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Short communication

The Nobel "Pride" Phenomenon: An analysis of Nobel Prize discoveries and their recognition

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ABSTRACT

The Nobel Prize is considered one of the highest forms of recognition of scientific accomplishment, conferring immense prestige upon its recipients. Given the significant time lag between the award and the discovery, Nobel Prizes are bestowed to individuals associated with institutions and countries other than the original place of the discovery. Contextualizing our research in status-seeking literature, we define the imprecise and sometimes excessive appropriation of Nobel Prizes by institutions and even countries as the "Nobel 'Pride' Phenomenon". Our empirical analysis focuses on the time and location of the 653 discoveries underlying each of the 350 Nobel Prizes in medicine, physics, and chemistry until 2024. About one-third of all Nobel laureates came from another institution or country. Furthermore, Nobel Prize creativity is highly concentrated, with more than 80 % of discoveries made in just five countries. These findings cast new light on the Nobel laureates' demographics, geographic and historical movements, and institutional affiliations, and have implications for research policy at institutions and national levels.

1. The Nobel "Pride"

Nobel Prizes bring fame to the individual laureate and recognition and prestige to the laureate's institution. These institutions—mostly universities and public research organizations—often brandish the Nobel Prizes they have won to demonstrate how effective their investments in basic research have been. Their pride is justifiable: breakthrough research requires a fortuitous combination of ideas, organization, and resources, especially in natural sciences.

One might expect that counting Nobel Prizes associated with institutions would be straightforward, but the tallied numbers vary widely. For example, the University of California at Berkeley has been especially successful with Nobel Prizes in physics, chemistry, and medicine. But how many such prizes have been won by its faculty? Two sources affiliated with UC Berkeley claim 19, 20, and 49 prizes (Regents of the University of California, 2023a and 2023b), respectively, and a US-national educational platform even has 82 prizes for UC Berkeley in these fields (BestMasterPrograms, 2023). Washington University in St. Louis's (WUSTL) website lists 24 Nobel prizes in natural sciences as affiliated with their university. The Nobel Prize organization itself lists 15 prizes for UC Berkeley and 3 for WUSTL (NobelPrize.org, 2024): Still exceptional accomplishments but below their own claims. Nor is the inaccurate accounting of Nobel Prizes limited to individual universities; it also exists at the country level. For example, Albert Einstein's Nobel Prize is claimed by the USA (because Einstein became a US-American citizen in 1940), Germany (because he was born there and taught in Germany at the time of the award), and Switzerland (because he was working in Switzerland when he published the research that was later recognized in the award). These differences are significant and cannot be explained away by simple miscounting.

Prizes not only reward the recipients but also draw attention to the context behind the award (Reschke et al., 2018); they are considered signals for outstanding work at excellent institutions and supportive scientific environments within countries. The desire of institutions and countries to associate themselves with a Nobel Prize is what we call the Nobel "Pride" Phenomenon. While the relevance of university or firm prestige is well documented (e.g., in recruitment, Cable and Turban, 2003), it leads to imprecise and often excessive appropriation of Nobel

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Prizes by institutions and countries.

Our research aims to bring clarity and transparency to the time and location of the research that eventually leads to Nobel Prize recognition. Despite previous research on the demographics, geography, and institutional affiliation of Nobel laureates, the mobility of scientists in the eventual pantheon of Nobel laureates is often unrecognized (Clynes, 2016). Systematic collection and analysis of the specific geographic and organizational context at the time of the Nobel-worthy discovery (crucial for understanding the institutional conditions that made this research possible in the first place) is largely missing. Therefore, we collected information at two additional important points in time: the location and institution at the time of the discovery underlying each award and the place of birth of each Nobel laureate. The discovery information is not as straightforward to find as one might expect and requires careful examination of each laureate's work. Analyzing these three events allowed us to make new observations about the geography and the institutional affiliation of laureates with regard to their Nobel Prize research. We show that approximately one-third of all discoveries were made in another country than the Nobel laureate's country of birth, and more than one-third of discoveries were made at institutions the laureate was no longer affiliated with at the time of the award. This means that approximately one-third of all awards have been imported from another institution or from abroad. We also find that international mobility is high before Nobel discoveries are made but decreases afterward in favor of inter-institutional transfers within the same country, highlighting the importance for institutions and countries interested in pursuing Nobel "Pride" of identifying exceptional talent early.

2. Prior research on Nobel laureates

The Nobel Prize, established by Alfred Nobel in 1895 and first awarded in 1901, is regarded as one of the most prestigious awards in the world, recognizing outstanding contributions to various fields of science, peace, and literature. While the Nobel Prize for peace and (to some extent) literature have often been politicized, the three Nobel Prizes for chemistry, physics, and medicine are much more agreed upon within the scientific community due to widely accepted principles of validity and reliability. As such, the award itself does not further validate a particular discovery, as the underlying science speaks for itself. However, a discovery's adoption and application in practice can be a lengthy process, which means that its value may, at times, be revealed only decades later, leading to significant time lags between discovery and the eventual award (Mitsis, 2022).

By the time a Nobel Prize is awarded, most laureates are established scholars in their field (Zuckerman, 1977) and the impact of the award on their scientific careers is therefore overestimated. The benefits for the institution of the Nobel laureates, however, are deemed quite significant (Mahendran et al., 2022). Ambitious scientists seek to work with high-profile scholars, making universities with Nobel Prize winners more attractive to incoming research talent (Cable and Turban, 2003). The work by Reschke et al. (2018) suggests that such benefits are more easily appropriable at the institutional level. Other benefits include improved access to outside funds, industry partnerships, student enrollment and retention, and impact on university rankings (Auranen and Nieminen, 2010; Mahendran et al., 2022; ARWU, 2023).

Organizations often advertise how many Nobel Prizes their faculty and employees have won, which is in line with the key tenets of signaling theory (Spence, 1973). Prizes have a positive impact on status and reputation (Azoulay et al., 2014). Organizational reputation acts as a brand (Cable and Turban, 2003), specifically in the case of Nobel Prizes (Urde and Greyser, 2016). Nobel Prizes are therefore status-enhancing instruments for universities and other research-invested organizations, especially in terms of merit-based prestige but also iconic symbolic-based status (Prato et al., 2024). Specifically, institutions associated with Nobel Prize-winning individuals seek to benefit from the "reflected glory" effect (Reschke et al., 2018), both at the individual level (e.g., when prestige, glamor, and assumed merits are associated with the Nobel laureate's colleagues) and at the organizational level (e.g., when the implied quality of a Nobel laureate's work is taken as an indication of the overall quality of science and research at the institution).

The institutional embeddedness of Nobel laureates—i.e., institutional support structures, incentive systems, and other often intangible components of a research ecosystem—influences individual scientist productivity (Merton, 1973). There are many unsung heroes in a good research institution: Colleagues who make incremental preparatory discoveries or whose work leads to dead-ends, redirecting research by others toward areas that eventually succeed. The focal point for the Nobel Prize is, of course, the institutional context at the time of the Nobel-winning discovery. Recent research has shown that the presence of and collaboration with more experienced senior researchers and past Nobel Prize winners improve both research output and career prospects of still unknown junior researchers (e.g., Li et al., 2019). Scientists also appreciate to mingle with other knowledge-workers, gravitating toward countries rich in cultivation and overall quality of life (Van Der Wende, 2015) or seeking to work in global cities and often remaining there (Verginer and Riccaboni, 2021). The United States has attracted significant inflows of foreign scientists (Auriol et al., 2013) who, on average, outperform domestic scientists (Franzoni et al., 2014). Schlagberger et al.'s (2016) study not only shows that the US dominates in terms of the number of affiliated laureates, with UC Berkeley, Columbia University, and MIT being the institutions with consistently high numbers of Nobel laureates, but also that the institutional affiliation of laureates frequently changes between Nobel discovery and the eventual award (at least during their limited observation period of 1994 to 2014).

We propose to explain the Nobel "Pride" phenomenon as a reaction of research institutions to brand association valuation, either directly (a high-value Nobel Prize improves the brand value of less-known university or research laboratory) or indirectly (Nobel Prizes are proxies for high-value research and university brands). The Nobel "Pride" is based on the perception of an institution's real or imagined contributions to Nobel Prize-worthy accomplishments. It manifests itself in excessive and occasionally inflated showcasing and brandishing of institutional affiliation with Nobel awards. Such advertising is an important signal in courting, conveying status, and reproducibility in the scientific community.

Whether perceived or actual, the brand value of an organization is a source of attraction—and as such, geographical and institutional relocation—for scientists, among whom are future Nobel laureates (Cable and Turban, 2003). Scientist mobility has been demonstrated to increase scientific productivity, personal competencies, and overall scientific impact, as evidenced by Franzoni et al. (2014), Uhlbach et al. (2022) and Netz et al. (2020). Therefore, it is reasonable to expect Nobel Prize winners to be at the forefront of such mobility. Due to the considerable time lag between an award-winning discovery and the award (Mitsis, 2022), scientists often relocate between discovery and its recognition. Previous research has either focused on individual star scientist biographies (e.g., Hillebrand, 2002) or institutions associated with Nobel laureates (e.g., Hollingsworth, 2004; Schlagberger et al., 2016; Bjork, 2019). According to Schlagberger et al. (2016), 77 % of the 1994 to 2014 Nobel laureates stayed in their home country for the entirety of their careers, but only 53 % obtained the Nobel Prize while employed at the institution where they did Nobel research. Van Der Wende (2015) found that one in four Nobel Prizes awarded to US-Americans between 1990 and 2000 went to an immigrant (a person who made the Nobel discovery or earned the Nobel Prize in a country other than his or her birth). This appears to contrast with findings from research on scientist mobility more generally, which suggests benefits of scientist migration and connections not only for destination countries (e.g., Yin and Zong, 2022) but also for countries of origin (i.e., birth) (e.g., Jonkers and Tijssen, 2008; Jonkers and Cruz-Castro, 2013).

