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Selection and Placement of the Scientific Elite. The Network of Nobel Prize Nominations in Physics and Chemistry, 1901-1969

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Table of contents:

1. Abstract

The Nobel Prize, renowned for its prestige, garners attention beyond typical scientific awards, amplified by broad media coverage and an extensive data archive of nominations. The Nobel Foundation's Statutes permit disclosure after 50 years since awarding. For my dissertation, I compiled a distinctive dataset of nominees and nominators in the categories of Physics and Chemistry using the Nobel nomination archive and additional data sources for the period 1901-1969. This dataset allows for the accurate analysis of the organizational affiliations of scientists within the nomination network.

My research is guided by a theoretical triad, enabling analysis of the skewed nomination network structure and the pivotal role of nominators in power dynamics, situated within sociological discourse on particularistic selection, global shifts in scientific hegemony, and academic prestige stratification.

Findings show a gender disparity in the composition of nominators throughout the observation period, with female representation substantially lower, even compared to female representation in academia as a whole, supplementing existing research on the underrepresentation of women as nominees and laureates. Inversely, members of the Royal Swedish Academy exhibit privilege as nominators, particularly in the early decades. However, this influence decreases over time, indicating a reduction in particularistic selection.

The shift in scientific hegemony that has been confirmed for Nobel laureates also becomes visible within nomination structures. German nominators wielded significant influence in the early decades, while US nominators dominated by the 1930s. Self-nominations mirror this shift, showing that these two scientific hegemons perpetuate their nomination power.

Nomination power is distributed unevenly, especially across countries. Nomination patterns demonstrate status sensitivity, with nominators favoring nominees of matching organizational prestige. However, there is insufficient evidence to support a clear organizational hierarchy in terms of successfully placing nominations. This indicates that placement power is not limited to high-prestige organizations. In fact, new organizations have an advantage in successfully placing nominations, demonstrating that organizational renewal can disrupt existing hierarchies within selection processes.

This study highlights the importance of analyzing the scientific prize landscape at various levels. It enhances the findings for the Nobel nomination network as well as literature on stratificational processes within science, particularly by providing an organizational view of top performers and scientific centers.

2. Introduction

The iconic presentation of the Nobel Prize attracts attention far beyond the usual scope of a scientific award. Prize winners often become celebrities of science, attracting admirers in the general population as well as media interest that never seems to cease. Numerous myths surround the annually awarded prizes, including misjudgments, debatable decisions, secret intrigues, neglected researchers, and the unmatched genius of the awarded winners. Many studies have already been devoted to the analysis of this spectacle, its famous laureates as well as non-laureates, oftentimes focusing mainly on qualitative narratives concerning individual scientists or decision-makers in various institutional positions.

In addition to that part of research, a quantitative branch has emerged that attempts to classify the Nobel Prize and its individual laureates in terms of organizational aspects and institutional processes. Despite the epic staging of what is incontestably the most famous scientific awarding, the Nobel Prize is not a fabled fairy-tale but a complex institution that encompasses a remarkably visible reward structure for the international scientific community. This dissertation shall do its part to cast a macro-perspective picture on the nomination process and contribute to the rationalization of the Nobel Prize. More precisely, the nomination structures of the Nobel Prize will be analyzed in their entirety up to the year 1969 for two out of three scientific award disciplines, Physics and Chemistry.

As a basis, I have used the records available at the online 'Nomination Archive' provided by the Nobel Foundation. In my dissertation project, I have expanded as well as compiled a unique dataset of these archival information. Both selection stages, those of nominators as well as those of nominees, will be examined in a historical context. The aggregated data offers an analysis on three levels: individuals, organizations, and countries.

My research objective is to provide an in-depth, methodically controlled, fine-grained analysis of the nomination process. First, analysis aims to ascertain whether the nomination process incorporates measurable ascriptive elements, following a discussion about universalism and particularism (Merton, 1973 [1942]; Parsons, 1964 [1951]) within the Nobel context, with a focus on the role of women and members of the Royal Swedish Academy as nominators. Furthermore, an investigation will be conducted to determine if the nomination process aligns with the shift of global scientific leadership from Germany to the United States at the beginning of the 20th century. This shift was conceptualized by Ben-David (1960, 1971), concretized by Hollingsworth (2006), and quantitatively confirmed by Heinze et al. (2019; 2020) for laureates. Finally, the principles of prestige and stratification in the Nobel nomination process are examined to determine if there is a skewed distribution and hierarchical structure similar to other academic social networks that promote the concentration of placement power on few prestigious actors (Burris, 2004). In terms of a middle range theory (Merton, 1968b), my intention is not to characterize systemic effects, but rather to consider particularistic features, shifts in scientific leadership, and placement mechanisms as several aspects among a multitude of possible research endeavors within the Nobel Prize framework.

As a start, I will give a very brief insight about the Nobel Prize as such and present relevant information about the nomination process. This is followed by a literature review of laureates as a Nobel population (chapter 3), the theoretical framework used (chapter 4), and my research hypotheses derived from these sociological concepts (chapter 5). In chapter 6, I will describe the data basis as well as data curation and methods used for analysis, after which I will present main findings in chapter 7, regarding mainly descriptive analysis (7.1), self-nominations (7.2), organizational network components (7.3), and regression analysis (7.4). Some excerpts of further interesting questions as well as outlooks on possible research approaches will precede a final conclusion. After graduation, I intend to make the extensive database presented in this dissertation publicly available as a repository.

2.1 A "Nobel" myth in science

There hardly is a single person who does not know about the Nobel Prize at all. Fame precedes this important scientific institution and sharpens the image associated with laureates to that of world-class performers. In the public's understanding of science, the Nobel Prize (NP) has become a significant marker of both intellect and scientific excellence: If scientists are known to be NP laureates, people know very well that they must be among the best. No achievement in the scientific community can be better classified by the public. Some laureates themselves have become practically synonymous with the Nobel Prize, such as Albert Einstein or Marie Curie. Though, not only do former luminaries play a major role in today's awareness of science: the case of a successful series 'The Big Bang Theory' shows that the Nobel Prize still has great symbolism today (Brodesco, 2018).

But let us briefly start at the beginning. Alfred Nobel, legendary founder of the award that bestows prestige on the most capable inventors, was an inventor himself: In the 19th century, he successfully marketed dynamite and amassed a sizeable fortune, which he gave to a foundation, known today as the Nobel Foundation. The motivation of this act is seen as an altruistic way to give something good back to humanity by supporting researchers and activists who are actually changing the world for better. Before his passing, Alfred Nobel was known primarily as the inventor of dynamite. The Nobel Prize has therefore been attested to his greatest invention (Liljas, 2016).

Several sources report on the turmoil of Nobel's life, his idealistic but also melancholic character, and the justification of his legacy (Norrby, 2010; Pederson, 2006; Ringertz, 2023). In general, the idea of a scientific prize met with little approval at the beginning of the 20th century. Otto Pettersson, professor at Stockholm University, is said to have made the following exclamation about it: "the stupidest use of a bequest that I can imagine! To seek reward for their work is not attractive for scientists" (Friedman, 2001, p. 16) and thus voiced what certainly many thought who were to be given a task in the awarding process. But the initial critique was eventually silenced. Pettersson himself was an active nominator, having nominated candidates in twelve years between 1901 and his death in 1941.

Key managing roles within prize awarding were negotiated for years after Nobel's death, but eventually assigned. Worth mentioning for this work are above all the constitutive regulations of Nobel's last will: Alfred Nobel created five prize categories to those accomplished the often recited *greatest benefit to humankind* (*Statutes of the Nobel Foundation*, 2023) in Physics, Chemistry, Medicine or Physiology, Literature, and Peace in the respective year.

The Nobel Foundation was established to continue administering Nobel's will, for example, to handle the finances, and, generally speaking, to execute his directives. The complete set of regulations is accessible in the Statutes of the Nobel Foundation, from which I only present the most important passages regarding the analysis of nominations in the prize categories of Physics and Chemistry in the following subsection. The actual awarding of the prizes was distributed among highly respected institutions within Sweden and Norway. For the two prize categories Physics and Chemistry, the Royal Swedish Academy of Sciences was designated to be the awarding body (*Statutes for the prizes awarded by the Royal Academy of Sciences*, 2023).

In the Nobel calendar year, the announcement of laureates is scheduled for October, while the grand awarding ceremony as a centerpiece of orchestration is held in December on the anniversary of Alfred Nobel's death. This meaningful date is surrounded by festivities that are more like a "Nobel-week" than just one day (Hargittai, 2003, pp. 7-11). Laureates take part in numerous appointments in and around Stockholm, though the week's highlight is the formal ceremony in Stockholm Concert Hall. When it comes to the proclaimed "magic" of the banquet, the Nobel Foundation itself abides by it, and even encourages the idea of it being an unforgettable moment: On the official website of the Nobel Prize, plenty of details about procedures are revealed. It makes the event more accessible to the general public, knowing, for instance, that even the scientists to be honored struggle with the strict dress code (*The Nobel Dress Code*, 2023).

Described as the Royal Effect, it notably is the presence of the Royal Swedish family that lends the Nobel Prize an aura of tangible nobility (Ganetz, 2017). The ceremonial design of the banquet, such as the fact that laureates receive their diploma, check as well as their medal from the current Swedish regent, speaks to the concept of invented tradition as a means of giving legitimacy to the Nobel Prize from the very beginning (Källstrand, 2018).

The question arises as to how much of the Nobel Prize is appearance and show, and how much is about a real contribution to science. In terms of its remarkable performance, the question seems rather trivial. In terms of the overall significance for rewarding individuals who contributed to scientific advancement, it lacks an easy answer, especially within an introductory part. To first return to Alfred Nobel himself: It is questioned if today's awarding corresponds to what he envisioned back in 1895 (Thompson, 2016). Nobel's original idea was to sponsor young talents at the very start of their careers, to make them financially independent for conducting groundbreaking research that leads to practical applications (Källstrand, 2022, p. 188). But the award evolved into the "gold standard" (Norrby, 2010, p. 38) of prizes, given to mature and already established scientists with discoveries mostly made within basic academic research.

Further criticism emerges mainly due to contestable award decisions. Casadevall and Fang (2013, p. 4685) have tabulated many of these, providing a useful overview: The majority of controversial cases arises from the exclusion of award-worthy contenders. The opposite error, awarding a discovery not worthy of a prize, is rather an exception, as in the case of Johannes Fibiger (he claimed to have identified cancer as an infectious disease, which turned out to be wrong). Furthermore, it shows that the phrase *greatest benefit to humankind* is disputable occasionally, as for example in the case of Egas Moniz, the originator of Prefrontal Lobotomy: a technique used to cure patients with nervous diseases that resulted in partially dramatic side effects (Tierney, 2010).

Additionally, award-granting-organizations such as the Royal Swedish Academy of Sciences and their respective committees are subject to persistent accusations of making chauvinistic, nationalistic, sexist or self-rewarding decisions (Friedman, 2001; Heinich, 2009; Lunnemann et al., 2019; Modgil et al., 2018; Sri Kantha, 1991), a serious concern I will later on supplement with data I obtained.

Other critical points shed light on the scientific landscape which has undergone major changes since the late 19th century. As in that period, the Nobel Prize is an advocate for a science-positive image of societal progress through scientific innovation, which centers on individual researchers. By contrast, the development of the 20^{th} century illustrates an increasingly science-critical picture due to scientific achievements/responsibilities in the context of world wars. Moreover, the idealistic image of the lone, ingenious researcher clashes with today's reality of science-teams in large laboratories of even larger research facilities doing what has been called “big science” (Price, 1963), for example in research projects like the Manhattan Project or facilities like CERN. As a whole, the Nobel Prize falls in a time span in which the universal truth of science, bestowed upon a selected few intellectuals, is debated anew in the context of a growing need of organizational management, collaboration and scientific consensus. Its way of telling heroic myths about iconic leaders clashes with a development in which individuals play a subordinate role, as individual contributions to discoveries cannot be attributed neither effortlessly nor equitably (Nye, 2019).

In that matter, there are calls for an increase in the number of laureates or for an award to entire teams or organizations. Up to now, a maximum of three laureates per category are allowed to share an NP, which repeatedly leads to exclusions. Researchers who do not fit the image of a scientist, dominated by European or North-American men, are particularly exposed to those. Today, it is difficult to imagine that Marie Curie's groundbreaking accomplishments, which led to her first NP shared with her husband Pierre and Henri Becquerel, were regarded merely as an assistantship, which could have potentially eliminated her from the prize. Unfortunately, such a fate befell other scientists such as Lise Meitner, Rosalind Franklin, Chien-Shiung Wu, Nettie Stevens, and Jocelyn Bell (Buterin et al., 2021; Des Jardins, 2010).

A general increase in the number of awardees would align more closely with the current scientific landscape and may benefit underprivileged groups. On the other hand, it would be detrimental to the Nobel Prize’s scarcity of honor, pursued to preserve the elitist image, and would run counter to the devotion to exceptional genius (Casadevall & Fang, 2013). After all, the Nobel Prize is awarded for scientific discoveries, but it is conferred upon the individuals who are credited with making those discoveries.

Furthermore, there is criticism of the narrow selection of award-worthy sub-disciplines within the award-disciplines as well as criticism on the selection of the disciplines themselves. The specific interpretation of a "discovery" leads to the exclusion of many fields of research (Zuckerman, 1977, pp. 50-58). On top, emphasizing that discoveries should have been made only recently, evokes a contradictious relation between sufficient novelty and required establishing of an invention. A precise classification of recentness has never been officially defined. Instead, it has been rendered by precedent in a processual way (Friedman, 1989).

