1007/s11192-017-2364-4

Fang, S., Huang, K., Jiang, Y., & Yang, S. (2021). Analysis of development characteristics of U.S. national laboratories and support to national innovation system. *Experimental Technology and Management, 38*(06), 1–6. https://doi.org/10.16791/j.cnki.sjg.2021.06.001

Gao, P. (2003). Review on the Nobel Prizes with a 100-year history. *Science & Technology Review*. https://doi.org/10.19318/j.cnki.issn.2096-1634.2016.06.04

Heinze, T., & Fuchs, J. E. (2022). National and organizational patterns of Nobel laureate careers in physiology/medicine, physics, and chemistry. *Scientometrics, 127*(12), 7273–7288. https://doi.org/10.1007/s11192-021-04250-0

Jiang, Z., & Chen, Y. (1994). The Nobel Prize in Science and Scientific Discovery. *Science and Society* , (02), 14–24. https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKjkpgKvIT9NkGsvn6cq9Bo2nGkVX8kK3ELyr2QQsJ2PJJDK0D9ItvH6gYJe02sN7-j8ZMwM44FeE&uniplatform=NZKPT

Jin, B., & Liu, J. (2006). Making science: Some characteristics of research from the phenomena of the Nobel Prize. *Science Focuse*. https://doi.org/10.15978/j.cnki.1673-5668.2006.06.001

Pan, L., & Zhou, C. (2016). The Nobel Prize in the time of big science. *Think Tank: Theory & Practice, 1*(06), 17–25. https://doi.org/10.19318/j.cnki.issn.2096-1634.2016.06.04

Schlagberger, E. M., Bornmann, L., & Bauer, J. (2016). At what institutions did Nobel laureates do their prize-winning work? An analysis of biographical information on Nobel laureates from 1994 to 2014. *Scientometrics, 109*(2), 723–767. https://doi.org/10.1007/s11192-016-2059-2

Shao, Y. (2002). Universities in National Innovation systems: an International Comparative study. *Science of Science and Management of S.& T.*(03), 9-12. https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKgchrJ08w1e7lwLRIsgSA99lIy-YTj37zk1TM21cBsymBmWLo_5wZGba4bWUit694PxgJF-GkyRw&uniplatform=NZKPT

Song, H., & Shi, Y. (2008). A probe into the Nobel Prize in a century. *Journal of Kunming University of Science and Technology (social Sciences)*. https://doi.org/10.16112/j.cnki.53-1160/c.2008.04.022

Xu, W., & Yuan, Q. (2004). Statistical analysis of the laureates of the Nobel Prize in physics. *Studies in Science of Science*. https://doi.org/10.16192/j.cnki.1003-2053.2004.01.007

Xu, Z. (2001). On the Significance, Attributes, and Configuration Development Management of Technology Human Resources. *Science and Technology Management Research*, (06), 62-64+43. https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKgchrJ08w1e7AZ-xq6cidhfnzHBZ5mZ4CR_ALBQ0pgr4hiHXAcoGqJSfgcP19uYrsNWuOiDKYfx6&uniplatform=NZKPT

Yuan, Z., & Zhang, Y. (2002). Analysis of modern university scientific innovative research from Nobel Prize. *Journal of Northwestern Polytechnical University (Social Sciences)*, (03), 57–61. https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKgchrJ08w1e7lwLRIsgSA991vXsDl9kmydl8dITYadc61M3c-3KhjgBrPt4LcNFig6LXr690_IqA&uniplatform=NZKPT

Zhang, C., Hao, F., & Yan, H. (2001). The charm of interdisciplinary research——an analysis of the centenary Nobel Prize in natural sciences. *Studies in Philosophy of Science and Technology*, (06), 63–67. https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKgchrJ08w1e7AZ-xq6cidhej_QX8LWMqCaLiTNLCukxM7xVU7gC_HQ13nKKcvtO87v0aLxycGuDv&uniplatform=NZKPT

Zuckerman, H. (1967). Nobel laureates in science: Patterns of productivity, collaboration, and authorship. *American Sociological Review, 32*(3), 391–403. https://doi.org/10.2307/2091086

Zuckerman, H. (1977). *Scientific elite. Nobel laureates in the United States*. Free Press.