Our investigation thus concentrates on Nobel laureates, in particular their geographical movement from birth, discovery and award, and the institutional affiliation at the time of their discoveries. Several other areas of research related to Nobel Prizes are interesting and important, such as age and the waiting time of eventual laureates until they receive the award, gender or racial diversity, the gap between rich and poor nations, differences between Nobel Prize categories, and the importance of personality traits. The limited number of Nobel Prize winners on the one hand and the lack of reliable information on the other make this research pursuit often difficult. Our focus is to address the identified gaps in the literature on Nobel Prizes—inconsistent reference frameworks, limited temporal coverage, focus on only one Nobel Prize category, lack of reliable historical data—and shed light on geographic, institutional, and temporal aspects affecting Nobel Prize success in the natural sciences. Recognizing that the context in which science takes place has changed since the inception of the Nobel Prize, we also aim to provide a time-sensitive analysis of our findings rather than mere averages over the entire data sample. This requires empirical research at the individual level of each Nobel Prize rather than at the science domain or country level, for which the necessary definitions and classifications would need to be clarified first.

3. Methodology and data

Our unit of analysis is the individual Nobel laureate. We focus on the three science prizes of physics, chemistry, and medicine. These prizes share a similar definition as to what constitutes the "greatest benefit to humankind" in a given year (NobelPrize.org, 2024): discovery (medicine), discovery or improvement (chemistry), or discovery or invention (physics). We summarily refer to the accomplishments for which Nobel Prizes are given as 'Nobel discoveries.'

A scientific discovery is rarely a single event occurring at a single point of time. Rather, it represents a complex process of collective recognition and construction of scientific knowledge as part of a retrospective analysis and characterization of observations and their interpretation (Caneva, 2005). In alignment with Dick's (2013) three stages of detection, interpretation, and understanding in scientific discovery, we characterize Nobel discoveries as going through three generic phases: (1) the original experiment, detection, insight or invention (such as Röntgen's discovery of a new type of rays two days before Christmas in 1895), (2) the disclosure, discussion and informal acknowledgment of the discovery, often in small scientific circles (such as Röntgen's conversations with his colleagues in January 1896), and (3) the formal publication or dissemination of the discovery to a wider audience (such as Röntgen's elaborations on further findings on this topic in the *Annals of Physics* in 1898).

For our investigation, we required data about the institutional affiliation at the time of the award and the time of the discovery, as well as the time and location of the birth of all Nobel laureates in physics, chemistry, and medicine since the Nobel Prize's inception in 1901. Consistent with our research aim, we sought phase-1 markers for all Nobel discoveries, identifying the institution at the time of the earliest insight rather than its eventual dissemination. Among the most comprehensive previous efforts collecting Nobel laureate data, Li et al. (2019b) created a database with discovery and award information for 545 out of 590 chemistry, physics, and medicine laureates between 1901 and 2016. We decided against using this database because their chosen institutional affiliation was measured by the affiliation at the time of the key publication (i.e., a phase-3 marker) and thus potentially introduces inaccurate institutional information due to the time lag between discovery and publication. It was also incomplete for our purposes, partly because their data ended in 2016 and partly because we required additional data on laureates that the Li et al. (2019b) database did not include. Other databases—such as Schlagberger et al.'s (2016) or Orrman-Rossiter's (2021)—do not have country-of-origin data, are focused on a single scientific discipline, or cover only a limited time window. Nobel laureates' demographic data are available on the official Nobel Prize website and information about the actual discoveries is (albeit with some effort) publicly available as well. Therefore, between March and November 2022, with an incremental update in October 2024, we conducted our own data collection, encompassing laureates from 1901 to 2024.

There were 350 Nobel Prizes (118 in physics, 117 in chemistry, and 115 in medicine) shared by 649 laureates, leading to 653 awards (four laureates received a Nobel Prize twice: Marie Skłodowska Curie, John Bardeen, K. Barry Sharpless, and Frederick Sanger). As each laureate was recognized for a distinct individual contribution to science, 653 is also the number of Nobel discoveries. Each Nobel Prize can be shared by up to three laureates, often for highly related discoveries. Unclear reporting on those numbers can be confusing and is one of the reasons why Nobel Prize numbers sometimes do not add up in public records. Another reason is connected to the Nobel "Pride" phenomenon: institutions often count laureates who are currently affiliated with them, who were employed at an earlier stage in their career, or who were recruited only after they were given their award. These inaccuracies are rooted in the lack of data transparency.

Our data collection and discovery identification protocol was as follows: We started with the official Nobel Prize website (www.nobelprize.org) to obtain data on all laureates and awards. This website contains a brief explanation of the rationale for awarding the Nobel Prize to each person. We then used this rationale to examine the specific discovery that led to the award. One advantage of studying Nobel laureates is the large amount of information provided and maintained by various organizations. In examining the discovery, we used the following sources in order of importance: The Nobel Foundation's website, biographies of scientists in the *Encyclopedia Britannica*, university websites of current and past employers, and Wikipedia. In parallel, we searched for contemporary interviews with Nobel laureates. Other repositories, such as *Nature's* annual reporting on Nobel Prize winners, were also consulted for additional references. Some discoveries were the subject of laureates' own reflection and publication (e.g., anthologies and autobiographies) or by scientists closely associated with the laureates, the underlying research, or the institution. Some of the recent laureates were contacted by email to clarify their discovery process. In some rare cases, we read the original publications and pieced together information recorded therein about the location and institutions at which the research had been conducted. (Please see the Appendix for an example of the application of this identification protocol to the 2023 Nobel Prize in physics.)

Two independent data collectors were trained to collect and interpret the data, and three researchers collectively reviewed the correctness of each of the 653 entries on Nobel laureates in the database. If the identification process did not arrive at definite information about a phase-1 event, we accepted a phase-2 event as a next-best proxy. If even a phase-2 event could not be identified, we resorted to the date and institutional affiliation of the first publication of the discovery, essentially a phase-3 event (the unit of analysis of Li et al.'s (2019) database). More recent Nobel Prizes were much better documented, and phase-1 information was widely available. Earlier Nobel discoveries took place more than a hundred years ago and were more difficult to identify through phase-1 disclosures. Each datapoint was thus checked multiple times by different researchers to increase reliability and validity of the data. We attained a 75.5 % rate for phase-1, 6.4 % for phase-2, and 18.1 % for phase-3 entries.

We created a database of all laureates and their associated discoveries. Each entry was designated a unique identifier and represents a specific laureate, award, and discovery. Additional information included the laureate's name, gender, year and place of birth, and—if applicable—the year of death (this information was also retrieved from the official Nobel Prize website), the award year, as well as the field and motivation for the award. We also recorded the laureate's affiliated institution at the time of the award along with the respective city, state and country from the official Nobel Prize website, as well as the institution, city, state and country information at the time of the discovery. If the discovery was made during a research visit at another institution, we recorded the hosting institution as the location of the discovery event. If multiple institutions were associated with a laureate at the time of the award, we recorded all affiliations. We applied the territorial definition of the country at the time of the event (i.e., a laureate's birth, a Nobel discovery, or the Nobel award). In case of countries no longer in existence, we recorded its legal successor (e.g., Germany as the successor of Prussia). We accounted for colonialization (e.g., Tunisia as a French colony) but ignored occupation as part of a war (e.g., the German occupation of Denmark between 1940 and 1945). This approach results in a single unique location and associate institution for each discovery. However, laureates have occasionally multiple affiliations when the award is given, and for the 649 laureates we recorded 725 affiliations.

Our approach ignores controversies over the perceived worthiness of individual laureates. Those not given a Nobel Prize are not considered in our analysis, whether they contributed to a discovery or not. We also included laureates whose contribution was not unanimously acknowledged (e.g., William Shockley claimed to have conducted the key research leading to the invention of the transistor on his own, a view contested by his 1956 Nobel co-awardees John Bardeen and Walter Brattain); our central point of reference was information made available by the Nobel Prize Foundation.

We compared our dataset entry-by-entry against the database by Li et al. (2019b) for all three overlapping categories: year of award, year of discovery, and discovery institution. Li et al. (2019a) used publications (phase-3) as a marker for discovery. Considering only the years that Li et al. (2019a) cover (1901–2016) for their 590 laureates and ignoring missing entries in their database (e.g., 42 % of their entries lack a discovery institution), our database yields a 100 % similarity between award years, 68 % similarity between discovery years (within a margin of error of one year), and a 57 % similarity between discovery institutions. The significant deviation between our assessment and Li et al.'s (2019b) is likely based on our use of phase-1 markers for Nobel discoveries and emphasizes the need for accurate research about the discoveries behind Nobel Prizes. Our data collection filled these gaps, corrected and ameliorated where information was not precise enough, and extended the data to 2024.