A widening time gap between discovery, publication, and the receipt of the Nobel Prize became apparent (Mitsis, 2022), which results in the increasing age of laureates and consolidates the idea that the Nobel Prize is a capstone of achievements.

Although there may repeatedly be criticism from the scientific community, scientists are just as often caught up in the mesmerizing hype surrounding the Nobel Prize. Regardless of the slim chances, a Nobel Prize is at least a daydream, if not even a career goal, for many young scientists. Researchers who think they are close to it often get tunnel vision and become frustrated with the regularly prolonged waiting time (Hargittai, 2003, p. 5). Thereby, the award becomes a final goal towards which scientists strive for a long time, practically a big bang at the end of one's career, or in other words a "ticket to one's own funeral" when it comes to scientific activities (Chan et al., 2014). In contrast to Alfred Nobel's idea, the Nobel Prize becomes a "means to an end", that has in a way become a "victim of its own success" (Zuckerman, 1977, p. 25).

Despite adverse anecdotes, the Nobel Prize envisions an impartial institution honoring cutting-edge scientists as paragons of their disciplines and of science itself. Sociologically, the concept of institutionalized values for doing science dates back to Robert K. Merton defining the ethos of modern science as a set of agreed-upon norms among scientists (1973 [1942]). His imperative of universalism in particular fits the portrait of the Nobel Prize. He bases the term on the work of theorist Talcott Parsons (1964 [1951]). As to its content, universalism means that science must be based on impersonal criteria, which presupposes that scientists ought to be measured by no standards other than their scientific achievements. Scientific findings should not be measured on the grounds of their discoverer. The opposite of universalism is particularism, in which criteria other than scientific quality enter into the process of generating new knowledge (Merton, 1973 [1942]).

Maintaining universalism in everyday science is challenging throughout. The effectiveness of this enactment is a debating point. For example, empirical studies have shown that there are biases towards underrepresented groups, affecting individual career patterns (Long & Fox, 1995) and the award of research grants (Viner et al., 2004). Shifting to the organizational perspective, there are findings of favoritism among individuals with the same affiliation in grant applications (Mom & Van den Besselaar, 2021).

Still, the Nobel Prize constitutes the image of a universalistic institution that selects an objective unit of laureates who have provided great scientific accomplishments. The Statutes emphasize that particularistic criteria, such as nationality or personal relations, do not factor into the selection process. Scientific merit takes center stage. Interpretations of how closely the Nobel Prize fits this depiction in practice vary, as I will outline in chapter 3.

Nonetheless, it is indisputably perceived as a seal of approval for outstanding research, demonstrating a process that reflects on the scientific reward system displayed: The "Matthew effect" describes a skewness in the distribution of credit and esteem towards well-known scientists that have made significant contributions in the past. While this process may raise hurdles for (yet) unknown researchers on an individual level, it elevates contributions from already honored scientists like NP laureates to greater visibility, perpetuating a process of success accumulating further success. As a potential drawback, the Matthew effect poses a risk of violating the imperative of universalism by unduly venerating authority over scientific merit. As a systematic advantage, though, it provides potential groundbreaking research with greater permeability and dissemination, making it less likely for innovative ideas to go unnoticed amidst the proliferation of publications (Merton, 1968a).

On an institutional level, the Nobel Prize evolved into an apparent sign of quality that adds to the social stratification of the scientific system. Universities and research institutes in which laureates circulate build up prestige, attracting more promising students and junior collaborators to fill their ranks. This process extends accumulated benefits that individual scientists can achieve during their careers to institutionalized cumulative advantages. Organizations at the center are portrayed as "evocative environments" (Zuckerman, 1977), fostering collaboration and mutual exchange between top scientists and their trainees. NP laureates working in a particular entity have become a measure of excellence for a university or even an entire nation. Especially for historical comparison of the emergence of scientific innovations and identifying facilitating factors, metrics used includes the number of laureates (Heinze et al., 2020; Hollingsworth, 2006).

University rankings, which are widespread in higher education landscape, similarly rely on this definition of science quality: For instance, laureates of the Nobel Prize as well as the Fields Medal (an equivalent award in the discipline of mathematics) as Alumni or current staff account for 30 percent of the evaluation on the renown Academic Ranking of World Universities (*Methodology of the Shanghai Ranking*, 2023).

For universities, it is not uncommon to stake 'claims' on freshly laureated awardees to highlight their prestige themselves. High-ranking universities habitually promote them on their web pages (*Nobel laureates from Harvard University*, 2023; *Nobel laureates from Humboldt University Berlin*, 2023; *Nobel laureates from University of Cambridge*, 2023). One laureate can be claimed by multiple entities of the same level, as it is up to interpretation which career stage is ‘claimable’ (Zuckerman, 1977, pp. 25-35). Claims range, for example, from bachelor-granting universities to last career stations before retirement.

Shifting to the level of nationalities, comparison plays a major role in acting out rivalries and trumpeting the accumulation of as many claimed Nobel Prizes as possible with the aim of promoting national and cultural success (Sneis & Spoerhase, 2023). Concerns arise that the award designed to honor individual genius evolves into a token of “institutional boosterism”, fostering unhealthy competition in contemporary science (Friedman, 2001, p. 277) .

For this reason, it is all the more important to analyze the Nobel Prize as a historical phenomenon, to contextualize it, and thereby also to rationalize it. After all, it should be evident from this chapter that the Nobel Prize is sustained by its prestigious aura. That said, this chapter ends with a conciliatory quote that shows both sides of the prize and is especially insightful in times of big science:

> *“The Nobel Prize is a great institution it we can detach ourselves from it in our daily work in science […] It directs our attention to past achievements and inspires us to learn from great examples. Finally, even though it elevates an improbably small number of people to the status of demigods, at the same time it helps us to see that it is human beings rather than faceless bureaucrats and automata that do science.”(Hargittai, 2003, p. 248).*

2.2 Rules and Regulations of the Nobel Prize

The Statutes of the Nobel Foundation, the constitutional component behind the Nobel Prize, explain the right to nominate. In view of the following analysis of nominations, it is worth pointing out a few basic facts collected mostly from the official website of the Nobel Prize.

In charge of awarding Nobel Prizes in Physics as well as in Chemistry is the Royal Swedish Academy of Sciences (from here on abbreviated RSAS), founded in 1739 with the overall goal to "promote the sciences and strengthen their influence in society" (*Official Website of the RSAS*, 2023). In addition to those two prizes, the RSAS grants other high-ranking science-awards like "The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel" or the "Crafoord Prize". Drawing on its ten classes based on scientific disciplines, it demonstrates a wide range of expertise. What is important to mention in this context is that the Swedish organization does not only have members of Swedish nationality, but a certain proportion of foreign members as well, which has made a lasting contribution to the internationality of today's Nobel Prizes, in addition to the laureates' nationality not being of importance (*Statutes for the prizes awarded by the Royal Academy of Sciences*, 2023).

Members of the RSAS in the respective scientific classes elect Nobel committees for Physics and Chemistry separately, consisting of five persons with a mandate of three years. Committee members may be re-elected twice in a row and may not be older than 70 years. The RSAS selects a chairman among the committee members each year and appoints an adjunct Secretary from within its ranks. The committee is able to proceed to a decision as soon as at least three members are present. Voting decisions, e.g. in case of selecting a Nobel laureate, take place by open ballot. In case of a tie, the chairman holds the casting vote.

The actual nomination process starts in September, when the committees distribute their invitations to selected nominators. Nomination privilege is divided into permanent and annually distributed rights among international scientific personnel through faculty down to special invitation, meaning that some individuals are allowed to nominate every year, while others get a one-time invitation for a specific year only (although they could be invited many years in a row through annually distributed rights). Permanent rights are given to members of the RSAS and the committees, former laureates as well as professors of the specific discipline from universities and institutes of Sweden, Denmark, Finland, Iceland, and Norway. Other chair holders outside these northern countries are invited annually, as well as individual scientists who have special expertise in the specific field but are not covered by the categories

(*Nomination and selection of chemistry laureates*, 2023; *Nomination and selection of physics laureates*, 2023). See Table 1 for a detailed overview.

It is noticeable that Physics is granted a more prominent position: Committee members as well as laureates in Physics are allowed to nominate for both prize categories, whereas this is not the case for Chemistry.

Table 1: Depiction of nominators for Physics and Chemistry

<table>
<tr><th></th><th>Physics</th><th>Chemistry</th></tr>
<tr><td rowspan="4">Permanent nomination right</td><td colspan="2">All members of the RSAS</td></tr>
<tr><td>Members of the Nobel committee for Physics</td><td>Members of the Nobel committee for Physics and Chemistry</td></tr>
<tr><td>Nobel laureates in Physics</td><td>Nobel laureates in Physics and Chemistry</td></tr>
<tr><td>Tenured professors in the Physical sciences at the universities and institutes of technology of Sweden, Denmark, Finland, Iceland, Norway (northern countries), and the Karolinska Institute in Stockholm</td><td>Tenured professors in the sciences of Chemistry at the universities and institutes of technology of Sweden, Denmark, Finland, Iceland, Norway (northern countries), and the Karolinska Institute in Stockholm</td></tr>
<tr><td rowspan="2">Annually distributed nomination right</td><td colspan="2">Holders of corresponding chairs in at least six universities or university colleges selected by the RSAS with a view to ensuring the appropriate distribution over the different countries and their seats of learning</td></tr>
<tr><td colspan="2">Individual invitations for special scientists not considered in the above-mentioned categories</td></tr>
</table>

This table illustrates the allocation of nomination rights for the two disciplines to be examined, as well as rights that are distributed annually or permanently.

Once invitations are sent out, submissions in the form of written justifications are validated until January 31 of the following year. Nominators are urged to treat their choice of candidate(s) as a secret. Non-Swedish nominators should consider in which language their nomination is submitted, as nominations in languages that “cannot be translated without particular trouble or considerable expense” (*Statutes of the Nobel Foundation*, 2023) are not obliged to be counted.

Apart from this, they are free in their decision. There is actually only one major limitation concerning nominations: Scientists are not allowed to nominate themselves for the Nobel Prize.

By September of the respective year, the committees review the proposals received, prepare detailed documents of the best suited contenders, and obtain expert opinions outside the respective committee if necessary. The procedure corresponds to shortlisting the best claims, rather than simply counting the nominations brought forward for specific candidates. Instead, the committees state not to be influenced by the quantity of nominations (Zuckerman, 1977, p. 40).

At last, the committees present their final candidate(s) to the relevant professional section of the RSAS, which in turn could express doubts or acquire second opinions from other professional sections. Otherwise, the award will be prearranged to the respective candidate(s) in early October and will not be made retroactively, even in the case of an obvious error of judgment. For a summary of the entire year's nomination process, a further visualization is provided in Figure 31 in the appendix.

As already discussed in the subsection above, a prize is to be divided between three people at most. Though, Norrby (2010, p. 29) notes that this rule was established not earlier than 1968, most likely in an attempt to find a compromise between Alfred Nobel's conception to honor individuals and the growing scientific landscape. Remarkably, it is not specified anywhere in the Statutes how many scientists may be nominated by one person in the same year and category. The expression "Work produced by a person since deceased shall not be considered for an award" (*Statutes of the Nobel Foundation*, 2023) also corresponds to one of Nobel's core ideas, as honoring young researchers with great potential for further innovations contrasts with honoring researchers who have already died. Bluntly stated, due to the exceeding exclusion of worthy candidates, "death may simplify the task of the Nobel committees" (Bishop, 2004, p. 25).

In the early years of the Nobel Prize, these rules, while not particularly complex in their entirety, were a source of uncertainty for nominators. The definitions of the temporal aspect *during the precedent year* as well as *greatest benefit to humankind* were unclear. Moreover, nominators were likely unsure which subject areas or individuals from which countries to nominate - from today's viewpoint, these uncertainties might appear peculiar, but at that time, nominators felt compelled to nominate scientists from their own country (Friedman, 2001, p. 23). Despite sending out roughly 300 nomination invitations, only a handful (approximately 20 per discipline) were returned, likely due to the vagueness in nomination rules. Precedent in the form of established laureates eventually resolved this ambiguity.

Everything discussed within the awarding process is recorded meticulously, though strictly confidential and will not be published as long as those involved are alive (if at all). The same applies to nominations, which are made public only with a delay of 50 years. That is how the Nobel Prize came to open its gates, literally at first, by granting researchers access to its archives. Subsequently, access was extended to a digital database, ensuring that not only few selected researchers but all science-interested people can now browse through the archives. The Nobel Prize thus paved the way for many studies presented in this or the next chapter, as well as for this dissertation. While its accomplishment of the duty to declare the *greatest benefit to humankind* may be a matter of debate, this decision is undoubtedly an immensely meaningful contribution to the study of science itself.

3. Classic and recent studies of the Nobel Prize

In this chapter, I will present relevant literature on NP laureates, their composition as well as demarcation. Laureates belong to a population that is studied both frequently and in many conceivable ways. This applies not only to the two scientific disciplines that will be examined more closely in this dissertation. Laureates from all disciplines, whether the Nobel Peace Prize or the later added Prize in Economic Sciences in Memory of Alfred Nobel, are routinely examined together, which may complicate explanations on the basis of single NPs (most NPs differ greatly, not only in their awarding field, but also in their awarding bodies and selection processes), yet on the other hand emphasizes relevant commonalities of the Nobel population.

Laureates are scrutinized in terms of their growing age (Karazija & Momkauskaitė, 2004), their collaboration patterns (Kademani et al., 2005) and networks (Wagner et al., 2015). Focusing less on the laureates themselves and more on their scientific impact, bibliometric studies highlight the specificity of laureates' publication patterns and the “boost” of their prizes (Bjørk, 2020; Kosmulski, 2020; Mazloumian et al., 2011; Zhou et al., 2014).

Of particular interest concerning the compilation of laureates are concentration processes with regard to national or institutional hegemonic positions. Hegemonic structures allow historical analysis in terms of innovation-enabling or -disabling environments characterizing the shift in global scientific leadership (Ben-David, 1960; Hollingsworth, 2006). On a micro-perspective, since the majority of laureates comes from Europe or North America (and within these continents especially from Germany and the United States), studies deal with a concentration at the level of nationality (Alhuzali et al., 2022; Nilesh & Pranav, 2018).

A recent trend in academic research has been to examine the organizational affiliations of awardees and their mobility patterns (Jiang & Liu, 2020). Researchers have analyzed the composition of the organizational Nobel population, focusing on different stages of laureates' careers, from the organizations where they received their degrees to those where they conducted their award-winning research (Schlagberger et al., 2016; Zhang & Zhang, 2023), and eventually where they received their awards. In conclusion, there is a highly skewed organizational landscape with specialized universities at different career stages, historical upward and downward trends, and elitist organizations at the top (Heinze & Fuchs, 2022).

A substantial question concerns not only the composition of laureates according to specific characteristics, but their actual selection and the mechanism behind it. Literature has developed several strands of theory in this regard.

One of the first empirical studies on the subtopic of selecting laureates originates from Harriet Zuckerman, who created the first profound enquiry on US American laureates in her dissertation and significantly shaped data collection as well as analysis on prize awardees for the next decades. In her book "Scientific Elite" she postulates a strong stratification of the scientific system with a concentration of authority on Nobel laureates, who ascend to the status of an "ultra-elitist" class once they attain the award (Zuckerman, 1977). Asking the question of how the selection of this elite, which is deliberately limited in number, occurs, she highlights social background, the importance of academic centers, individual career patterns and early relationships to the elite through mentoring connections. She links these findings to institutional processes such as the accumulation of advantageous stances that lead to the early differentiation of the 'chosen ones', adding substance to the "Matthew effect" (Merton, 1968a). In fact, Merton relied on her broad data on interviews with laureates.

For Zuckerman, there is a clear hierarchical structure underlying the science system. The sole failing in this system manifests itself in so-called "Candidates of the Forty-First Chair" (Zuckerman, 1977, p. 42) who, although befitting the status of laureates in every way, have never received a Nobel Prize. This means that although the elite clearly segregate themselves in the pyramidal system, selection does not work perfectly because of the scarcity of prizes. Zuckerman thus reinforces the belief in a largely universalistic system that selects for ability and produces few fallacies, in spite of those being highly visible through famous non-laureates as Dmitri Mendeleev or, a rather recent example, Stephen Hawking.

The perpetuation of success, and any potential negative effects of idolization, accordingly occur late in the careers of laureates who have already won the Nobel Prize. The selection itself is first and foremost characterized by meritocracy and, therefore, is in its design independent of historical events.

From this theoretical foundation sprouted a variety of subsequent studies that clearly position themselves in Zuckerman's succession to characterize the US scientific elite based on the social construction and enactment of global excellence (Hansson & Schlich, 2021; Heinze & Fuchs, 2022; Heinze et al., 2019). Key themes include prioritizing academic centers and accentuating macro-perspective career trajectories (Chan & Torgler, 2015; Cortés & Andrade, 2022) and distinguish Nobel laureates as elitist based on patterns of bibliometric factors such as productivity and impact (Gingras & Wallace, 2009; Li et al., 2020), as first established by Eugene Garfield (1986). Even beyond contemplating the Nobel Prize alone, a closely networked and highly stratified elite reveals itself within scientific prize landscape, providing evidence for the generators of pathbreaking discoveries (Ma & Uzzi, 2018).

There are, however, other approaches to the question of how awardees are selected after all. Research on this specific issue looks back on a long tradition, which differentiates into data driven branches with respective thematic priorities. First of all, several studies specialize on individual case analyses and precedents. Their primary aim is to examine why a certain candidate received (or did not receive) the Nobel Prize. As a data basis, studies focus on committee reports, evaluations or personal correspondence (Friedman, 2001, 2022; Schmidt-Böcking et al., 2019), though recent studies additionally gain insights through the online nomination archive (Ko et al., 2024; Seeman & Restrepo, 2023a). Most notable within this context is the Nobel Prize for Medicine or Physiology, with numerous publications by Niels Hansson and co-authors. They discuss individual cases as illustrative examples of various medical subdisciplines, such as the precedent of Lady May Mellanby and Walter Hess for dental research (Hense et al., 2022), Ferdinand Sauerbruch, August Bier, Friedrich Pauwels, and Gerhard Küntscher for (orthopedic) surgery (Hansson, 2018; Hansson & Schagen, 2014), and several candidates for neurology (Hansson, Palmen, et al., 2020) as well as otorhinolaryngology (Hansson, Drobietz, et al., 2020), often asking why there were many nominations but ultimately no prize for the respective scientist or even for scientists in the subdiscipline as a whole.

Although these studies are revealing for individual scientists, they tend to miss underlying processes and structures, in some sense 'the bigger picture' (Friedman, 1989). On the contrary, research strands were established that include more contextual information on overall processes. Especially the early years of the Nobel Prize are studied thoroughly through a historical lens as far as processes within Swedish awarding bodies, more precisely within the Nobel committees and the RSAS, are concerned. In his book published on the occasion of the

100th anniversary of the Nobel Prize, Robert Marc Friedman describes key decision-making processes within the relevant organizations at the micro level. His central hypothesis is that it is primarily networks of relationships, political circumstances, and personal maneuverings that determine who wins the Nobel Prize (Friedman, 2001). Sociologically, he refers mainly to particularistic selection criteria.

Friedman regards the so-called "human face" as well as “human agency” involved in selecting laureates increasingly negatively. For the RSAS and the Nobel committees, he sees great opportunities to influence the awarding process to their own interests and indeed reports that there were efforts to do so (p. 56). Titles such as "little popes of Uppsala" (p. 122) result from these organizational possibilities and personal abilities of some committee members to assert their own views and preferences and to put their own stamp on committee decisions. Friedman repeatedly describes specific individuals such as Svante Arrhenius, whose extensive (international) contacts granted him more influence than other committee members in determining prize recipients. Arrhenius advocated for specific scientists he deemed worthy to receive the prize, while opposing those he deemed as unworthy. He heavily influenced the process until his death in 1927 and was considered not only a conductor but also a proponent of an internationally connected scientific community, despite his bias towards German science even at the start of World War I (pp. 87, 99, 111, 130, 182, 217).

Thus, while influential individuals do have significant control over the selection process, the nationality of the awardees also carries significant weight in the political calculations at play. Particularly during wartime, selecting prize winners became a delicate balancing act between opposing parties. The labeling of awardees became more nationalistic. Max von Laue's prize was celebrated as a German success in the beginning of World War I. In contrast, Charles Glover Barkla was labeled "Britain's candidate". Nomination processes were complicated by boycotts between hostile warring parties. During World War II, Adolf Hitler even ordered a boycott of the entire Nobel Prize, in opposition to the views of several German scientists (pp. 83, 102, 202).

According to Friedman, the Nobel Prize’s appearance of quality as a means of providing objectivity serves to engage in a culture of national competition and to assert a sense of cultural self-importance, as he illustrates in various examples of wartime episodes in the early 20th century. “There are no grounds, based on history, for assuming the laureates constitute a unique population of the very best in science” (p. 267), he concludes. This fundamentally disputes whether the Nobel Prize is based on meritocracy, contradicting Zuckerman’s merit-based theory.

He takes particular issue with the worship of laureates as heroes, giving them recognition beyond their fields of knowledge. Indeed, this phenomenon of regarding laureates as superheroes or 'ultra-humans' with extraordinary abilities to save the world is commonly referred to as "Nobelitis" or "Nobel disease" (Diamandis, 2013). Known examples include laureates who use unproven methods to treat diseases (such as cancer), challenge scientifically established results (such as for HIV or climate change), and present controversial opinions regarding societal inequalities. To avoid any confusion about Zuckerman's usage of the term "ultra-elite" in this context: She refers to laureates' capabilities in their specific areas of expertise without portraying them as superheroes. Although she observes the rise in laureates' media exposure and characterizes the Nobel Prize as a mechanism for generating celebrity beyond professional domains, this factor is not intrinsic to laureates' elitist status but a byproduct of societal developments.

Friedman's statements draw on the research of Elisabeth Crawford, given that her basic point of reference centers as well on historical processes that shape the odds of winning. However, Crawford focuses on the individual candidates, building the first "Nobel population" record of nominees as well as nominators with respective biographical features concerning nationality.

The juxtaposition of nationalism and internationalism within the science system drives her arguments at different levels, linking world-historical, structural, and institutional elements. As an example of nomination clusters at the national level, she analyzes the period of World War I, in which nominations were strongly divided between Allied (Belgium, Canada, England, France, Italy, Russia, and the United States) and Central (Austria, Czechoslovakia, Germany, Yugoslavia, Hungary, and Poland) powers (Crawford, 1992, pp. 54-78).

As an illustrative case, Crawford examines the interplay between the Kaiser Wilhelm Society (now Max Planck Society) and the Swedish Nobel Foundation, shedding light on the importance of institutional dynamics, particularly in the context of global scientific collaboration. The interaction between these two entities revolved around the engagement of Kaiser Wilhelm Society staff in the NP selection process, including roles as laureates, nominees, and nominators during the period from 1911 to 1939.

With respect to laureates, Crawford observes that their association with the Kaiser Wilhelm Society was primarily administrative and managerial rather than research-oriented. Many institutes were established to sponsor outstanding researchers, either recent laureates or those on the verge of receiving the Nobel Prize, such as Max von Laue, Richard Willstätter, and the eponymous Max Planck. The case of Fritz Haber illustrates the connection between Nobel committees and the staff of the Kaiser Wilhelm Society in the appointment of high-ranking administrators: When Friedrich Schmidt-Ott was tasked with appointing a director for the newly established institute for physical chemistry, he consulted with Svante Arrhenius in Sweden. Arrhenius, who had a significant impact on Nobel committee decisions, considered Haber a suitable candidate. This was due to Arrhenius' strained relationship with Walther Nernst, which had limited his influence at the Chemical Institute of the Humboldt University in nearby Berlin, as well as Haber's good chances of becoming a laureate in the near future (indeed, he received the NP for Chemistry in 1919, retroactively for 1918). Laureates provided international recognition for excellence and thereby enhanced the prestige of local organizations such as the Kaiser Wilhelm Institutes. Their recognition attracted attention, funding, and talent to the institutes, strengthening ties with the Nobel Foundation (Crawford, 1992, pp. 106-124).

In a follow-up study, Crawford extends her observation period to 1950 and finds a strong tendency towards what she terms “own-country” nominations. Half of all nominators in the four major countries (France, Germany, the United Kingdom and the United States) nominate scientists from their own country, with France having the highest rate and the United Kingdom having the lowest. “Own-country” nominations predominantly occur during and after wartime, making it a time-variant particularistic feature. On average, the “own-country” nomination rates of laureates are lower than those of non-laureates (Crawford, 2001).

The contrast between Crawford's work and Zuckerman's is evident in her explicit critique (Crawford, 1992, pp. 141-145). In particular, Crawford's concepts of historically relevant contexts clash with Zuckerman's seemingly ahistorical concept of the "ultra-elite" in science. Crawford sees the decision of whether an outstanding researcher receives the Nobel Prize as contextually relevant: historical circumstances, political processes, decision-makers in Sweden and their personal incentives all contribute to the result, which makes it less possible to speak of a universalistic selection process.

Zuckerman, on the other hand, emphasizes universalism, that is, outstanding scientific achievement, as the prime factor in the selection of laureates. She does not deny that particularistic or micro-processual principles may also play a role, but the principles of social stratification that are decisive for her are located earlier in the process, form the "crucial first cut", so to speak, after which other criteria may also be used to choose between scientifically equal candidates (Zuckerman, 1977, p. 49).

In a sense, the difference between Zuckerman's and Crawford's approach lies in their perspective on the importance of these particularistic principles. Historically-oriented researchers like Crawford or Friedman focus on anecdotal evidence pointed out in numerous reports. Sociologically-oriented researchers like Zuckerman and Merton acknowledge potential breaches in an otherwise universalistic system, but they consider the occurrence and explanatory power of these breaches to be limited. Merton at one point refers to it as "highly motivated gossip" (1968a, p. 62). It is also important to note that Zuckerman and Merton's sociological perspective is based on universalism as a social norm. They acknowledge that norms are not always followed in reality but may be violated. Such violations can potentially reinforce the norm itself through subsequent social processes of self-affirmation. Thus, deviant behavior does not necessarily undermine the underlying norm, but rather reinforces it through the social discourse that follows the norm breach.

Both the points of friction and the points of agreement between these two important works are still being further discussed and empirically tested within current research. See for example Bukodi et al. (2022) for a recent research project that supports Zuckerman's general hypothesis of a timeless "ultra-elite" as a case example for the UK. On the other hand, Seeman and Restrepo (2023b) underscore Crawford's interpretation through their descriptive study on the uncertain impact of a candidate’s amount of received nominations. Their analysis is based on an assessment of nominations for selected laureates in Chemistry, identifying several common dynamics, such as fluctuating nomination rates (a dip in nominations followed by a significant increase within the award year), avalanches (few nominations until suddenly many nominations in the award year), and sudden pairings of laureates who end up sharing an award. Regarding imbalances between shared NPs and their pairings within nominations, the authors conclude that the nomination process serves as an RSAS instrument to provide general information as well as to legitimize their final selection. They state that nominations have not been the critical, overriding factor in the selection of laureates, but rather that particularistic aspects of the selection process, such as personal biases in the form of friendships and rivalries between prominent figures, have been more pronounced.