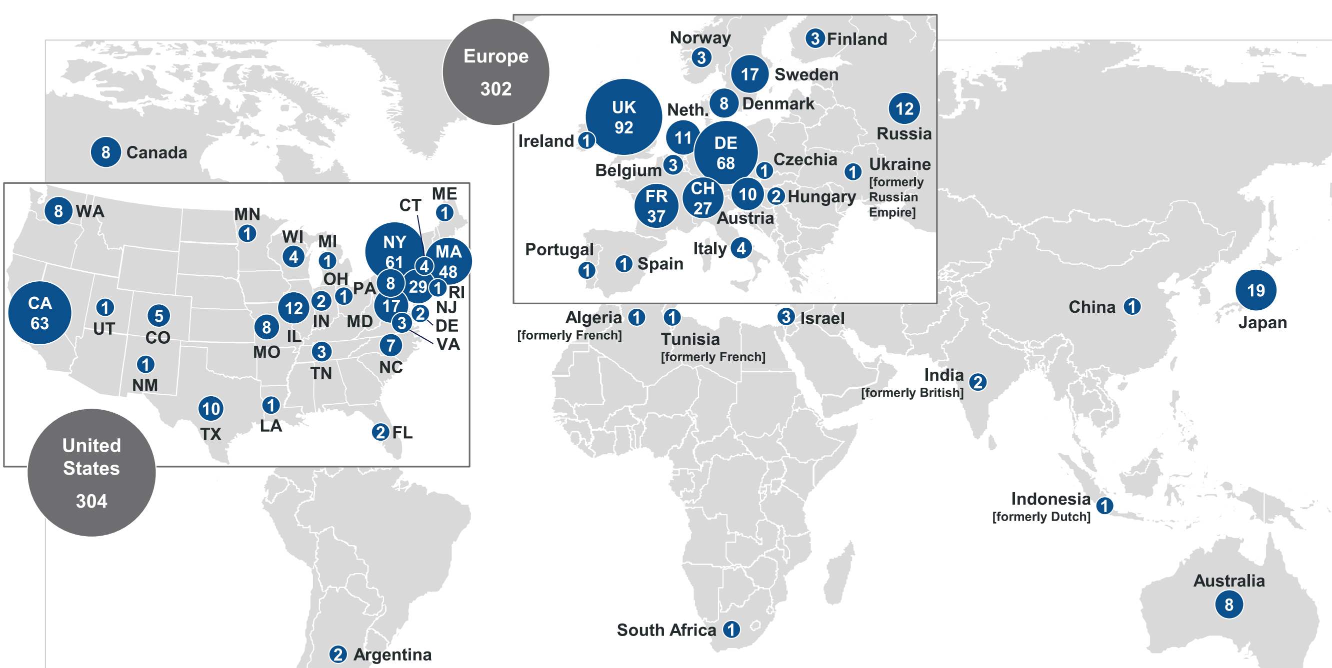
4. Analysis

Our analysis primarily leveraged the availability of discovery location, institution, and time, i.e., data that has not been available in this depth and breadth in previous Nobel-related research. Specifically, this data allowed us to examine the geographic and institutional movements of eventual laureates, both cross-border and domestic, both before and after their Nobel-winning discoveries.

4.1. *Geographic movements of Nobel laureates*

The locations of Nobel Prize-winning underlying breakthrough discoveries are geographically highly concentrated. Fig. 1 highlights the USA's and Europe's dominance in the Nobel landscape, representing 93 % of all discoveries that culminated in a Nobel Prize. Although technically one nation, the United States exhibits significant heterogeneity of dispersion of Nobel Prize discoveries (and awards) across states, not unlike the European Union. For this reason, both the USA and the EU are analyzed at the level of its member states. Europe's Nobel discoveries are fairly concentrated, with four nations—the UK, Germany, France, and Switzerland—accounting for 74 % of its Nobel discoveries. In the Asia-Pacific region, which is still a relative newcomer to originating Nobel discoveries, Japan and Australia take the lead with 19 and 8 prize-winning discoveries, respectively. Despite significant investments in national science and technology, China is still underrepresented; however, given it nowadays takes more than two decades to be recognized with an award, the current share of Nobel Prizes reflects China's accomplishments in science conducted in the last millennium. India is also lagging behind, as are countries in Latin America and Africa.

In the Eastern United States, New York State and Massachusetts emerged as the geographic epicenters of Nobel discoveries, collectively accounting for 35.9 % of the nation's contributions. On the West Coast, California leads all US states, claiming 20.7 % or 63 discoveries—trailing Germany by just five discoveries on the global stage. The remaining



Note: Discoveries indicated as per geographic location. The affiliation of the location to a country at the time of the discovery used to be different in several cases (e.g., Tunisia as a former French colony, or Ukraine as a former territory within the Russian Empire).

Fig. 1. Nobel Prize-winning discoveries per geographic location [1901–2024].

43.4 % of the 304 discoveries are dispersed across 24 US states, pointing to a widespread commitment to innovation and scientific excellence.

A country's capability in science and academia has often been gauged by how many scientists it produces and how many it attracts (Furman et al., 2002). The Nobel Prize gave us a unique window to analyze the geographic movement of individual laureates and whether these moves took place before or after their discoveries. Fig. 2 offers a comparative analysis of major Nobel-contributing countries, examining their ability to attract discoverers and eventual award winners. Each country was normalized to the number of Nobel laureates per capita. The right-hand half represents countries that recorded more discoveries than births of eventual Nobel laureates (i.e., immigration destinations prior to discovery), and the upper half represents countries with more Nobel awards than discoveries (i.e., immigration destinations after discovery). Fig. 2 shows that some countries have been more successful than others in attracting future Nobel laureates before they made their discoveries, and some countries have been better at attracting eventual laurates after they made their discoveries. The USA stands out as the sole nation in the upper-right quadrant, demonstrating that it was the only net winner in attracting both discoverers and award winners. Only four European nations—Switzerland, Sweden, France, and the UK—were net immigration countries of Nobel discoverers, but, with the exception of the UK (which is emigration-neutral), they also lost more future Nobel laureates to immigration than they gained. More future laureates moved to Denmark, Germany, Canada, and Italy after their discoveries, while Austria, Netherlands, and Russia saw future laureates leave after their discoveries. Although leading in terms of absolute numbers of awards and discoveries, the USA is actually worse (relative to all awards) at attracting future discoverers than e.g. Switzerland, and worse at attracting future award winners (post-discovery) than e.g. Canada or Denmark.

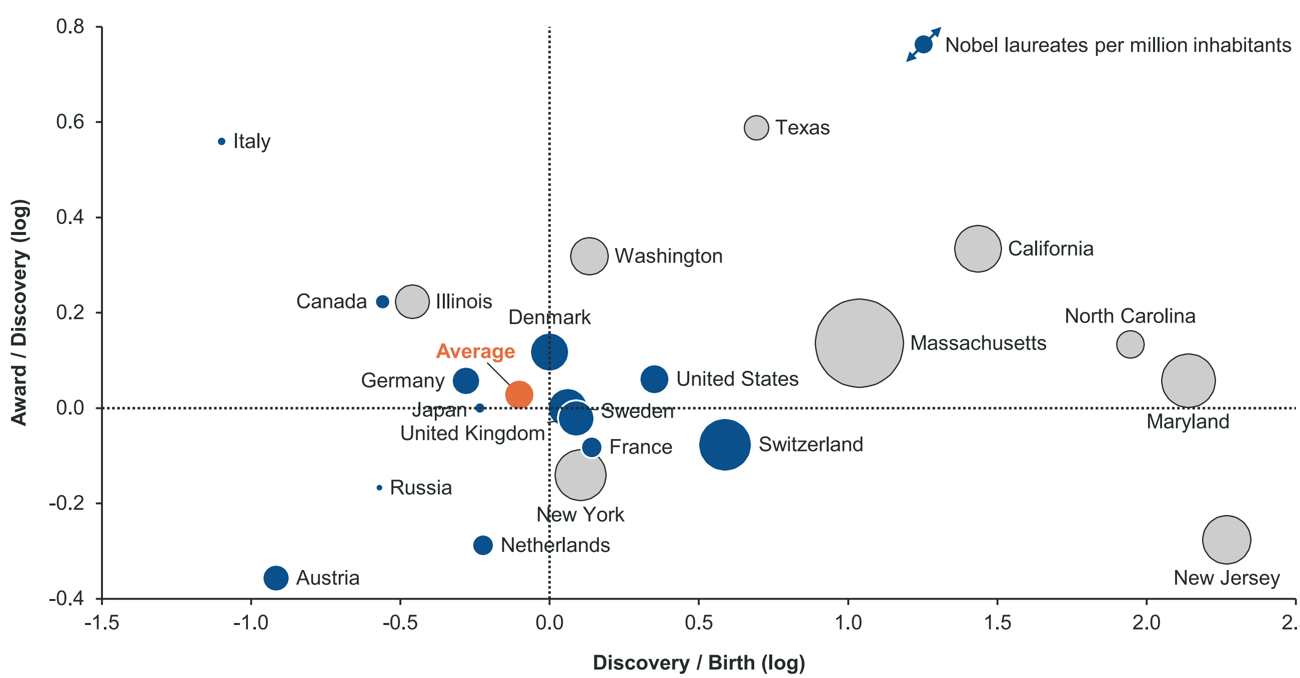
Many of the states of the USA witnessed an exodus of young scholars born there but who made their Nobel discoveries primarily in one of only eight other states (in the order of declining discovery-to-birth ratio): New Jersey, Maryland, North Carolina, California, Massachusetts, Texas, Washington, and New York. Illinois presents a unique case: it lost future discoverers but regained even more laureates by the time they won Nobel awards.

Considering all countries, we observe an average net drain of future laureates from birth-to-discovery (0.90), but also (on average) a small influx of future laureates following their significant discovery (1.03). This dynamic illustrates the global competition for talent, with some nations vying to provide the best environments for groundbreaking research and innovation (Franzoni et al., 2014).

Europe is the birthplace of over half (54.4 %) of all Nobel laureates. However, approximately one in five, i.e., 19.4 %, moved to North America (USA and Canada) before making their award-winning discovery, dropping Europe's share of discoveries to 46.2 %. An even greater share of laureates emigrated from Asia-Pacific to North America (30 %) before making their Nobel Prize-winning discoveries, with 20 % of them moving to Europe. This shift underscores the allure of North American institutions in particular and Western ones more generally as places for cutting-edge science (Fig. 3), but also the potential of Asia as a place for future Nobel discoveries and awards should these migration trends abate or even reverse.

In stark contrast to their European colleagues, North American-born laureates exhibited limited international mobility. A mere 3.5 % ventured abroad to make their award-winning discoveries. The number of European scientists coming to North America and North American Nobel scientists leaving for Europe is somewhat more balanced (8.3 % vs. 3.5 %) after discoveries have been made and before awards are received, while Asia-Pacific and other regions of the world show little reverse brain drain. This statistic speaks to the opportunities and resources available in key countries and a deep-rooted academic culture that retains its brightest minds.

Fig. 4 depicts the percentage of Nobel Prize winners who either moved internationally between birth and discovery ("foreign-born") or who moved between discovery and award ("foreign-discovery"). 29.2 % of all Nobel laureates are foreign-born, testifying to the global origin of breakthrough science, interpolated by $y = 0.187e^{0.0059x}$. The total share of foreign-born laureates slightly increased—primarily due to an inter-war dip in low-teen percentages in foreign-born laureates—but has



Note: Only countries and US-states displayed that have been awarded with Nobel prizes more or equal to the median (= 7).
A value greater than 0 on the ordinate x-axis indicates countries with more discoveries than births, and a value greater than 0 on the coordinate y-axis indicates countries with more awards than discoveries.

Fig. 2. Net-gains and losses of Nobel laureates between birth and discovery and between discovery and award by country of affiliated institutions [1901–2024].

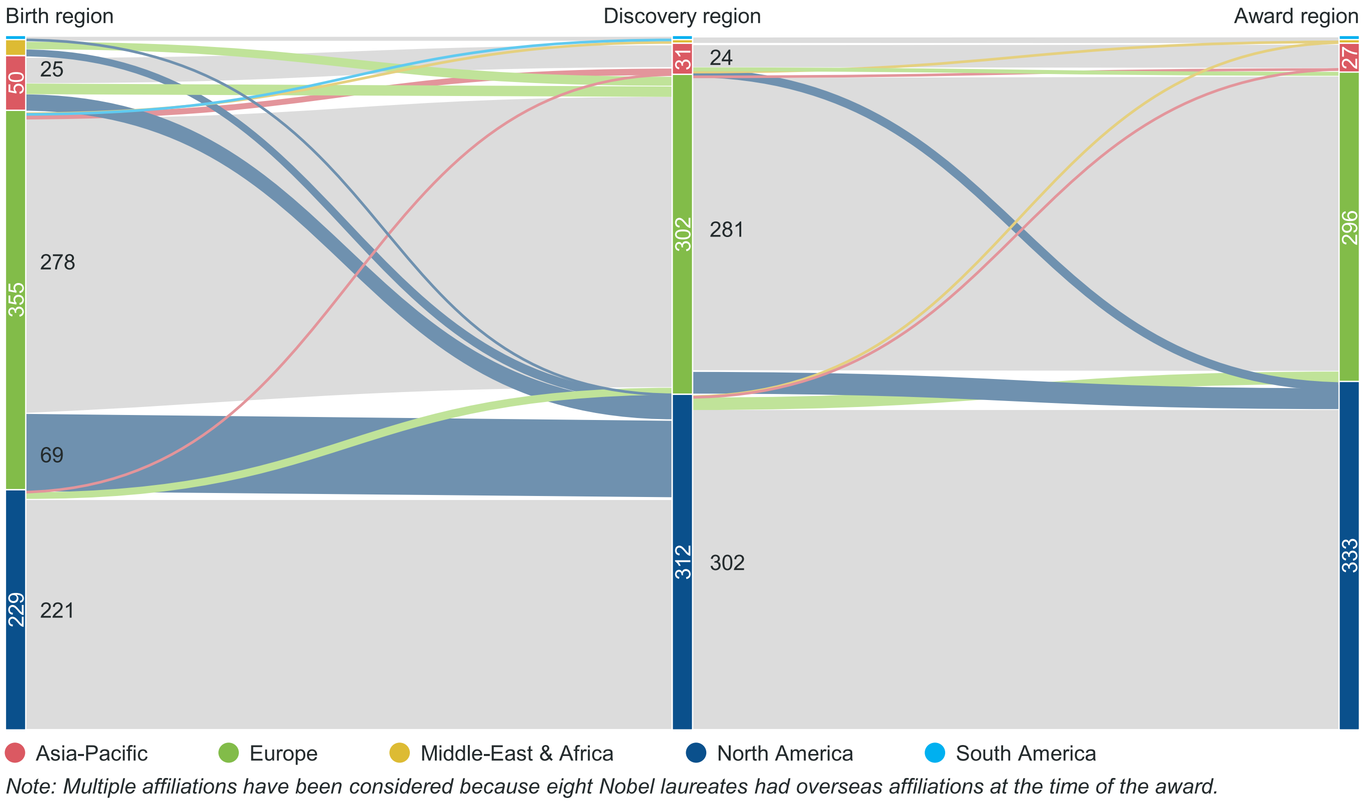


Fig. 3. Relocation of future Nobel laureates to other geographies by region [1901–2024].

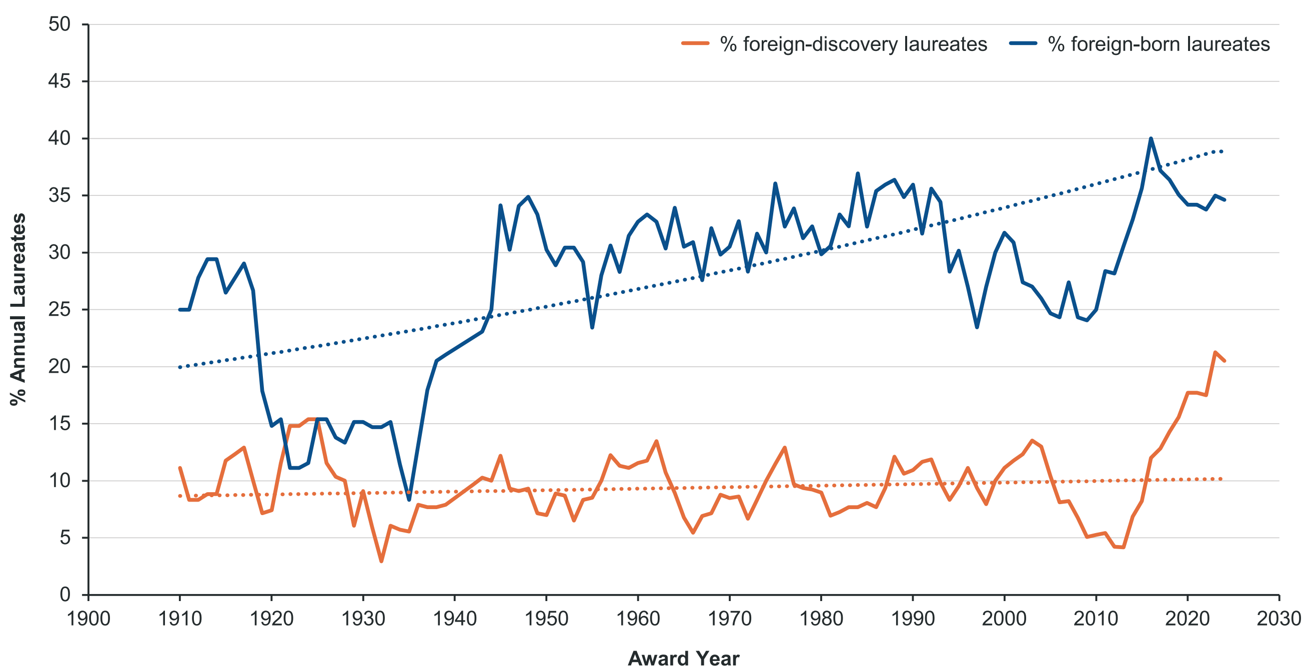


Fig. 4. Share of Nobel laureates with foreign discoveries or foreign birth [10-year moving average, 1901–2024].

been firmly in the 30–35 % range for most of the remainder of the 20th century and peaked at about 40 % early in the 21st century.

There are only minor differences across the three disciplines of the Nobel Prize considered in this study: The chemistry Nobel Prize has the highest share of foreign-born laureates (31.0 %), whereas medicine has the lowest share (27.1 %). This is similar for foreign-made discoveries, where chemistry again has the highest share (11.2 %) and medicine has the lowest share (10.0 %).

While many laureates are foreign-born, only 10.6 % of all Nobel Prizes were awarded for discoveries made outside the country of the award of the laureate. Improved scientist mobility would have suggested that this share should have increased since the early 1900s, but it has remained remarkably stable over time, with only a quite recent upward trend, and interpolated overall by a slow growing $y = 0.0854e^{0.0014x}$.

This observation is even more remarkable given the prolonged waiting period for laurates to be eventually recognized for their discoveries, which essentially gives them more time to move away or retire to a different country. The fact that this is not the case underscores how attractive countries of discovery remain for these scientists late in their careers.

Nobel Prizes are not only won mostly by scientists hailing from just a few countries; they also seem to be highly concentrated by country of birth and country of discovery. 80.6 % of all Nobel laureates were born in just nine countries (Fig. 5), with only two of them—the USA and Russia—also making it into the top 9 countries by mere population. Only five countries—the USA, UK, Germany, France, and Switzerland—are needed to explain at least 80 % of the locations of both discovery and eventual awards of Nobel Prizes. The concentration at the global level is mirrored within the United States, where just eight states account for 81.6 % of all US Nobel discoveries.

The Herfindahl-Hirschman-Index (HHI) offers a quantitative lens to assess the concentration of Nobel discoveries at the country level (Fig. 6). The HHI is a common measure to assess market concentration, where the concentration is calculated as $HHI = \sum_{i=1}^{N} (MS_i)^2$. We defined the "market share" of a country (MS_i) in a given year as the sum of Nobel Prizes up to that year whose discoveries were made in the specific country MS_i divided by the total number of Nobel Prizes up to that year. Ignoring the first decade after the introduction of the Nobel Prize, this concentration was moderate at best. However, after World War II, the concentration of Nobel Prizes has steadily increased to oligopoly-like levels, suggesting increasing institutional advantages that relatively few countries provide to both native and foreign-born scientists.