Since data on nominations have become available online and, due to the 50-year freeze, on a wide range, it currently paves the way for large-scale quantitative studies to capture the structure of nominations, and to shed more light on those issues still debated. On a descriptive basis, network plots of nominations reveal both structural trends like the growth of the system as a whole between 1901 and 1970 as well as individual features for identifying scientists who nominated most or least successfully (Withers et al., 2022).

A comprehensive study of the network between nominators and nominees constituting all Nobel Prize categories (Physics, Chemistry, Medicine or Physiology, Literature, and Peace) up to 1965 (Gallotti & De Domenico, 2019) shows that nominations are more likely to occur between individuals who share certain characteristics like gender or nationality. Framed as political homophily, world politics are captured in the data. The Iron Curtain led to an exclusion of Soviet individuals in the nomination process, while the World Wars had a significantly negative impact on German science for submitting nominators and nominees.

As a recent area of research, studies aim to identify factors of success in quantitative terms. One crucial aspect that has garnered attention in the nomination process is academic reputation. Research has shown that being nominated by a previous winner in any of the three academic categories significantly increases the chances of winning (Gallotti & De Domenico, 2019). The question at hand is often to what degree nominees' scientific performance (reflecting a measure of meritocracy) and ascriptive attributes of nominators ('academic and administrative identity') play a decisive role (Chen et al., 2023), thus linking these ascriptive factors to the broader debate about universalism and particularism (Ko et al., 2024).

The availability of extensive data in the online archive will undoubtedly lead to more such studies in the future. My dissertation aims to contribute to this quantitative re-evaluation of the Nobel Prize network and to provide new perspectives to complement the existing research presented in this chapter. For this purpose, I will first outline my theoretical framework (chapter 4), followed by an explanation of my research objectives and the presentation of my hypotheses (chapter 5).

4. Theoretical Framework

As demonstrated in the previous subchapter, extensive research has been conducted on the selection and composition of Nobel laureates as well as the resulting nomination network. However, much of this research is limited to individual showcases within the network, but does not explore the network as a whole. To complement this approach, I seek to base my analysis on broader contexts and to align it with sociological literature.

For analysis, I will draw on three classic sociological concepts. These concepts will be explained in more detail in the following subchapters. Starting with the duality of universalism and particularism applied to the Nobel Prize, I will examine scientific hegemony and leadership, and finally focus on stratification in the context of prestige and inertia as well as plurality and renewal.

4.1 Universalism and Particularism

The dualism of universalism and particularism was first derived from Talcott Parsons' pattern variables (1964 [1951]), which are behavioral options from which an actor must choose in any setting. Parsons distinguished five dimensions, with the most significant for this analysis being the opposing pairs of particularism and universalism as well as ascription and achievement. Particularism refers to an individual or group following their own inclinations. Universalism, on the other hand, prioritizes connection to a broader community and is the opposite of favoritism towards a particular individual or group. This perspective is based on universally valid legal and moral rules. Ascription is based on a characteristic that a person possesses from birth, such as belonging to a certain group. Achievement is based on a person's actual performance and competence.

Robert K. Merton, one of Parson's former students, incorporated these pattern variables into his ethos of science (1973 [1942]). One of the principles of this ethos is universalism, which emphasizes the impersonal nature of science. Scientific claims should be evaluated based solely on objective criteria and proven knowledge, rather than on the personal or social attributes of their proponents. Particularism is the contrary, a system in which ascriptive aspects, such as the gender or nationality of scientists, intervene and shape their capacity to contribute to science.

Regarding the Nobel Prize, there is a question about whether the awarding of prizes is based predominantly on universalistic or particularistic criteria. Studies have shown support for both sides, as explained in the last chapter. In universalism, laureates are selected for their scientific achievements, with an emphasis on an impersonal and objective measurement. Harriet Zuckerman (1977) conducted a quantitative study that portrays laureates as the top of a stratified scientific system, marking them as the scientific elite based on their scientific achievements. However, other studies suggest that Nobel Prize decisions may be influenced by factors such as personal connections, political circumstances, or the personal interests of committee members (Crawford, 1992; Friedman, 2001). This raises questions about whether laureates are selected based on meritocracy, meaning scientific achievements, or ascription, such as personal networks of influential actors.

4.2 Global shift in scientific leadership

Scientific leadership, exemplified by the shifting center of innovation from Germany to the United States in the early 20th century, is a multifaceted phenomenon that encompasses institutional dynamics and organizational behaviors. Ben-David's conceptual framework (1960, 1971) sheds light on this transition, delineating the decentralized and competitive landscape of German universities, especially in the late 19th century. This phase was characterized by scientists gravitating towards German institutions offering state-of-the-art facilities, academic autonomy, and promising career prospects, transforming science from an amateur activity conducted in private laboratories to a professional activity conducted in permanent bureaucratic organizations.

Despite these strengths, German universities faced internal structural constraints that hindered the adoption of new research fields. The university system was characterized by a highly skewed distribution of power, where influential chairholders held ultimate authority over their subordinates, including students and graduate assistants. Mechanisms were established to counterbalance the influence of university professors. The *Privatdozentur* was one mechanism for granting lecturing rights to those with a *Habilitation*. However, individuals granted this position did not receive regular salaries and instead relied on student tuition. Therefore, checks and balances did not meet the expected level of effectiveness, proving insufficient to drive reform. The university's core, consisting of professors, resisted significant structural modifications that would have bridged the gap in power and status between those with and without chairs. Furthermore, resistance to innovative studies and applied sciences further entrenched conservatism. Initiatives for new fields of science turned to central government institutions such as the Physikalisch-Technische Reichsanstalt (later Bundesanstalt) and the Kaiser Wilhelm Society (later Max Planck Society) for support, bypassing university structures (Ben-David, 1971).

As a result, the formal structure of universities impeded the formation of effective scientific communities and perpetuated power imbalances. Though competition among universities within the decentralized academic market in Germany and German-speaking regions prevented oligarchic tendencies from dominating, providing mobility freedom to scientists, it primarily facilitated significant innovations driven by individuals or small group initiatives rather than institutional foresight, which became plain in excellent research groups of famous scientists that attracted students from all over the world to their labs. Despite facing challenges, Germany maintained its scientific leadership in early 20th century. This was partly due to the large group of pre-WWI scientific leaders and the inertia within the international scientific community, which continued to favor German universities. Visiting scientists held a favorable view of German universities, unaffected by structural tensions or occupational uncertainties (Ben-David, 1960).

Several factors contributed to the ultimate shift of scientific leadership from Germany to the United States. The internal organizational features in the United States were more conducive to the growth of new research fields. This included effective leadership, collegiality between faculty members instead of stark hierarchies and personal dependence, research-based education in graduate schools, and scientific careers via tenure track. In the United States, there was a more pronounced level of decentralized competition with a plurality in funding sources. This fostered an environment conducive to innovation as different states and organizational types such as private universities competed with each other for researchers and students. The lack of significant monopolies within the US system enabled universities to demonstrate their value by offering innovative ideas, and new courses of study and research, effectively promoting their merits to attract staff, students, and resources (Ben-David, 1971; Hollingsworth, 2006).

Hollingsworth expands on Ben-David's concept of shifting scientific hegemony by emphasizing the influence of institutional environments on the behavior and innovation potential of research organizations. He highlights the path-dependent nature of societal institutions and their impact on the variability in the rate of major discoveries across different contexts. Hollingsworth's (2006) analysis underscores four critical aspects of institutional environments that externally shape the behavior of research organizations: the appointment of scientific personnel, the implementation of specific scientific disciplines within organizations, funding levels, and required training for personnel appointments.

The level of external control exerted over organizations is a crucial factor. Stronger external control tends to promote uniformity in organizational structure and behavior, which limits autonomy, flexibility, and ultimately innovation. Conversely, weaker external control allows for greater variability and flexibility, which facilitates innovation within research organizations. This contrast is exemplified by the institutional landscapes of the United States and Germany. The US scientific landscape is characterized by heterogeneity, an egalitarian culture, and substantial organizational autonomy. In contrast, the German scientific environment is marked by homogeneity, authoritarianism, and stringent bureaucratic procedures (Hollingsworth, 2006).

Hollingsworth provides the example of Rockefeller University (2004) to illustrate the conditions that promote innovation in conducive environments. The institute's relatively small size, decentralized structure based on projects, and associated flexibility and adaptability allowed for the production of numerous innovations in the 20th century. Hollingsworth explains these characteristics in terms of the institute's organizational leadership. The leadership demonstrated their willingness to take risks by securing sufficient funding for innovative but risky research. They also showed a keen instinct for recruiting diverse staff, which promoted interdisciplinary communication and fruitful research projects. Additionally, they implemented flexible work processes and informal rituals, such as cafeteria designs that fostered opportunities for loose networking.

Quantitative analyses support the qualitative assessments of Ben-David and Hollingsworth, providing empirical evidence for the historical shift of scientific leadership (Heinze et al., 2019) and the influence of institutional environments on innovation (Heinze et al., 2020). These analyses demonstrate that the United States emerged as a global scientific power from the 1930s onwards, as evidenced by career stages of Nobel laureates ranging from educational background to post-award stages. Countries exerting more control over research organizations, such as France and Germany, have been less successful in producing Nobel Prize winners compared to countries with exerting less control, such as the United Kingdom and the United States.

One factor contributing to the rise of the United States and the prolonged decline of Germany in scientific leadership is the migration of scientists between regions. Scientists tend to move from countries with stringent control to those with looser control (Heinze et al., 2020). This mobility is driven by researchers seeking more conducive research environments, as well as by forced migration due to factors such as political persecution.

During the Nazi regime, numerous scientists left Germany, prompted by discriminatory laws, such as the Law for the Restoration of the Professional Civil Service, targeting Jewish and other ‘undesired’ groups within civil service, including university staff. While exceptions existed until 1935, such as for war veterans or those who lost family in WWI, up to 18 percent of professors in fields like chemistry, physics, and mathematics were dismissed between 1933 and 1940, with many others fleeing ‘voluntarily’. Prestigious universities like Göttingen and Berlin were particularly impacted, losing significant percentages (40-60 %) of their personnel (Waldinger, 2010; Waldinger, 2012).

Migration thus not only substantially altered the student-to-faculty ratio at top universities, negatively impacting faculty quality and teaching; the loss of star scientists especially led to a long-term downfall in German publication output (Waldinger, 2016). Conversely, the influx of German émigrés to the United States bolstered US American science, as evidenced by an increase in patenting rates within fields where scientists working in Germany had dominated (Moser et al., 2014), demonstrating a shift in scientific leadership.

4.3 Organizational renewal and stratification

A complex relationship arises between the need for renewal and innovation on one side and the persistent forces of exploitation, stratification and resistance to change on the other side. These ideas represent different paths in academic literature, each with a significant impact on the creation and spread of knowledge.

March's (1991) concept of ambidexterity highlights a fundamental dilemma in organizational learning: the balance between exploring new ideas and perfecting existing procedures. This dichotomy is evident in the ongoing tension organizations face when allocating resources between refining existing technologies and venturing into new areas.

Scientific advancement requires a delicate balance between originality and adherence to disciplinary norms. The concept of stratification is posited to offer informational benefits by organizing the competitive landscape, effectively simplifying intricate intellectual competitions into more tractable organizational hierarchies. This transition promotes predictability among participants, with status emerging as a marker of quality amidst uncertainty (Sauder et al., 2012).

The impact of status and prestige is significant in shaping the academic landscape, especially within the hierarchical environment of research universities in the United States. Jappe and Heinze (2023) provide an overview of research on academic stratification, highlighting the rigid hierarchy and social exclusivity that inhibit upward mobility for universities, faculty, and students. One challenge related to intellectual renewal is the potential for status hierarchies to act as gatekeepers. In networks, central nodes, such as disciplinary elites, may suppress or delay novel ideas. For instance, research has shown that in computer science, the hiring networks of faculty members can affect the spread of ideas. Notably, findings indicate that ideas originating from less prestigious organizations possess a limited reach, even when their quality matches that of ideas from esteemed counterparts (Morgan et al., 2018). This phenomenon highlights the significant influence of institutional prestige on the dissemination of ideas within academia.

Contemporary studies of academic hierarchies rely on theoretical conceptions of established theories: Prestige hierarchies, as expounded by Max Weber, are perpetuated through the adoption of distinctive lifestyles (‘Lebensführung’) by privileged groups and the imposition of barriers to social interaction between higher and lower status groups (1999 [1922], pp. 677-685). Pierre Bourdieu's elaboration on economic, social and cultural capital further elucidates how membership in exclusive groups, characterized by mutual acknowledgment and recognition, serves to fortify boundaries and perpetuate status differentials within society (Bourdieu, 1986).

Based on these principles of social closure and social capital, Burris (2004) conducted a landmark study in which he proposed that academic prestige is to be conceptualized as a form of status honor that is reproduced through the closure of social exchange between status groups and that can be measured by the magnitude of social capital possessed by individual or groups of academics. Regarding Weber’s work on marriages in the Indian caste system, he argued that they were the most important form of social exchange for privileged groups to acknowledge each other, establish reciprocity, and reaffirm group boundaries (1946 [1916]). This concept can be applied to academic networks, where the exchange of PhDs between departments serves as a similar mechanism for affirming and reproducing status divisions. Observations indicate that prestigious universities tend to hire graduates from other high-ranked universities, which suggests social closure. Additionally, high-ranked universities often place their graduates in lower-ranked universities without diminishing their own status. This captures Weber's observation regarding the distinction between brides and bridegrooms from lower-ranked status groups.