4.2. Institutional affiliations of Nobel laureates

One of the reasons for the occurrence of the Nobel "Pride" phenomenon is that the institutional affiliation at the time of the discovery is not always the same as the laureate's institution at the time of the award. Often, institutions recruit researchers who go on to win Nobel Prizes for work they have done elsewhere. Fig. 7 depicts the total number of Nobel Prizes awarded and where discoveries were made. The older the institution, the more time it had to win Nobel Prizes, but we were careful in tracking individual organizations' histories and mergers and acquisitions. In Europe, the University of Cambridge and the Max-Planck-Gesellschaft stand out, while in the US, the field behind Harvard University is closer together. Notable from a Nobel "Pride" perspective is that being on the faculty at the University of Cambridge appears to be a better place for discovery than for winning the Nobel Prize, while the situation is reversed for researchers of the Max-Planck-Gesellschaft. Heidelberg University can claim seven Nobel Prize laureates but has not recorded a single onsite Nobel discovery so far, while Washington University in St. Louis has contributed to eight Nobel discoveries but has only won three awards so far. Many of the institutions who attracted eventual Nobel laureates are renowned for excellent research already: MIT, Stanford University, or the Max-Planck-Gesellschaft. They have been the origin of many Nobel discoveries in their own right. Other institutions—such as the University of Cambridge or Bell Labs—have enabled more Nobel discoveries than they won Nobel Prizes. They may feel shortchanged in the recognition of their scientific productivity, but their situation is enviable compared to institutions such as Tulane University and the University of Hamburg who have made one, resp., two Nobel discoveries but saw their researchers leave and win Nobel Prizes for other institutions. In total, the top 20 institutions representing the five places with the most Nobel Prize-winning discoveries in the four respective regions account for slightly more discoveries than awards granted to faculty or employees, which is somewhat unexpected given that there are up to three award laureates per discovery. Fewer Nobel Prizes are associated with industrial firms, with Bell Labs leading IBM and GlaxoSmithKline both in discoveries and in prizes awarded to their employees. However, anecdotal evidence suggests that the Nobel "Pride" also plays a role in industrial R&D (e.g., Georgescu, 2022).

43.2 % of all Nobel laureates changed their institutional affiliations between discovery and the award (Fig. 8). This is certainly an underestimation of actual movement (see, e.g., Schlagberger et al., 2016), as we ignore multiple institutional changes and scientists that potentially returned to their discovery institution. The mobility did not vary much by Nobel Prize discipline: 41.6 % of all chemistry laureates changed institutions between discovery and award, compared to only 44.9 % of all physics laureates and 42.8 % of medicine laureates. We observed a declining trend of laureates switching their institution ($y = 0.4874e^{-0.002x}$), possibly due to the increasing resource commitments

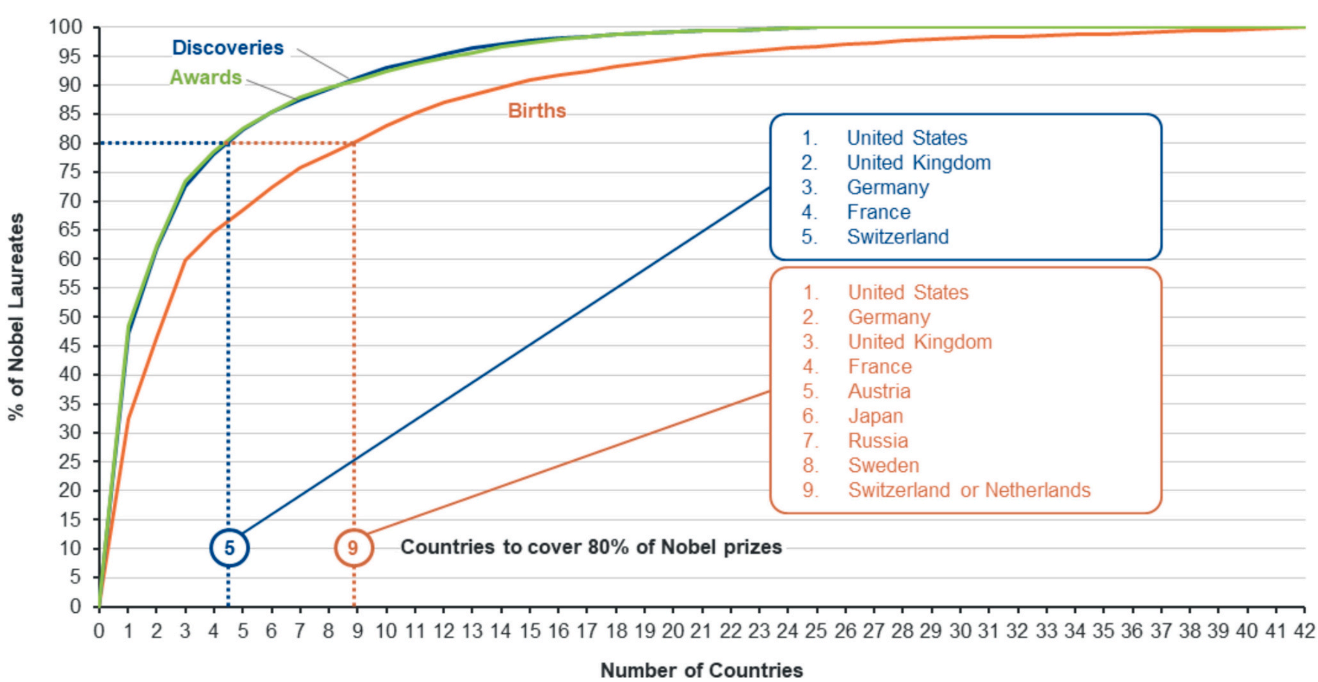


Fig. 5. Concentration of Nobel laureates by country [1901–2024].

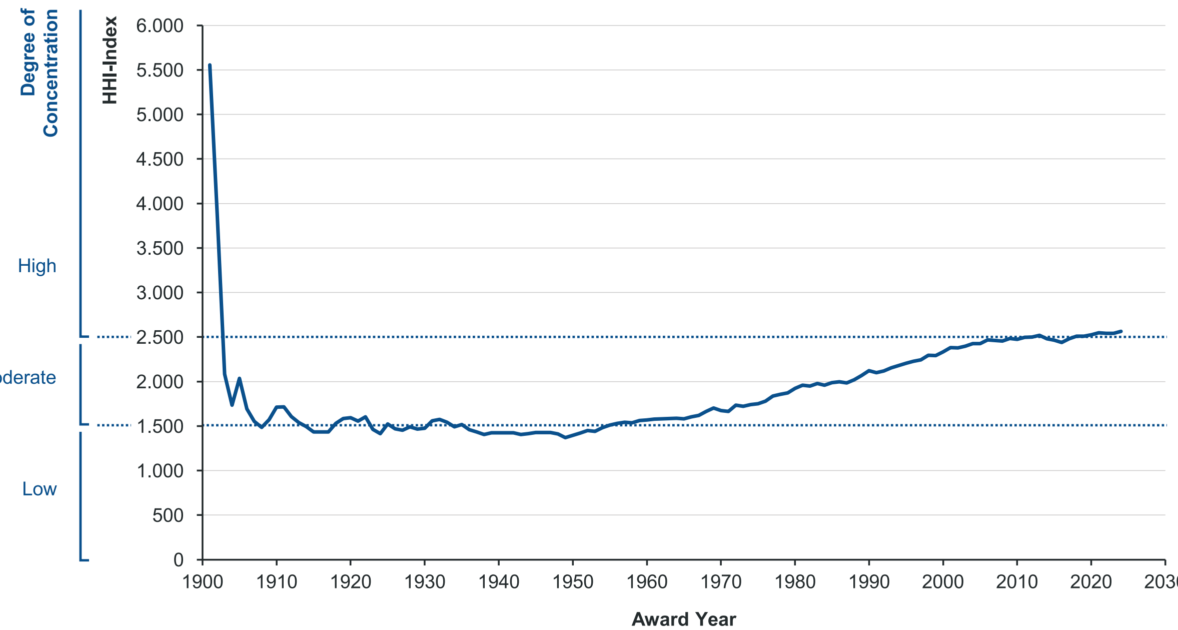


Fig. 6. Herfindahl-Hirschmann Index (HHI) concentration of Nobel Prize-winning discoveries by country [1901–2024].

required for conducting basic research in foundational science disciplines or institutions being able to hold on to top scientists more easily recently.

A total of 312 institutions were either affiliated with a scientist awarded a Nobel Prize or served as a location for a Nobel discovery. As suggested by Fig. 7, some institutions were more successful in generating Nobel discoveries or affiliating with scientists who were given the award, yet it still takes 101 institutions to account for 80 % of all Nobel discoveries and 110 institutions for 80 % of all Nobel awards to their faculty and employees (Fig. 9). While this frequency chart reveals a concentration of Nobel discoveries by institution that is significantly lower than by country (see Fig. 5), it also suggests little difference in concentration between discovery and award of the Nobel Prize.

Still, focusing specifically on Nobel discoveries (Fig. 10), three institutions account for 12 % and 32 institutions for at least half of all discoveries made by their scientists. Of an estimated 31,000 universities worldwide, only 150 are listed as being the site of a Nobel discovery, 160 as having a faculty member who has won a Nobel Prize, and 196 as having some Nobel claim at all. That is less than 0.6 % of all universities worldwide. Universities make up 62.8 % of all Nobel institutions (discovering or winning faculty), with research institutes (such as the NIH or the Max-Planck-Gesellschaft) accounting for 26.6 %, and industrial firms (such as IBM or Bell Labs) for 10.6 % (two Nobels could not be institutionally classified). There are no estimates for the number of research institutes, but the number of firms easily surpasses the number of universities. Based on those numbers, we conclude that Nobel science is highly oligopolistic. To be included in the elite club of Nobel-affiliated institutions, a school, research institute, or industrial firm must have an affiliation with a scientist who made at least one discovery or has been awarded at least one Nobel Prize. Out of the 312 distinct organizations in this Nobel club, 218, i.e., more than two-thirds (70 %), have an affiliation with just one such discovery or award. Of 242 institutions with at least one Nobel discovery, 165 of them (or 68 %) also won at least one award. Of 236 institutions that won an award, 72 of them (or 31 %) never made a single Nobel discovery.

5. Discussion & implications

5.1. *Who is leading, who is lagging?*

In absolute terms, every country affiliated with even just a single Nobel discovery is already a winner, having enabled exceptional contributions to science. Nobel discoveries have been made in 27 countries so far, out of 193 countries recognized by the United Nations. Have countries improved their productivity in terms of Nobel discoveries over time? Fig. 11 shows how individual countries (including individual US states) have fared, in Nobel discoveries per million inhabitants, before and after 1960 (which is close to halfway between the start of the Nobel Prize in 1901 and the last year of our data, 2023). The USA is the leading country in its affiliation with Nobel discoveries and awards, and thus a natural benchmark against which to compare other countries' progress.

In relative terms, i.e., in Nobel discoveries per capita, the UK, Sweden and Switzerland have been consistently punching above their weight. This contrasts sharply with historical Nobel powerhouses such as Germany, France, Netherlands, and Austria, which—despite having been very productive early on—have seen their stronghold on Nobel Prizes decline with regard to discoveries made. Denmark has kept up with the USA. Our analysis also showed that while some countries saw increased output of Nobel discoveries (e.g., Japan and Australia, with newcomers Norway, Israel and China), there are no new contenders that could challenge the USA's position as being the most productive country for discoveries with eventual Nobel recognition. Considering the USA's internal landscape, faculty and employees at institutions in Massachusetts, New Jersey, New York, Missouri, California and Maryland contribute the lion's share of US Nobel Prize-winning research, outperforming national and global averages in discoveries.

5.2. *Attracting future Nobel laureates*

Institutions and countries are interested in attracting the most talented scientists worldwide, as they create scientific breakthroughs and lay the foundation for industrial innovation and increased standards of living and wealth. Nobel Prize-winning talent is a rare and valuable asset, prompting countries and universities to either try to nurture such talent domestically or attract it from abroad. To our knowledge, the process of attracting involves individual scientists moving across

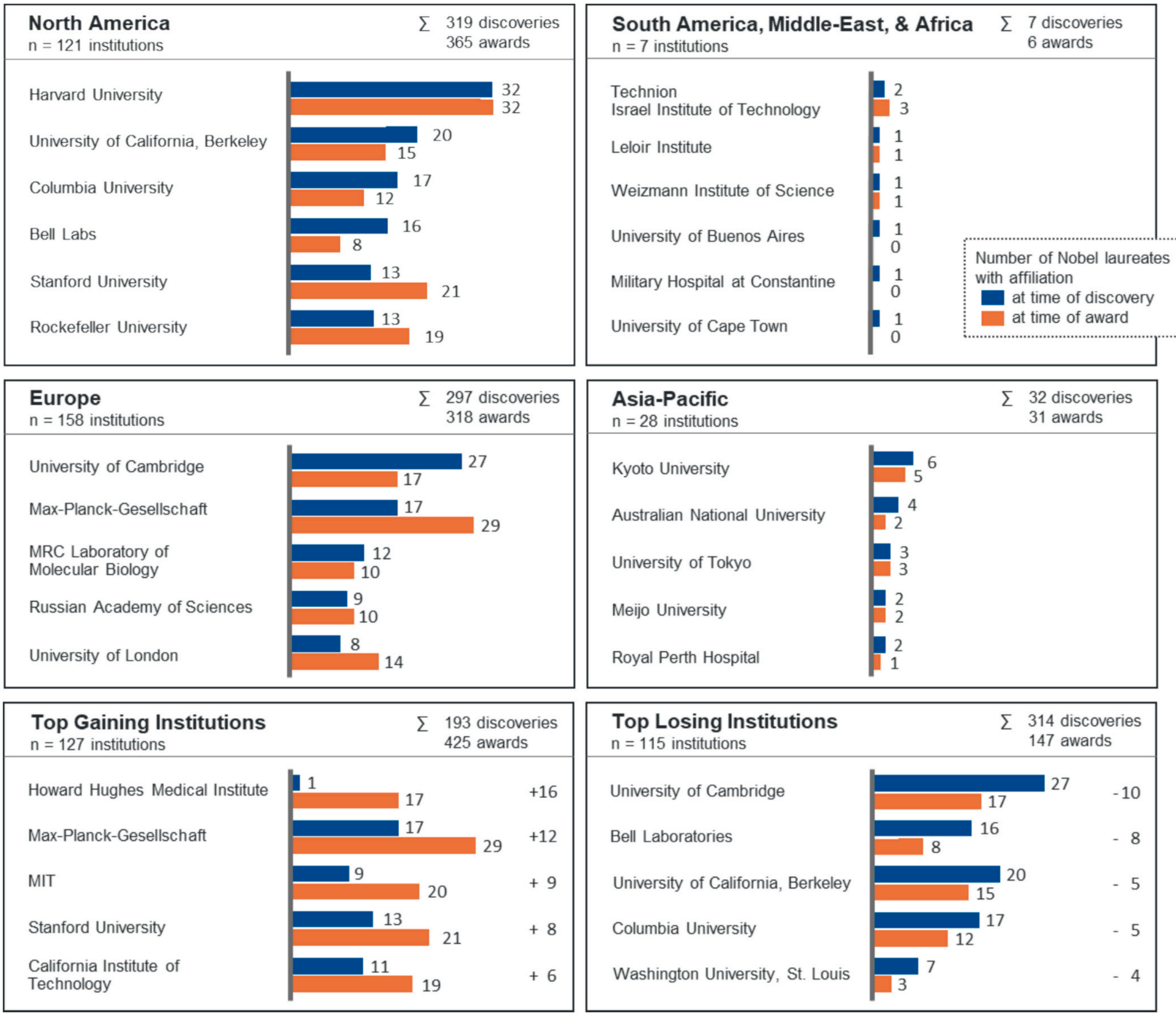


Fig. 7. The top 5 institutions ranked by number of discoveries and awards per region, as well as top 5 winning (more awards than discoveries) and top 5 losing (more discoveries than awards) institutions.

borders entirely voluntarily, being incentivized by the carrot rather than compelled by the stick.

Fig. 12 shows how successful countries have been in attracting eventual Nobel Prize laureates before and after discovery (on a per capita basis). It is clear from the data that the majority of international movement among scientists occurs prior to their Nobel Prize-winning discoveries. Comparatively, there is less such geographical movement between discovery and award. Although some foreign scientists immigrate after their Nobel discoveries have been made (Fig. 4), we also observed a declining trend of domestic relocation between different institutions once such a discovery has been made (Fig. 8). The results depicted in Figs. 3 and 12 suggest that the effects of increased geographical mobility of scientists seem to be strongest in the early stages of the scientists' careers, i.e., before Nobel discoveries are being made and not after. This observation has implications for science policy at the national level as well as for the research policy of institutions with intentions to improve their chances of creating Nobel Prize winners.

Leading countries such as the USA, the UK, and France are close to the overall average (Fig. 12). As was the case for seven US states, more than half of all discoveries won for Canada and Switzerland were made by foreign-born laureates. Europe, as a whole, was the birthplace of 54.4 % of all Nobel laureates, but can only claim 44.6 % of all prize winners at the time of the award. More specifically, Europe has had 302 discoveries, with 87 (28.8 %) of those made by scientists born in another country and 24 (27.6 %) of those born outside Europe. At the same time, 19.4 % of European-born laureates found their way to the USA before their award-winning discoveries, while only 2.6 % of North American laureates came to Europe for their discoveries. Sweden, Germany and Denmark are the only countries and Illinois the only US state with institutions that have been successful at both attracting future Nobel Prize winners before and after discoveries. Overall, however, Fig. 12 reinforces the conclusion that most cross-border relocations occurred before the seminal Nobel discoveries were made. The almost complete absence of countries from Asia-Pacific, Africa, and Latin America does not do justice to the fact that Japan and Australia have made substantial contributions with home-grown Nobel discoveries; however, their institutions do not seem to be able to translate these achievements into sufficiently strong sources of attraction for foreign scientists to relocate there. Complementing Franzoni et al.'s (2012) work, Canada, the USA (in the order of declining ratio of foreign-born discoverers: North

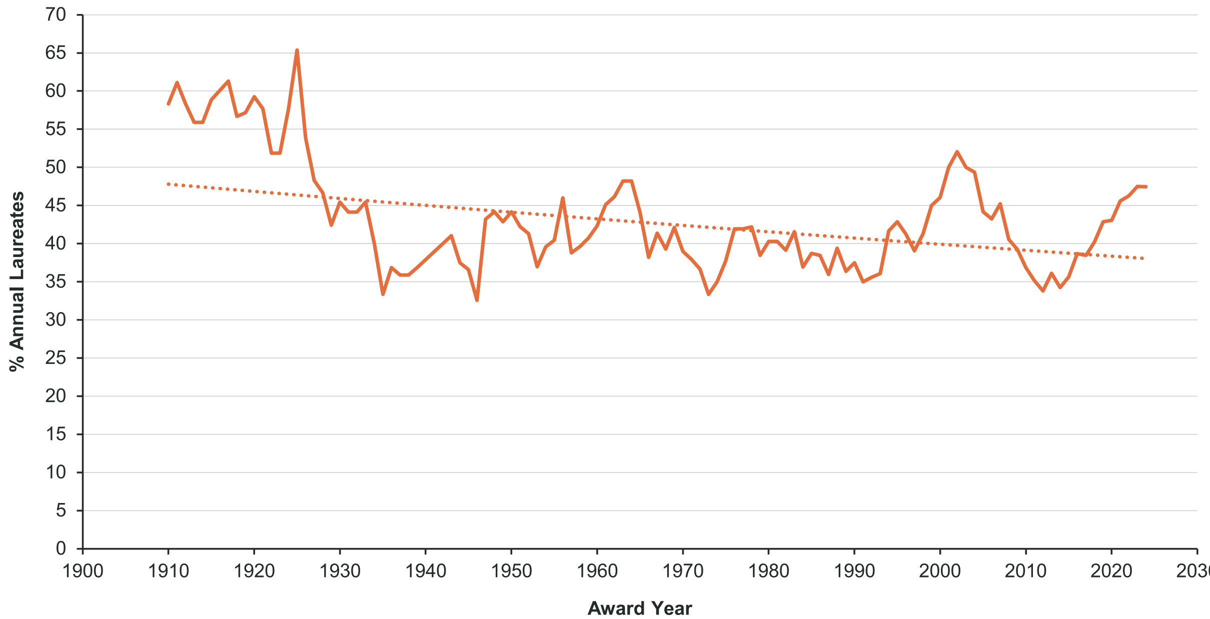


Fig. 8. Share of Nobel laureates who change their institution after discovery [10-year moving average, 1901–2024].