From a micro-perspective, high-status universities have to acquaint positions in less prestigious universities to expand their social capital, as economic capital, that is the capacity to employ academics, is widely distributed among universities. Lower-status universities are eager to have those network ties, also gaining social capital from hiring a high-status graduate. But on the institutional perspective, it is an unequal distribution of social capital, as high-status graduates in this way monopolize employment in all universities, extending the networks of their high-status universities having ‘kinship’ in a multitude of organizations.

To measure the impact of social capital on departmental prestige, Burris uses network analysis in three disciplines (sociology as a main, history and political sciences for a comparison) to construct a hiring matrix that ranks universities after their ability to place graduates among faculty. Results show that the top 20 percent of departments account for roughly 70 percent of all faculty placements with a strikingly upward closure, showing that graduates from non-top-20 universities are rarely hired at the top. Mobility follows a horizontal or downward trend, but seldom goes upwards. Centrality within the PhD exchange network is a significant indicator to explain variance in departmental prestige.

By synthesizing the theoretical perspectives of Weber and Bourdieu, Burris gains a nuanced understanding of the dynamics of prestige and stratification within academic institutions. This rounded comprehension laid the groundwork for more studies concerned with graduate exchange among universities, setting the focus to prestigious universities' ability to place their graduates successfully among the academic landscape. Results underpin Burris' conceptual groundwork, indicating that there is an imbalanced hierarchy of universities, where only a small number of highly reputable institutions with strong placement capabilities account for more than 75 percent of the faculty across all universities (Clauset et al., 2015; Lee et al., 2021; Morgan et al., 2018). On top, self-placement, in this case universities hiring their own graduates, is more frequent than anticipated given negatively-associated connotations such as "inbreeding" (Yudkevich et al., 2015; Zuckerman, 1977), particularly at prestigious universities (Wapman et al., 2022).

5. Hypotheses

One aim of my research is to determine if there are any particularistic elements in the nomination process that can be measured quantitatively. Chapter 4.1 outlines the conceptualization of particularism, which originated from Parsons (1964 [1951]) and was later expanded by Merton (1973 [1942]). The examination of whether particularistic elements are present in the nomination process has mostly relied on anecdotal evidence. One quantitatively measurable element that is still discussed in current studies (Ko et al., 2024) in the context of particularistic influences is the phenomenon of self-nominations by individual countries. However, this measurement is not entirely unquestionable with regard to the sociological classification of particularism and universalism.

For example, although Crawford detects high numbers of 'own country' nominations in her analysis (2001), it is debatable if, due to this observation alone, one can assume the relevance of particularistic features. The candidate of an 'own country' nomination could still have a good claim to the prize in terms of scientific quality and therefore, defying the particularistic appearance, more properly be defined as a universalistic nominee. Vice versa, a nomination between two different countries could nevertheless be particularistically motivated as a good deed amongst friends. The juxtaposition between these two concepts is complex and therefore difficult to apply.

At the same time, Crawford employs a language that is evaluative, implying that low numbers in ‘own country’ nominations are esteemed as all the way good (pure universalism, coined in Merton’s language), while high numbers are inferior (the contrary, particularism). She explicitly addresses a distinction in countries’ nomination performance: “the French were the most chauvinistic, with some 60% of nominations going to other French scientists. The British were the fairest, with just 35% of nominations for their fellow countrymen and women” (Crawford, 2001).

For the high proportion of ‘own country’ nominations, she offers three possible explanations: favorite-sons (candidates who received the majority of nominations from a given country), insularity (isolated national communities with little knowledge of foreign science), and reciprocity (nominations are viewed as a resource to be traded within one's own nation as a circle of acquaintances) (Crawford, 1992).

Other entities, even members of the Nobel committees, pick up on this use of language and interpretation, such as Bo Malmström, who calls US American scientists more chauvinistic in the regard of Nobel Prize nominations (Holden, 1989). He criticizes them for nominating scientists from their own country instead of nominating the best scientists. However, the extent to which these two principles contradict each other is unclear and depends on the individual case. Indeed, Malmström makes this point with reference to an individual case, namely the 1988 Nobel Prize, when three Germans won but did not receive a single vote from the United States. This, he states, is contrary to the spirit of the Nobel Prize. US nominators tend to coordinate their nominations, especially at prestigious universities, thus counteracting the secrecy of nomination. These statements are not yet provable, because Malmström also acted against the actual rules to keep nominations a secret for at least 50 years.

Another example depicting Crawford’s principle of “favorite sons” is more illustrative, as demonstrable through obtainable data. To her interpretation, Henri Poincaré, renowned theoretical physicist, is such a favorite son of the French nation, for he received many votes from French nominators, especially in the later years until his death in 1912 (Crawford, 1992, p. 53). However, Poincaré was a worthy candidate per se, being nominated 26 times by scientists working outside of France (namely from the United States, Switzerland, Italy, Spain, Sweden, Germany, Russia, The Netherlands, UK and Japan), including nominations from influential scientists and Nobel laureates such as Hendrik Lorentz and Albert Michelson (Nominations for Henri Poincaré, 2023). In terms of the juxtaposition presented, Poincaré’s claim could be interpreted both as particularistic and as universalistic, because the committees discussed his case seriously (fitting the image of a Candidate of the 41st chair). An indicated reason that ultimately spoke against awarding Poincaré was his solely theoretical significance (Verhulst, 2012).

Although the debate over merit-based nominations is of considerable interest, it is difficult, if not impossible, to classify the nomination network according to objective standards. Therefore, I will analyze self-nominations but avoid categorizing them as either meritocratic or particularistic nomination patterns. Instead, I will place these patterns in a sociological context that deals with stratification mechanisms and perpetuation processes, as described in chapter 4.3.

Regarding quantitatively measurable particularistic features within the nomination process, I want to rely closely on Merton who states that scientific achievements should be judged solely on their merits, without regard to ascriptive criteria such as the gender or organizational affiliation of the researcher (1973 [1942]). In the context of NP nominations, the implementation of particularistic criteria in the selection of nominators may have the observable effect of excluding certain groups from nomination for reasons other than their general ability, while favoring other actors on the basis of ascription.

Specifically, I aim to examine two particularistic features that may shape the selection of nominators: Firstly, I want to shed light on the position of women in the Nobel network. Studies have shown that women are disadvantaged in the role of nominees and laureates (Charyton et al., 2011; Lunnemann et al., 2019; Mahmoudi et al., 2019; Meho, 2021; Modgil et al., 2018), but up to that point, studies have not focused on the role of female nominators. Nominators are a crucial first step within the network, as they have the power to vote for and potentially place their candidates. It is important to note that nominations often occur between scientists of the same gender (Gallotti & De Domenico, 2019), which implies that if women are underrepresented as nominators, they consequently are underrepresented as nominees. Regarding this, I hypothesize:

H1a: Women are disadvantaged in the nomination network, resulting in fewer female nominators and nominees.

Additionally, I will examine the role of RSAS members as nominators. If they represent a dominant group among nominators, this would be an indication of a particularistic feature, since they do so on the basis of their organizational control over the entire nomination procedure. As laid out in chapter 2.2, the RSAS chooses committee members from its ranks, who in turn appoint nominators, receive nominations, discuss candidacies, and eventually select a laureate with the approval of the RSAS.

RSAS members have significant control over the procedure, embodying nearly every function of the process except for the candidacy choices presented by nominators in their nominations. However, if RSAS members constitute a large proportion of the nominators themselves, this would mark the nominations as a mockery process that violates impersonal, universalistic criteria. This concern has been presented in studies relying on anecdotal evidence (Friedman, 2001). I want to show whether this pattern holds up to quantitative measurement. Therefore, I hypothesize:

H1b: RSAS members are privileged in the nomination process, and thus dominate the nomination network.

Based on the insights gleaned from Ben-David (1960, 1971) and Hollingsworth (2004, 2006) further described in chapter 4.2, it becomes evident that the dynamics of scientific leadership underwent significant transformations during the first half of the 20th century. Germany played a leading role in professionalizing science and scientists, which resulted in initial successful implementations within university structures. However, it did not foster sufficient opportunities for renewal, which made it difficult to adapt to new fields of research and ideas. The expulsions and migrations of prominent scientists from Germany (Moser et al., 2014; Waldinger, 2012; Waldinger, 2016), coupled with the conducive environment and scientific infrastructure of the United States, facilitated the shift in scientific hegemony. Empirical analysis confirms the ascent of the United States as a global scientific hegemon, marked by the indicator of Nobel Prize laureates (Heinze et al., 2019; Heinze et al., 2020). Adding to that, I aim to demonstrate whether nomination mechanisms align with this shift in hegemony.

I expect the shift from Germany to the United States to become evident in the selection of nominators. This means that in the early decades of the award, nominators were primarily working in Germany. At latest by the time the Nazis came to power in 1933, the majority of nominators would be scientists working in the United States. I assume that the shift in nomination power drives another mechanism, placement power. The awarding institutions may have favored nominators from the center of science and, due to their accomplishments and esteem, placed more value on their preferred candidates. Nominators from Germany may have had a more influential position to place their candidates when Germany was a scientific hegemon, resulting in weakened placement power after its downfall. In contrast, the United States is expected to experience an increase in placement power over time. The selection of nominators and their impact are connected to the dynamics of scientific leadership, which is reflected in the following hypotheses:

H2a: The global center of nomination power shifted from Germany to the United States in the first half of the 20th century.

H2b: The global center of placement power shifted from Germany to the United States in the first half of the 20th century.

The last theoretical perspective addresses the intricate interplay between prestige, stratification, and renewal within the scientific community. In chapter 4.3, I detailed the existence of a rigid hierarchy within academia, which has been especially investigated within the United States (Jappe & Heinze, 2023). Highly prestigious universities form a distinct group that distinguishes itself through the closure of social exchange and upward mobility, resulting in a stratified academic landscape. Hierarchy is reinforced by the exchange of personnel, contributing to the accumulation of cumulative advantage for high-prestigious organizations that successfully place their graduates, accounting for the majority of all recruitments, and inertia within academia (Burris, 2004).

To determine if there is a similar crystalline stratification within the Nobel nomination procedure, I aim to compare the observation of this precise hierarchical structure within today's academic elite with the structure of nominations. I consider nominations as a mechanism of social exchange, with nominators as the active side from which nomination power emanates.

First, I will examine whether there is a concentration of nomination power at the descriptive level for countries and organizations. This aligns with the concept of prestige, wherein certain countries, often those with established research institutions and a history of scientific excellence, wield disproportionate influence within the nomination process. Furthermore, organizational stratification results in prestigious research organizations having significant influence over the nomination process, using their status to shape the trajectory of scientific recognition. This concentration of nominators highlights the hierarchical nature of the scientific community, where established institutions hold considerable power in determining who receives recognition. The following hypotheses address these aspects:

H3a: The distribution of nominations is skewed among countries, resulting in a concentration of nominators from a small number of countries.

H3b: The distribution of nominations is skewed among organizations, resulting in a concentration of nominators from a small number of organizations.

A special way of exhibiting nomination power consists of nominating colleagues from one's own entity such as affiliated country and/or organization. This is as close as scientists can get to self-nominating, as voting for oneself is prohibited by the NP Statutes.

This behavior matches universities hiring their own PhDs, which is a common recruitment pattern that is more frequently observed at prestigious universities (Wapman et al., 2022), reflecting social closure between status groups. This marks hiring their own graduates a privilege of high-prestige actors.

For self-nominations, Elisabeth Crawford analyzed patterns on the national level up to the 1950s (1992, 2001), concluding that low rates of self-nominations reveal a fair behavior of countries, while high rates of self-nominations show chauvinistic motives, which implies that this pattern is connected to questions of particularism and universalism. As previously stated, determining whether a nomination between scientists of the same country is based on ascription (common nationality) or merit (scientific achievements) is a complex question, and perhaps it anyway is even more interesting to assess the structural components that underlie self-nominations.

Therefore, my study relies on literature that focuses on stratificational reasons for differing rates of self-nominations. I will examine whether there are comparable patterns to those of graduate networks, and hypothesize the following:

H3c: The distribution of self-nominations is skewed among organizations, resulting in a concentration of self-nominations in a small number of organizations.

Lastly, my inquiry focuses on the extent to which placement power can be identified within the nomination network. The term "placement power" (Wapman et al., 2022) refers to the skewed faculty hiring processes within academia. Prestigious universities have the ability to place their graduates in any university, while low-prestige universities face difficulties in placing their PhDs, resulting in limited upward mobility.

I will examine mechanisms that determine the position of actors at different levels within the Nobel nomination network, using placement power to analyze the ability of nominators not only to vote (nomination power), but also to successfully place a nominee, whereby placement means that the nominee receives the NP in the given year. Similar to faculty placement, differences in nominators' capability to place nominees are expected to result from their workplace's position within the organizational network. Given that there is a hierarchy among universities, with organizations at the center being prestigious nominating organizations and organizations at the periphery having less nominating power, this will affect their ability to place nominees, with peripheral organizations having a reduced chance of placing nominees relative to central organizations.

The inertia of the stratified hierarchy may also prevent nominators from new organizations from successfully placing their submitted nominees, analogous to Morgan et al.'s (2018) finding that new ideas generated from the periphery of a network do not diffuse as smoothly as ideas from the center. This finding highlights the challenges faced by newcomer organizations in navigating the stratified landscape of scientific recognition. Newcomer organizations may encounter barriers, resulting in fewer successful nominations compared to their established counterparts. The following hypotheses emphasize the role of organizational status in shaping nomination outcomes:

H3d: The distribution of placement power is skewed among organizations, resulting in a concentration of successfully placed nominations from a small number of organizations.

H3e: Nominators from newcomer organizations place fewer successful nominations than established organizations.

My dissertation aims to contribute to a better understanding of the scientific elite of the Nobel Prize, to classify its structural composition and placement mechanisms on the basis of historical developments and with regard to the principles of stratification within science. In doing so, I pursue a theoretical triad that encompasses the principles of universalism vs. particularism, scientific leadership, and prestige/stratification. My approach complements the existing literature with a fine-grained, historically precise dataset on Nobel Prize nominations and grounds analysis on sociological theories. My results are compatible with modern studies of placement mechanisms within science, and thus not only add to studies of the Nobel Prize, but also elucidate principles about the structure of the scientific elite in general.

6. Data and methods

My principal intention is to present a comprehensive data base using records of the Nobel nomination archive (Nomination archive, 2023) and to supplement it with additional relevant material where information is missing. To promote transparency in scientific data and facilitate further research, I will make my compiled database available as an open access repository after graduation.

Previous studies have primarily relied on individual or national data pertaining to the individual scientists within the network. Drawing on Crawford's method, I have consulted individual biographies and aggregated further levels of analysis from them. Crawford, for example, aggregates her data on nationality by the country where scientists worked when they first entered the nomination network. Scientists' nationality might change retroactively, if they spent at least eight years in another country (Crawford, 1992, p. 27). In the dynamics of her time frame covered, it is essential to track shifts in scientists' mobility resulting from migration patterns including those caused by world wars and persecution in countries such as Germany. Therefore, Crawford focuses on substantial changes in assigned nationality and illustrates a progression when compared to earlier research that linked scientists with their country of origin (Küppers et al., 1982).

Gallotti and De Domenico (2019) have a notably greater data pool and thus take a different approach to assign nationality based on a majority rule: Every scientist is hence associated to only one country for the whole observation period.

To complement the results found through these strategies, I will take a more fine-grained assignment to nations, as will be laid out in the following. To enhance the organizational perspective on the Nobel Prize, I will analyze affiliations at a deeper level. To further highlight organizational components within the nomination network, I will address the Royal Swedish Academy's authority in quantitative terms, enhancing the qualitative findings thus far.

In line with Crawford (1992), I sum up the categories of Physics and Chemistry, resulting from their common awarding structures like the awarding body (RSAS) and due to data availability. In the nomination archive of the Nobel Foundation, data on the Nobel Prize in Medicine or Physiology was lacking decisive years at the point of data collection. In total, my data covers the time span from 1901 to 1969.

Nominations for Physics and Chemistry are fully archived up to the 50-year-freeze of information. At the time of the first data collection, this encompasses data on all valid nominations up to the year 1965 for both disciplines. To cover for the whole decade, further data was collected up until 1969 in a second step. Information on the discipline of Physiology or Medicine is still only available up to 1951, missing crucial years for analysis. It would be beneficial to compare all three scientific award categories, however, restricting the analysis to Physics and Chemistry remains reasonable, given their shared nomination processes as well as the shared awarding body, the RSAS (for Physiology or Medicine, the Karolinska Institute is in charge).

In an initial step, I used a basic non-coding tool (*Octoparse - Web scraping tool*, 2023) to obtain general information on all nominations within the two categories, including information about the year and discipline as well as the names of the nominators (those who sent a nomination) and the nominees/candidates (those who received a nomination). I checked the data for plausibility (see chapter 6.1) and added further information manually (see chapter 6.2), as I will describe in detail in the next subchapters.

To gain insight into the data structure, Table 18 in the appendix illustrates a sample data series from the 1901 Physics NP nominations. This example will be referenced periodically to clarify data procedures. It should be noted that this sample only includes a limited number of variables for demonstration purposes and does not represent the entire dataset.

Data is stored in Microsoft Excel and sorted by nominations, with each nomination having its own row with the essential information, corresponding to the arrangement in the nomination archive, and enhancing information. A nomination always represents a relationship between two individuals in a particular year: one nominator and one nominee. Even if a nominator votes for multiple individuals in one vote within the archive, I will treat each connection as a distinct relationship, ensuring a dyad in each row. In Table 18, an example illustrates how Knut Angström split his nomination in 1901 between two nominees, Wilhelm Röntgen and Philipp von Lenard. Nonetheless, his votes for the scientists are treated separately, thereby generating a pair in both rows. Because of this different counting, my numbers do not necessarily match the archives. In total, my dataset counts 8832 nominations with 17664 individual entries (8832 on the nominators' side, 8832 on the nominees' side).

To clarify, when I use the term "nomination", I refer to the distinct dyads between individuals (8832 in total), whereas when I use the term "entry" I refer to specific biographical information about nominators and nominees, of which there are two in each row (one for the nominator, one for the nominee, see Table 18 in the appendix for clarification).

My dataset captures different levels of entities, the smallest of which are individuals: Individuals in the dataset are either nominees, nominators, or both, and identify distinguishable scientists. In Table 18, Svante Arrhenius appears as both a nominee and a nominator. His entries are retraceable through distinct naming. Although biographical information may change over the course of the years, individuals' entries are traceable throughout their nominations/entries. In total, there are 3319 individuals in my dataset, of which 2225 only act as nominators, 620 only act as nominees, and 474 act as both. For clarification, when I use the terms "individuals" or "scientists," I refer to all persons in my dataset, not considering their specific role.

In analyzing nominators, the number of candidates they put forward in one year is often of secondary interest. For descriptive analysis, it is important to only consider whether nominators nominated in a given year, and not the number of candidates they voted for. Thus, I created a reduced dataset for analysis on nominators by deleting multiple nominations by the same nominator in the same year, resulting in a total of 5952 nominations. This set is used for analysis in chapters 7.1 and 7.4.2.

Proceeding up the scale, I use the term "organizations" to describe the scientists' main workplace, and "cities" and "countries" to represent the location of that workplace at different levels of aggregation.

Assortment by nominations can be extended to person-driven arrangements, by individuals, or more specifically, by nominees or nominators. Furthermore, in the course of analyzing the likelihood of success, it becomes important to organize the data by claims, displaying nominees' chances to win the Nobel Prize. Thus, the dataset is aggregated in such a way that all nominations in a given year for a given nominee are taken together. On the other hand, to find out if nominators exhibit placement power, it is important to also sort by their claims to find out what characteristics might make nominators more or less successful. These procedures are explained in more detail in the regression analyses in chapter 7.4 and are only mentioned here to illustrate the flexibility of the data. The different levels, as well as the additional information I collected, allow the dataset to be organized in different ways, and thus offer a lot of potential for analysis that I do not fully exploit in the course of this dissertation. Consequently, making the dataset available as a repository will provide further insights for new analyses.

My analysis aims to shed light on principles of nomination as well as placement power. For that, I distinguish between the roles of nominators and nominees, investigating if both sides take part in achieving a successful nomination. Secondly, I explore the impact of individual, organizational and national attributes within the process. A principal question remains whether the selection process follows the shift in scientific hegemony, and whether it exhibits the same stratification as described for academia, especially within the United States, giving the majority of placement power to nominators from prestigious organizations.

A first sample of two percent of entries submitted by nominators was reviewed by a student assistant for consistency and random errors, revealing a low error rate. Three out of 230 entries contained small errors in biographical information, while nine other entries provided previously missing information. Although these values suggest satisfactory data quality, I opted to conduct a comprehensive dataset check to attain the highest possible data quality.

The final data set, including both the information from the archive and extended information, was checked in its entirety by my student assistant, thus 4-eyes principle applies to my dataset. The creation of the extensive database alone was a step that took nearly two years, especially because of the extended coverage until 1969. The review of the entire dataset also took about a year. It revealed a low rate of identified errors or previously absent values in records, with the latter being significantly more prevalent than the former, as observed in the initial sample.

Years of birth and death, as well as organizational affiliation, were the most common source of errors or previously missing values, which can be explained by the fact that, in the case of relatively unknown scientists, this very detailed information could only be found after considerable, time-consuming investigation. All irregularities found during the review were evaluated and corrected where necessary.

6.1 Data curation

The initial data mining process was conducted in early 2020 and included the following information for each nomination between 1901 and 1965 listed in the archives in the Physics and Chemistry categories: year, discipline, name of the nominator, and name of the nominee. Although more information was available, I chose not to include it by default. This was partly because information was not consistently available for every scientist, such as the scientist's job title, and partly because data still needed to be checked for accuracy and correctness.

Two years later, in 2022, the Nobel Foundation released more data which extended my dataset, resulting in a complete observation period from 1901 to 1969. I have not only retained the data from the online archive and enriched it with new information, but also conducted plausibility checks. These checks revealed certain inaccuracies on the individual level, of which I will describe a few of greater significance in the following.

It is important to note that the nomination archive is constantly being expanded, checked, and corrected by the Nobel Foundation, which is why errors or corrections I lay out in the following may have been incorporated into the archive in the meantime since data collection.

In two nominations of the archive, the Physics NP was most likely confused with the Peace NP, as nominees as well as nominators in both cases are no scientists at all. Especially on the nominee's side, there are indications for a false classification: Arthur Neville Chamberlain, Prime Minister of the UK, (*Case example of Arthur Neville Chamberlain*, 2023) and Grenville Clark, US American lawyer of the Harvard Corporation, (*Case example of Grenville Clark*, 2023) were nominated once each for the Physics NP and then 10 and 41 times, respectively, for the Peace NP. The two nominations in question were excluded from my database.

Few nominations are not attached to a single person as a nominee or nominator: There are cases in which the nominator is unknown or a nameless member of the Chemistry committee. Anonymous reporting may result from a variety of reasons, including limited information, deliberate omissions made by the Nobel Foundation (*Nomination archive manual*, 2023), or practical considerations, like illegible handwriting (as encountered in two instances). For nominators in my dataset, this applies to roughly twenty nominations, which renders it a minor imprecision. For nominees, the impact is even less substantial since the database contains only four nominations in which the nominee was either a company or the impersonal *nuclear scientists*. In case of an unknown nominator *or* nominee, a nomination was not excluded from my dataset, as it still holds relevant information for the respective other entry.

Nominations that violate the general rules or Statutes are excluded from the online archive per se, for example, scientists nominating themselves. Nevertheless, there are some nominations that, according to the Statutes, will at least not lead to a Nobel Prize, namely those to researchers who are already deceased at the time of nomination. Such nominations were included in my dataset, while checking for misidentification. In 16 out of 21 nominations where this occurred, the nominee had passed away a maximum of three years before. The time gap may be attributed to the slow dissemination of information in the first half of the 20th century. In the remaining cases, nominees had been deceased for up to 18 years, suggesting that the nominator may not have comprehended the prize's rules. These instances were also reviewed for potential misidentification.

More curiously, there are three instances in which a nominator who was already deceased made a nomination. The nominators are all well-known, so misidentification due to lack of familiarity should not be a serious factor. It may be that other actors from the same organization with similar sounding names were confused for them. However, according to the archive, Sahachiro Hata posthumously nominated 13 years after his death, Johannes van der Waals 3 years after his death, and Hendrik Kramers 6 years after his death. This is clearly a data error, but the source of the error cannot be identified. Since there were only three such cases, these nominations are retained nonetheless, but were set to unknown at the individual level.

Due to these minor discrepancies, I cross-checked all information on nominators and nominees in the nomination archive and obtained supplementary biographical details from sources other than the nomination archive. The sources mainly comprise Wikipedia and the Encyclopædia Britannica as renowned online encyclopedias, the National Academy of Sciences, the Atomic Heritage Foundation, the American Institute of Physics with its magazine Physics Today, the American Chemistry Society, and the Science History Institute as professional organizations in the fields of Physics and Chemistry, providing extensive coverage of scientific biographies. For each individual in my database, these sources were consulted by default to provide a reliable basis for biographical entries.

Depending on the scientists' general prominence, some information could not be found in the default sources. In these instances, I have consulted other websites, including more specialized scientific organizations (e.g. the Electrochemical Society) nationally-based organizations (e.g. the Accademia delle Scienze di Torino), dictionaries with a more national imprint (e.g. Australian Dictionary of Biography), online archives of libraries or universities (e.g. MIT Libraries Institute Archives), university faculty pages or professorial catalogs (e.g. Catalogus Professorum Universiteit Utrecht), scientific projects on historical data (e.g. Historia Mathematica Heidelbergensis), websites focusing on scientists' obituaries (e.g. Legacy.com), newspapers (e.g. The New York Times), publishers (e.g. Cambridge University Press), and available websites by or for scientists themselves.

Table 19 in the appendix provides a complete transcript of all 144 sources used. Sources in bold were accessed by default, constituting a substantive base for biographical data, while non-bold sources were used only if no entry was found in the standard references.

For better clarification, the names of each individual in my database must be distinct and spelled identically in all entries. This allows for nominations of an individual as both a nominator and a nominee to be consolidated into a single notation if necessary. I changed duplicate entries for different persons and established a single, and distinct name for each individual. An example of such a double entry from the archives occurred with Nobel laureate *Aleksandr Mikhailovich Prokhorov*, who also appeared in the nomination archives as *A M Prochorov*. Duplications mainly concern scientists whose names were less common in 20th century Northern Europe, as well as scientists with compound names, such as Abraham Cornelis Sebastiaan van Heel, accounted both as *Abraham C van Heel* and *A C S van Heel*.