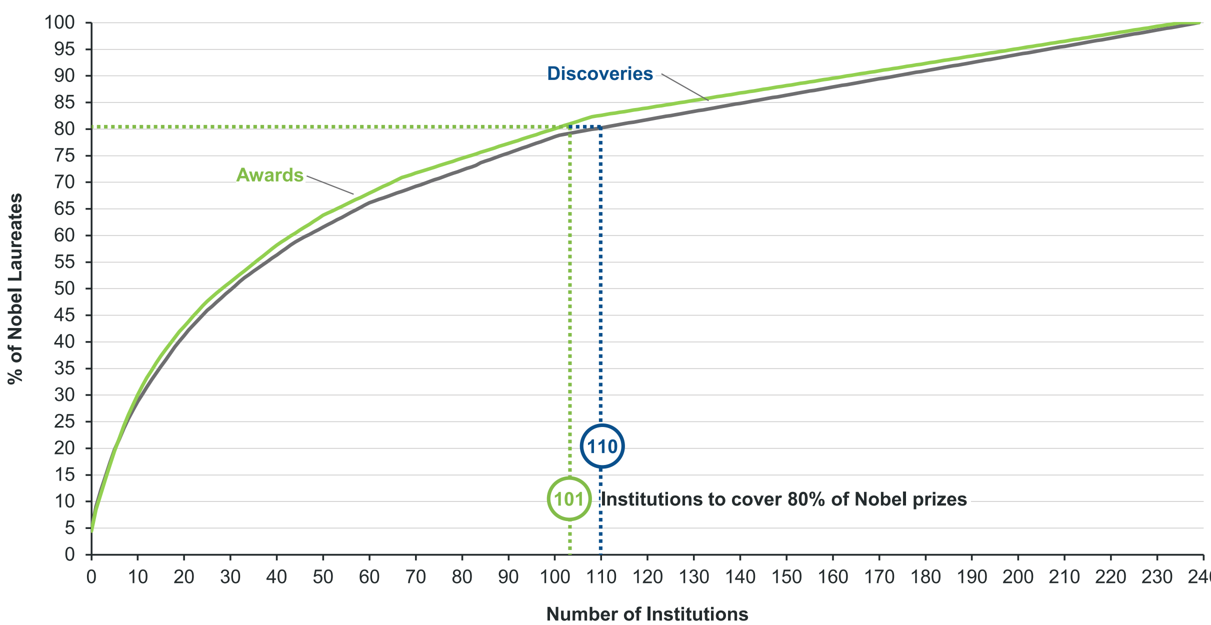


Fig. 9. Concentration of Nobel Prizes by institution [1901–2024].

Carolina, Maryland, California, Washington, Texas, Massachusetts, New Jersey, and New York), and Europe (especially Switzerland and France) are the most attractive countries for future Nobel laureates.

6. Conclusions and limitations

Membership in the Nobel Club is not entirely for prestige and glory only; it also has relevance for university rankings (e.g., in the ARWU (2023) Academic Ranking of World Universities calculations), fund-raising, and talent attraction. The allure of these benefits for institutions and countries is what leads to the Nobel "Pride" phenomenon. We posit that the number of Nobel Prizes institutions claim for themselves exceeds both the discovery and the award count. While these figures are used to signal a highly productive research environment, certain features of that phenomenon have not been well understood until now. We focused on the bragging rights based on being "the birthplace of Nobel winning discoveries" as opposed to being "the institution where Nobel winners retire." Almost one-third of the Nobel laureates have won the prize in a country other than the one in which they were born, and more than 43 % of them won it at an institution other than the one at which the original discovery occurred. We expect that the trend toward the concentration of Nobel Prizes by relatively few institutions will continue due to the rise in both the scope and scale of resource requirements and experimental infrastructure in basic science research. As an implication for national policy, this suggests that those countries with award winners should maintain their attractiveness for excellent research by remaining open for immigrants and investing in research infrastructure and education. Only a few countries have been able to gain ground on the leading attractors worldwide, notably Japan. Once a discovery is made, relocation appears to be primarily domestic in

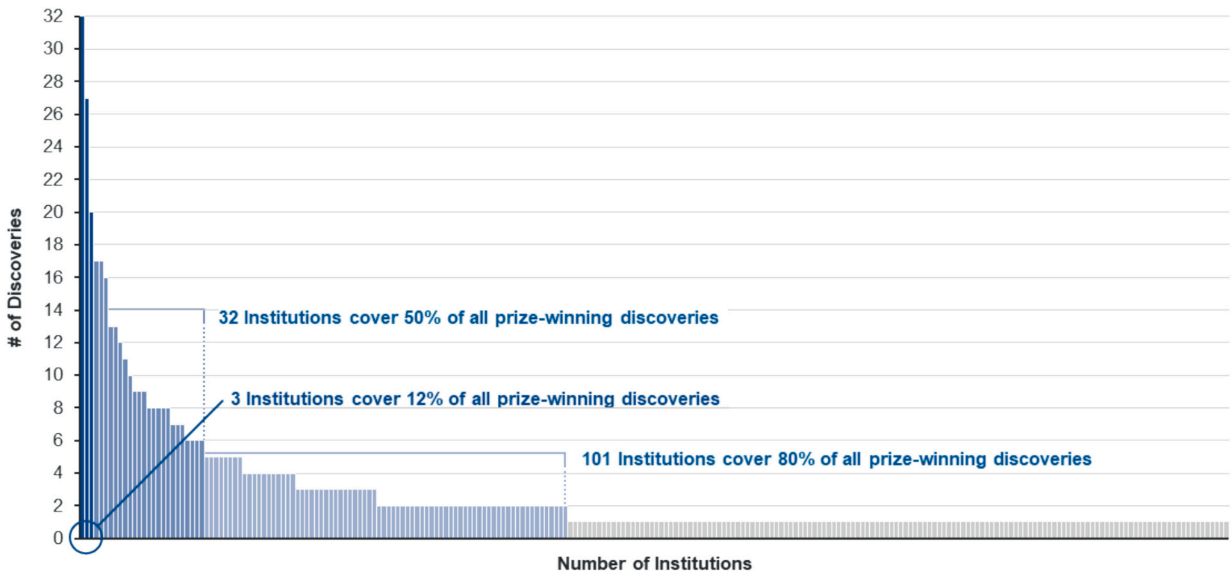


Fig. 10. Concentration of Nobel Prize-winning discoveries by institution [1901–2024].

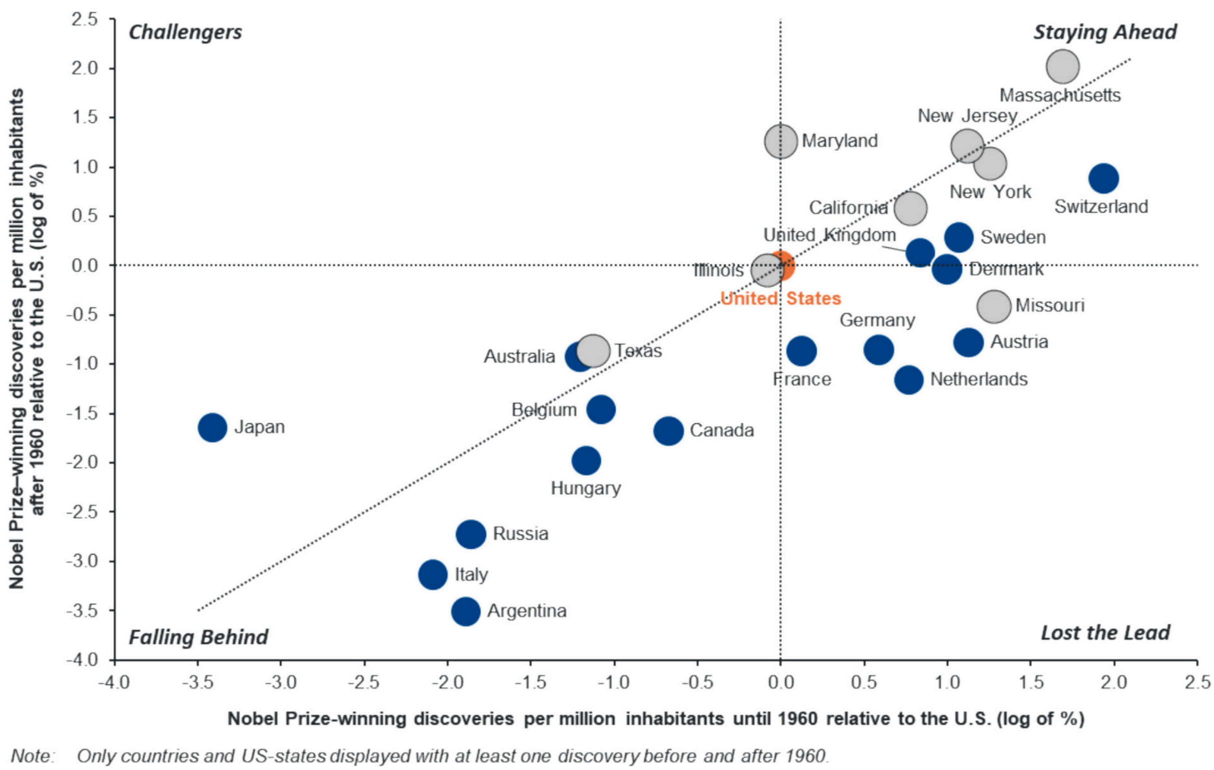


Fig. 11. Nobel Prize-winning discoveries per million persons relative to the USA [pre-1960 vs. post-1960, log of %].

orientation and a matter of moving between institutions. The "war for talent" (whether or not that talent eventually wins a Nobel Prize) is often driven by pre-established reputations and financial rewards. Institutions with a strong track record of Nobel discoveries could strategically campaign on a policy of using their resources on young scholars who might make the next Nobel breakthrough to differentiate themselves from institutions that offer more attractive conditions for late career scientists—notwithstanding the frequently made observation that young aspiring researchers want to rub shoulders with senior and accomplished scholars (Reschke et al., 2018; Li et al., 2019).