Scientists who have acquired a title of nobility during their lifetime or have changed their name for any other reason are also affected, such as *Sir Geoffrey Ingram Taylor*.

Curiously, there are also scientists with the same name and therefore oftentimes the same entry who are actually different persons. This occurred with *Friedrich Kohlrausch*, professor in Germany, and his nephew *Karl "Fritz" Kohlrausch* who was a professor in Austria. Their biographical entries in the nomination archive got mixed up. In those cases, I separated the individuals through a middle name, so that they are distinct from one another.

This tends to happen in families with a long academic tradition, where sons inherit their father's name(s) and continue his scientific legacy. Historically, however, these cases are easy to distinguish because the nomination periods are sufficiently far apart for a clear division to be assured. The entry of *Karl-Friedrich Bonhoeffer,* for example, includes not only his own nominations but also those attributable to his father *Karl Bonhoeffer*. This can be said with certainty, as Karl-Friedrich was only ten years old at the time of the first nomination falsely attributed to him. Moreover, the biographical information (medical impact, resides in Wroclaw/Breslau) rather fits his father Karl. Other case examples of mixed entries between family members are *Jean* and *Francis Perrin*, *Erich Max* and *Erich Albert Müller*, *Hans* and *Emil Erlenmeyer* as well as *Hermann Otto* and *Emil Hermann Fischer*.

Another reason for these mix-ups is the similarity of names among scientists who have taught at the same universities, such as the misidentification of *Alexander Robertson* as *Archibald Robertson*, who both worked at the University of Liverpool, but at different times. It occasionally occurs that life dates are mixed up within the nomination archive. Examples of this include the entry of *Lothar Meyer*, whose life dates point to a German chemist in the 19th century (died long before the nomination period). The entry most likely refers to the US American professor *Lothar Mayer* from Chicago University. Mix-ups were also detectable for *Carl* (German chemist from Göttingen) and *Charles Wagner* (French pastor, who studied in Göttingen, too, but was actually nominated for the Nobel Prize in Literature), *Salomon Solis-Cohen* and *Seymour Stanley Cohen* (both professors in Philadelphia at different periods), *Simon*, *Silvanus* and *William Thompson*, *Hugo* and *Hessel de Vries*, and *Johannes* and *Jan Rydberg*. Caution and contextual clues are essential to ensure accurate identification between several individuals, given the scarce information.

To address another inaccuracy of the nomination archive, (first) names are oftentimes abbreviated using the first letter, such as *L Schiff* instead of *Leonard Schiff* (this concerns more than five hundred individuals), or are spelled incorrectly (mainly small spelling errors that could be due to handwritten notes such as *Oskari Routola* instead of *Routala*). As a result, biographical details of those scientists are more difficult to acquire. I tried to rectify as many inaccurate or incomplete names as possible, though not all information was retrievable, leaving some scientists with incomplete forenames and biographies.

Furthermore, the archive contains some errors that I was unable to reconcile with my sources. Isadore Amdur, for example, is portrayed in the archives as a Japanese woman from Kyoto (*Case example of Isadore Amdur*, 2023). I found no clue of her in my sources, though life data match to Isadore Amdur, male chemist from MIT ("Isadore Amdur, Physical Chemist at MIT, Dies," 1970). In these cases, I always deferred to my sources presented in Table 19 to ensure data accuracy.

The previous cases demonstrate that the nomination archive contains more details regarding nominees and nominators than their names. Nevertheless, this information is not uniformly available and fluctuates significantly based on the person's status. Thus, I classified the relevant information manually based on the supplementary sources exhibited in Table 19.

My data enhancement is explained in detail in the next subchapter.

6.2 Data enhancement

Additional data on scientists was collected at three levels: individual, institutional, and national. Unless otherwise noted, additional variables were collected for both nominators and nominees and are time-variant, meaning that they refer to the exact year of nomination and may change over time.

For the individual level, birth and death years were collected first, primarily for the plausibility checks explained in chapter 6.1. Basic variables representing gender and age at the time of nomination ensured a similar purpose of description. If an individual is awarded a Nobel Prize during their career, the year and discipline of the award are recorded. For individuals who have received multiple Nobel Prizes, their first one is recorded to mark the initial achievement of receiving the prestigious award. The disclosure of this information serves divergent purposes for nominees and nominators. While information on nominators is used to identify possible benefits of having nominated as a prize-worthy scientist, information on nominees is used as an indicator of success, marking the nominations that led to a Nobel Prize.

For nominators, my major interest consists in documenting a time-variant laureate status as a binary variable to indicate whether or not a scientist has already received a Nobel Prize at the time of the respective nomination. For example, Wilhelm Röntgen submitted one nomination in 1901, the year he received the Nobel Prize in Physics himself. As he was not a laureate at the moment of the nomination, he will only be categorized as a nominating laureate from 1902 onward. Yet, his status then applies to all his votes in the future, regardless of the number of years that have passed since the awarding. As Robert K. Merton famously expressed: “Once a laureate, always a laureate” (1968a, p. 57). This laureate status applies to both Physics and Chemistry, meaning that laureates in one category nominating for the other still count as laureates. Scientists acting at the borders of the disciplines are typically well regarded in both disciplines, such as Svante Arrhenius, a founder of physical Chemistry. The purpose of this variable is to examine the influence and nomination patterns of laureates, since they might be quite different from other scientists due to their renown and their privilege to nominate every year in their respective category (or, in the case of Physics, for both categories).

The laureate year recording for nominees aims to distinguish successful nominations from the overwhelming majority that do not result in a Nobel Prize. See Table 18 in the appendix for explanation: In 1901, Wilhelm Röntgen received the Physics NP, making nominations in that year to him successful while all others are categorized as unsuccessful. This also affects Röntgen's nominators, Angström and Arrhenius, who each submitted one successful and one unsuccessful nomination.

Similar to nominators’ laureate status, this variable is binary, discipline-spanning and time-variant, but changes not just at one point and remains that way for the entirety of all upcoming nominations: it refers specifically to the year of awarding. For instance, Guglielmo Marconi was nominated 15 times for the Physics NP between 1901 and 1933. In 1909, he won the award, which makes any nominations he received that year a success. However, it is up to interpretation whether nominations received after 1909 (in Marconi’s case, one nomination in 1929 and one in 1933) should also be considered successful, given that he had already received the prize in the past.

Possible explanations for post-award nominations could be, mostly for nominations that came only a few years after the award, that information dissemination was too slow in the first half of the 20th century. As shown in Figure 31, nominators receive their nomination letters soon after the announcement of last year’s prizes and might not have heard the news of freshly laureated scientists until their nomination deadline in January.

Another reason for post-award nominations by one year precisely may be attributed to delayed award ceremonies, which often occurred during times of war. For instance, Albert Einstein was awarded the Physics prize in 1921, but did not receive it until 1922. In these exceptional circumstances, both years were considered to be successful nominations because the nominators in 1922 could not have known that Einstein was already the previous year's winner. The Nobel committees have postponed announcements several times to clarify certain cases. In some years, it has been cancelled altogether due to various circumstances. These cancellations affect the Physics NP for the years 1931 and 1934, the Chemistry NP in 1917, 1919, 1924, and 1933, and both categories in 1916, 1940, 1941, and 1942. Regarding postponed prizes, Table 20 in the appendix provides an overview of laureates whose awards were not announced until the next year and therefore have been categorized for more than one successful nomination year in my database.

For post-award nominations that are farther away from the actual awarding (in my observation period, the greatest time span between awarding and nomination belongs to Werner Heisenberg, who was nominated in 1969, 37 years after his award), a more proper explanation might be a new claim to a Nobel Prize. As laureates typically are esteemed and pioneering scientists, it is reasonable to assume that, in these cases, they made multiple prizeworthy discoveries. Carl David Anderson, for example, was awarded the Physics NP in 1936 for "his discovery of the positron" (*Nobel Prize of Carl David Anderson*, 2023) together with Victor Franz Hess. After his award, he was nominated again 18 times between 1941 and 1953. In the online archive, justification for nominations is not always submitted. Therefore, it can only be speculated, based on my sources listed in Table 19, that Anderson's post-award nominations pertain to his further research. In collaboration with his doctoral student Seth Neddermeyer he later discovered the subatomic particle *muon*.

Several reasons suggest that this discovery may serve as a foundation for his post-award nominations. First, 13 out of 18 nominators included Seth Neddermeyer in their nominations for the respective year. Moreover, Anderson's doctoral adviser Robert Millikan, who collaborated on his and Neddermeyer's project, nominated both of them 10 times. Finally, Anderson himself nominated Neddermeyer 7 times during these years. Assuming my suggestion is valid, the latter fact could be interpreted in the light of the Matthew effect. Neddermeyer had already collaborated as a student in the first Nobel discovery of the positron, and Anderson may have desired to give his mentee full credit for the *muon*. Otherwise, since self-nomination is prohibited by the Statutes, this is the closest a scientist can come to hinting at discoveries for which he might also be considered for a prize. These hypotheses are not intended for data compilation, but rather serve as a general example to aid in understanding the reasons behind post-award nominations.

The examples of Marie Curie and John Bardeen demonstrate the possibility of scientists winning a second Nobel Prize by making multiple noteworthy discoveries. Specifically, Marie Curie who received her second award during my observation period, therefore had three successful nominations: one in 1903, leading to her shared Physics NP, and two in 1911 for her Chemistry NP. Bardeen's second award in 1972 falls outside the observation period, but it provides a thorough explanation for his 23 post-award nominations between 1961 and 1969.

To accurately evaluate which factors contribute to successful nominations, it is crucial to maintain a clear distinction. In this regard, post-award nominations are only counted as successful nominations in the cases presented in Table 20, as there is a clear explanation. The other rather speculative explanations mentioned are not considered. Consequently, all additional post-award nominations are classified as not successful.

As the number of cases shows, this is only a minor ambiguity in the data: In general, post-award nominations only make up a small amount of nominations (225 in total, roughly 2.5 percent of all nominations). Omitting all cases of explainable nominations such as those listed in Table 20, alongside the case examples of Curie and Bardeen, around 100 cases remain, comprising approximately one percent of the total nomination count. These few instances can be neglected, irrespective of their cause.

Another variable I collected, in addition to the archived data, is membership in the RSAS. To provide a quantitative overview of this Nobel-relevant organization's nomination patterns, scientists are documented as being or not being members at the time of their nomination. This information was obtained specifically from the Swedish Wikipedia page (*Lista över ledamöter av Kungliga Vetenskapsakademien*, 2023), where the names of all members and their corresponding years of admission are catalogued. Membership is a binary concept that changes over time, similarly to the laureate status for nominators. Thus, tracking changes in the membership status of scientists from non-members to members can reveal nomination patterns driven by particular interests. Membership in the RSAS serves as a potential indicator of such clusters.

Further explanation of characteristics on the individual level can be found in the already mentioned case of Carl Anderson. Anderson was a doctoral student under one of his nominators, Robert Millikan, and in turn nominated his own doctoral student, Seth Neddermeyer.

I identified mentoring networks among nominators and nominees by examining the biographies of scientists. A mentoring relationship is established when an individual completes their graduate studies or a junior staff appointment with the other, indicating a direct relationship and a clear hierarchy. While there is an approach to structure mentoring networks like whole academic families (Chariker et al., 2017; Tol, 2023), which involve not only doctoral "fathers" or "mothers," but also siblings, cousins, or grandparents, I only examine the direct relationship between mentor and mentee. To continue with Anderson's example, there is a connection between him and Millikan as well as between him and Neddermeyer, but there is no connection between Millikan and Neddermeyer. Furthermore, it is not important whether the mentor is the nominee or nominator, since the basic assumption is that these nominations might be influenced by a personal relationship.

Additional information regarding individual scientists in the network generally enable more elaborate conclusions, including their positioning in the network and their importance based on their frequency of nominating or being nominated.

My data incorporates levels of organizations, cities, and countries to provide additional context on individual scientists. Notably, the inclusion of organizational membership is a novel approach for examining Nobel Prize nominations. Table 19 contains the sources used for this variable. Scientists are categorized based on the organization they were employed with during the year of nomination, thereby allowing changes in organizational affiliation to be tracked. Ernest Rutherford, for example, was a busy nominator, having submitted 18 nominations over 11 years, spanning from 1912 to 1937. Until 1919, he was a professor at the University of Manchester, after which he relocated to the University of Cambridge, where he worked for the rest of his life. As a result, all nominations after 1919 (the first of which was in 1922) are recorded under University of Cambridge.

If individuals work for multiple organizations, as is frequently the case for distinguished scientists serving on Directory Boards, Commissions, holding visiting professorships, adjunct memberships, and fellowships, they are categorized by their primary employment organization for simplicity's sake. In my dataset, this often results in classification as a tenured professor at a university or as a group leader at a research organization. Sometimes, scientists may hold both positions simultaneously, which can complicate the process of classification. One example is Carl Neuberg, who served as a professor at Friedrich-Wilhelm University (now Humboldt University) of Berlin and concurrently held a directing/group leader role at the Kaiser Wilhelm Institute (now Max Planck Institute) for biochemistry. Cases in which it is difficult to determine the primary organizational affiliation are infrequent in my data set (only 2% of all entries), thus both workplaces are recorded.

As scientists in the dataset are often in advanced stages of their careers and may be already retired at the time of nomination, I only list their most recent organization if they still have some degree of affiliation, such as being a professor emeritus. This ensures that the information provided is current and relevant. In cases where retired scientists lack any connection to their previous workplace or any new affiliations, their workplace is not recorded.