On the other hand, not all Nobel discoveries are exclusively attributable to the institutional or geographic context in which they occur. Many countries lost their ability to claim affiliation with a Nobel Prize because bright young scientists emigrated early in their careers. It is difficult to ascertain (and impossible with our present data set) whether the original idea that eventually led to a breakthrough discovery and was subsequently rewarded with a Nobel Prize occurred even before these scientists migrated away from their home countries. There is documented but anecdotal evidence that Nobel discoveries were inspired by research visits to foreign countries or institutions, but the actual breakthrough occurred after the scientist's return. Future research should aim to overcome this limitation in our data, which

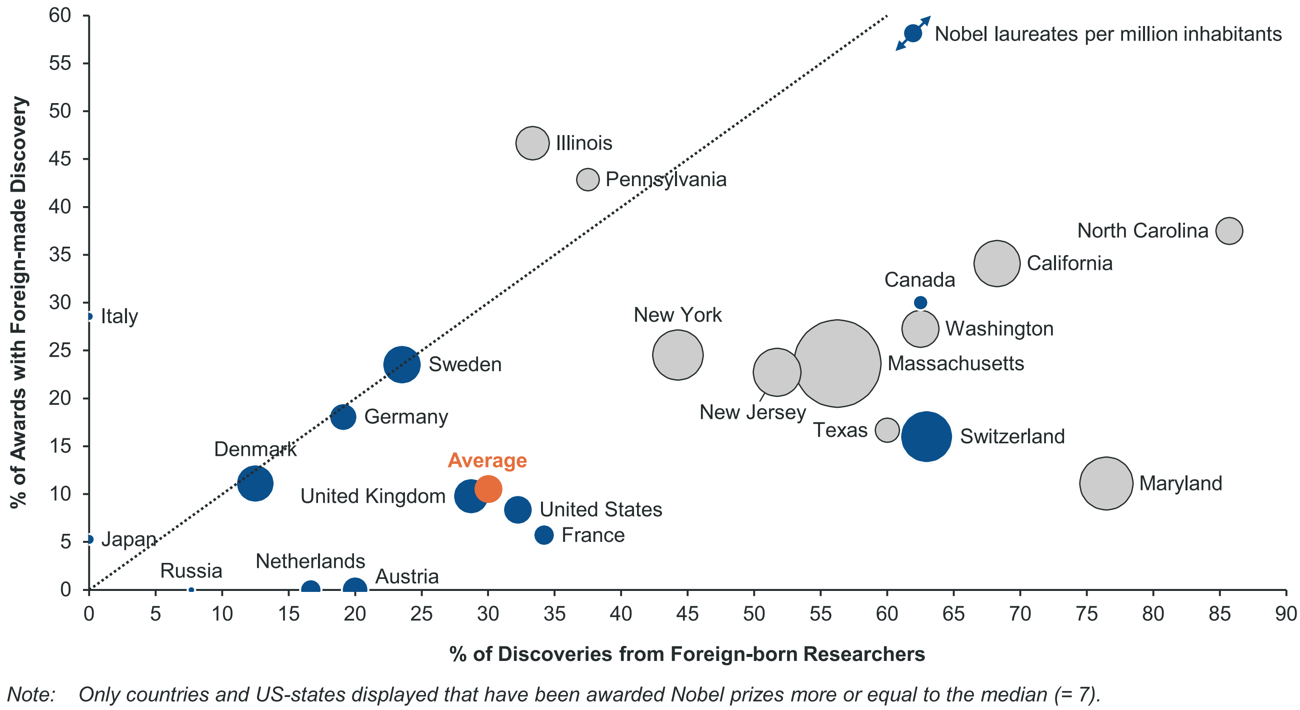


Fig. 12. Share of Nobel discoveries and awards from another country [1901–2024].

would require substantially more detailed accounts of the genesis of breakthrough discoveries than we had access to, but which may be next to impossible to collect for all Nobel laureates. Considering proportional wins for shared prizes could further refine the results. Our analysis was also unavoidably limited by the small sample size of actual Nobel discoveries and awards. Future research could consider all institutional changes made by eventual Nobel laureates as opposed to only at the time of discovery and the award. Moreover, conducting a detailed comparative analysis between Nobel Prize winners and nominees (expanding on the age lens applied by Baffes and Vamvakidis, 2011) could reveal key success factors and enhance our understanding of elite science recognition. Other interesting avenues for further development are the extension of this research into the other Nobel Prizes (literature, peace, and economics) and perhaps also to other research prizes given for discernable accomplishments such as the IEEE Medal of Honor, the Lasker Award, the Fields Medal or the Turing Award.

CRediT authorship contribution statement

Max von Zedtwitz: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tobias Gutmann:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Pascal Engelmann:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

We illustrate the application of our discovery identification protocol in the example of the 2023 Nobel Prize in physics. This prize was given to three individuals (Anne L'Huillier, Pierre Agostini, and Ferenc Krausz) with the same motivation (as per the Nobel Prize website): "for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter."

Starting with Anne L'Huillier, her Nobel Prize website at https://www.nobelprize.org/prizes/physics/2023/lhuillier/facts/ states that "in 1987, Anne L'Huillier discovered that many different overtones of light arose when she transmitted infrared laser light through a noble gas. She continued to explore this phenomenon, laying the ground for subsequent breakthroughs in producing attosecond pulses." We therefore recorded 1987 as the year of Nobel discovery for her part in the prize, filing it as a phase-1 event.

Next, Pierre Agostini's Nobel Prize website at https://www.nobelprize.org/prizes/physics/2023/agostini/facts/ states that "in 2001, Pierre Agostini succeeded in producing and investigating a series of consecutive light pulses, in which each pulse lasted just 250 attoseconds." We therefore recorded 2001 as the year of Nobel discovery for his part in the prize, again a phase-1 event.

The identification of the discovery event is a little bit more complicated in the case of Ferenc Krausz. His Nobel Prize website at https://www.nobelprize.org/prizes/physics/2023/krausz/facts/ does not indicate a precise year of discovery motivating the award. However, it states that "at the turn of the millennium, Ferenc Krausz and his team – in a series of experiments – generated and measured light pulses shorter than one femtosecond, controlled and measured the electric field oscillations of visible light, and used these tools for real-time observation of fundamental electron phenomena, predicted in the last century." This is not sufficiently precise to ascertain a specific year of discovery.

An *Enc. Britannica* website at https://www.britannica.com/biography/Ference-Krausz reveals that he "was awarded the 2023 Nobel Prize in Physics for his experiments with attosecond pulses of light" and that "Krausz and his group were among the first to generate attosecond pulses and published their results in 2001." This information suggests

2001 as a phase-3 marker for the discovery.

Since Krausz spent most of his career in Germany and Austria, we consulted the German Wikipedia page at https://de.wikipedia.org/wiki/Ferenc_Krausz, which states "Mithilfe intensiver, aus ein bis zwei Wellenzyklen bestehender Laserpulse konnte Krausz' Gruppe im Jahr 2001 erstmals einen Attosekunden-Lichtpuls (aus extrem ultraviolettem Licht, EUV) sowohl erzeugen als auch messen und wenig später damit auch die Bewegung von Elektronen auf subatomarer Skala in Echtzeit verfolgen. Die von Krausz und seinem Team demonstrierte Kontrolle der Wellenform von Femtosekundenpulsen und den daraus resultierenden reproduzierbaren Attosekundenpulsen erlaubten die Etablierung der Attosekunden-Messtechnik, wie sie heute als technologische Basis für die experimentelle Attosekundenphysik dient." (Translation: "Using intense laser pulses consisting of one or two wave cycles, Krausz's group was able to both generate and measure an attosecond light pulse (from extreme ultraviolet light, EUV) for the first time in 2001 and shortly afterwards also track the movement of electrons on a subatomic scale in real time. The control of the waveform of femtosecond pulses and the resulting reproducible attosecond pulses demonstrated by Krausz and his team enabled the establishment of attosecond measurement technology, which today serves as the technological basis for experimental attosecond physics.") This information suggests that the breakthrough discovery was also made in 2001, not just published in 2001, constituting a phase-1 event.

We cross-referenced this information with his 2001 *Nature* publication (https://www.nature.com/articles/35107000). A 2001 discovery and publication in the same years also seems reasonable given the median review time for *Nature* in the early 2000s of 85 days, i.e. less than three months (see https://www.nature.com/articles/530148a). We therefore recorded 2001 as the year of discovery for Ferencz Krausz's part in the 2023 Nobel Prize.

Data availability

Data will be made available on request.

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