Consequently, some individuals lack a current workplace at the time of nomination or have an uncertain workplace due to insufficient information. These are considered missing values and make up roughly 1% of the dataset, a minor loss of data. In cases where some information was discernible, these are shown in my dataset, such as scientists working in their own small laboratories or in companies that are not further described (e.g. Edmund von Lippmann, "director of a sugar refinery"). Nominator data loss outweighs that of nominees, with 90 percent of missing values being attributed to nominators. This may reflect the larger pool of nominators and the fact that nominees by definition should have made a substantial impact on the scientific community, resulting in information about them being more readily available.

The whole dataset contains 509 different organizations as scientists' main workplace. To sustain historical comparability of data, organizations employ a single name, even though it may have changed during the approximately 70 years under observation. As a general convention, the most recent name has been used. All Kaiser Wilhelm Institutes therefore are documented as Max Planck Institutes. The Rockefeller Institute, which is now known as Rockefeller University, is only referred to by its latter name. I checked for organizations that merged or split during the observation period, focusing on their continued separability through the use of distinct names or their integration under a single name, though, the aim is to maximize historical accuracy at the respective time of nomination. For instance, in my dataset, the University of Paris, which underwent significant structural changes in the 1970s and now consists of 13 distinct universities, is still represented as a single university.

Data on scientists' work organizations leads to additional considerations at the organizational level: This includes examination of the organizational network itself, different types of organizations, organizational status driven by prestige, as well as the historical development of influential institutions or newcomers.

To cover another organizational attainment, I checked in scientists' biographies if they collaborated in the Manhattan Project, as many physicists in the 1940s worked there in addition to their regular affiliation. This is true for 9 percent of all entries, with more nominees than nominators working within the Manhattan Project, with entries for Physics clearly outweighing those for Chemistry. Information about the project sites is also retrieved, showing that most of the scientists worked at the Los Alamos site. Data is obtained explicitly from the website of the Atomic Heritage Foundation (also listed in Table 19).

Based on the organizational affiliation data, the next step is to gather information about the organization's location, more specifically, the city in which it operates. This process enables identification of metropolitan areas and enables the generation of other geographic variables, such as coordinates for visualization and distances between two locations connected through a nomination. Similar to organizations, cities have distinct, unique entries throughout the observation period, meaning that duplicate names are prevented through recording additional information (e.g.: *Cambridge (US)* and *Cambridge (UK)*). Geographical relocations of organizations were documented as closely as possible, exemplified by Max Planck Institutes which have often changed locations within Germany in the post-war years (the MPI for Chemistry, for instance, moved from Berlin to Mainz).

If scientists have multiple workplaces in different cities, both cities are recorded. For those scientists for whom no working organization could be retrieved, at least a city of residence was sometimes found, although in a few cases still no information is available. Yet, when aggregating data at the country level, information could be found for nearly all of the scientists in the dataset. Only two nominees' residence could not be assigned to a specific country, and four entries on the nominators' side were either completely unknown or could not be identified at all (loss of data falls below 1% at this point).

Similar to Crawford (1992) and Gallotti and De Domenico (2019), I gathered data on the national background of scientists. As information on nationality is hard to obtain for scientists with international mobility, both of the studies rather rely on national affiliation, which I intend to do as well. Gallotti and De Domenico take a less detailed approach in assigning scientists to countries by a majority rule. Crawford provides more details by including a change in the country of residence after eight years abroad as a rough rule of thumb. She does not specify explicitly how she arrived at this approximate guideline of eight years. In this respect, the design of my data collection aims to enhance precision. Instead of imposing an arbitrary benchmark, I record the current working country of scientists at the time of nomination to determine their national affiliation, enabling annual changes to be tracked with accuracy.

Thus, apart from long-term migrations often motivated by wars (especially from Germany to the United States due to the Nazi regime), shorter-term shifts are tracked, which are typically produced by regular job changes. This is shown in the cases of Cornelis Bakker, who left the Netherlands to work in Switzerland at the newly established CERN until his premature death in a plane crash, and Enrico Persico, who worked as a professor in Canada for three years before returning to his country of origin, Italy. In total, changes at the national level affect about a hundred scientists, merely constituting 3 percent of all actors in my dataset. This might suggest that mobility in the nomination network is mainly observed among individuals who were compelled to migrate because of persecution. The majority of scientists might tend to spend their careers in one country unless forced to do otherwise by external circumstances. But this conclusion depends heavily on the database. I have solely examined the years in which scientists acted as nominator and/or nominee, not their detailed curricula vitae. As such, I can only account for country shifts within nomination years. Furthermore, considering that nearly one third of nominators do not nominate more than once in the dataset and consequently cannot shift, this conclusion is not sustainable. The same applies to the conclusion that, because both nominators and nominees have rather established careers once they enter the nomination population, organizational changes tend to happen less frequently in the observed data, only impacting 8 percent of scientists. This, too, cannot be concluded, as datapoints are only available if scientists sent out and/or received a nomination.

Another aspect that makes my data more fine-grained in the interaction of levels is historical resilience. Information about country affiliation per se is historically variable, as especially within the first half of the 20th century in Europe, borders in my observation period shifted. Therefore, my dataset presents information not only on the current geographic boundaries of countries, but also on their territorial expansion during the time of nomination. However, I only consider legal border changes in my analysis and disregard any territorial shifts resulting from imperialism or military annexations during World War I and II, which includes Germany's takeover of neighboring countries. Although the annexation of Austria, known as the "Anschluss," occurred just prior to the start of World War II, it is not regarded as a territorial shift in my dataset.

Shifts of borders I considered are presented in Table 21 in the appendix. As a brief note, the presentation is not historically profound, but is limited to the shifts that occur in the dataset. For example, one of the significant shifts in Europe during the early 20th century was the disintegration of the Austro-Hungarian Empire in 1918. Until then, scientists from organizations in Austro-Hungarian cities such as Prague, Budapest, Vienna, Zagreb and Krakow have (been) nominated together under the label of Austria-Hungary. The dissolution resulted in the emergence of several nations that were or have nominated in my dataset after 1918: Scientists from Prague are categorized as Czechoslovakian, from Budapest as Hungarian, from Vienna as Austrian, from Zagreb as Yugoslavian, and from Kraków (Krakau) as Polish.

The inclusion of this historically refined country categorization allows for a comparison with present-day conditions and opens up additional avenues for analysis, including self-nominations. By 1918, for example, nominators from Strasbourg (see Table 21 for details) sent half of their votes to other German cities and only one vote to a French city. The rate of self-nominations may vary depending on the classification. By current conditions, Strasbourg is a French city. However, considering its historical nomination, it was German until 1918.

Furthermore, to enable comparison with NP laureates, a separate set of variables collected specifically for nominees focused on their highest degree: I obtained information regarding graduation year, degree-granting institution, location (city), and country (as per current and historically accurate classifications).

6.3 Methods

In this subchapter, I will shed light on the methods used for analysis. Calculations were performed within the program R, using its interface RStudio, and Microsoft Excel.

To measure stratification within nominations in terms of their distribution for countries and organizations (see chapter 7.1), I use the widely applied Gini coefficient for measures of inequality (Hasell, 2023). It represents the relative dimension of the inequality gap between the line of perfect equality and the Lorenz curve observed for the given distribution. It measures inequality on a scale of 0 to 1, with higher values indicating greater inequality. A value of 0 indicates a perfectly equal distribution. In the context of the distribution of nominations across countries, this would mean that each country submitted the same number of nominators. A value of 1 indicates perfect inequality - where one country submitted all nominations.

To examine the relationship between two categorical variables (see chapter 7.3), I utilize two measures. Firstly, I employ a Pearson's chi-square test (Azen & Walker, 2021) to determine if there is an interdependence between the two variables. The chi-square test compares the observed frequencies of categories with the frequencies that would be expected if the variables were independent. The test calculates a chi-square statistic, which measures the difference between observed and expected frequencies. Higher values indicate a greater deviation from independence, suggesting an association between the variables. Similar to other hypothesis tests, such as the t-test, the chi-square test requires obtaining a critical value from the chi-squared distribution table using the significance level and degrees of freedom to test the chi-squared value against this value, which indicates a significant dependence between the variables if the calculated chi-squared value is greater than the critical value.

As a second step, I use the Phi coefficient to measure the strength and direction of a relationship between two categorical variables, each of which has two values (binary), resulting in a 2x2 contingency table where each cell represents the frequency of occurrence for each combination of the two variables. Phi values range from -1 to 1, with 1 indicating perfect positive dependence and -1 indicating perfect negative dependence between the two variables.

A value of 0 indicates no association between the variables. Small positive or negative values indicate a weak relationship, while values close to 1 or -1 indicate a strong association.

For ordinal variables, such as rankings that show an organization's position in a distribution as implemented in chapter 7.2, a Spearman rank correlation is used to assess the strength of a relationship between two variables. It ranges from -1 (indicating a perfect negative correlation) to 1 (perfect positive correlation). A correlation coefficient of 0 indicates no statistical relationship between two variables.

Chapter 7.3 employs a network perspective to analyze the nomination network of the Nobel Prize at the organizational level. Individual organizations are represented as nodes, with nominations among them (more precisely, between their affiliated scientists) depicted as edges. The network displays directed edges, indicating a sending organization (where a nominator who submitted a nomination is employed) and a receiving organization (where a nominee is employed). Loops in the network indicate self-nominations, where scientists employed by an organization nominate other scientists from the same organization.

To improve readability in complex network diagrams spanning time periods (Figure 24 and Figure 25), I use the concept of hubs and authorities, as introduced by Kleinberg in the context of the World Wide Web (Kolaczyk & Csárdi, 2014), to visualize important nodes and their function within the network. Hub nodes are characterized by how many authority nodes they point to, and authority nodes are characterized by how many hubs point to them, illustrating the functions of nominators and nominees, respectively.

To determine the central and peripheral nodes within the network, various centrality measures may be applied (Borgatti et al., 2018). For analysis, I initially use normalized degree centrality, which assesses the centrality of an organization by considering both incoming and outgoing edges (nominations) relative to the total size of the network (number of edges divided by n-1, where n is the number of nodes in the graph). This enables the comparison and contextualization of centrality values across different networks/years.

In directed networks, degree centrality can be examined in a more nuanced manner by distinguishing between incoming and outgoing edges. In the context of the nomination network, this differentiation reflects the dual roles of nominators and nominees, making it useful for role-specifics. To ensure targeted analysis, I have thus complemented normalized degree centrality with outdegree centrality, which measures only outgoing nominations and emphasizes the nominators' role, and indegree centrality, which measures only incoming nominations and emphasizes the nominees' role. Both measures have been normalized for comparison across networks for different years.

From the annual centrality measures of individual organizations, I have derived a network-specific prestige score that represents organizational status within the network: To achieve this, I assign organizations to quartiles based on their 10-period moving average normalized degree values (the basic degree value as well as more specific indegree and outdegree values). This enables tracking of nomination patterns for peripheral, middle-low, middle-high, and central organizations. Each quartile corresponds to 25 percent of the entries with central organizations having the highest degree values and peripheral organizations having the lowest.

I use this past network position to investigate the influence of organizational status, specifically positioning within the center versus the periphery of the network. By aggregating centrality measures over time, the goal is to capture the lasting prestige and influence of organizations within the nomination network.

In chapter 7.4 and its subchapters, I use inferential statistics in order to explain which variables best predict successful nominations, and, more precisely, nominators' placement power. Logistic regression analysis models the probability of a binary outcome variable, such as success or failure, based on one or more explanatory variables. The term binary refers to a dichotomous variable that can take two distinct values, typically coded as 0/no and 1/yes. In my analysis, the binary outcome variable represents success in the nominee achieving a Nobel Prize, coded as yes or no to denote success or failure of the distinct nomination, respectively. Logistic regression estimates a non-linear relationship between explanatory variables and the outcome, providing a more flexible framework for analyzing categorical outcomes compared to linear regression models (Best & Wolf, 2015).

The coefficients in logistic regression represent the change in the log-odds of the outcome for a one-unit change in the explanatory variable. Logistic regression coefficients can be interpreted in terms of their significance as well as their direction, indicating a positive or negative effect on the dependent variable based on their sign. However, their scale lacks meaningful interpretation. To assess the effect size, average marginal effects (AMEs) are employed. The AME provides a robust measure of effect size compared to other metrics and offers an intuitive interpretation by representing the average effect on the change in probability of success for a 1-unit increase in an explanatory variable.

For evaluating model fit, I use two pseudo-R-square measures, acknowledging that their interpretation is not as straightforward as with linear regression's R-square. Like R-square, these measurements range between 1 (indicating a perfect fit) and 0 (indicating no explanatory power). McFadden's pseudo-R-square is conservative, as it never reaches the value of 1 (best fit). Nagelkerke's R-square leads to greater values. It is important to evaluate both measurements with caution. I supplement this perspective with the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Of particular importance is the BIC, which penalizes the inclusion of additional explanatory variables, thus favoring sparsity. Smaller BIC values suggest a better balance between model fit and complexity, indicating improved model fit (Best & Wolf, 2015).

7. Results

The following subchapters present findings from my analysis, including insights on who is eligible to nominate at the individual, organizational, and national levels within the next subchapter. Subsequently, results from the organizational network are presented, followed by logistic regression analyses. In general, I will supplement my research objectives explained in chapter 5 with additional, noteworthy findings. Though, to maintain clarity and precision, Table 2 summarizes my research hypotheses. In the final conclusion, I will expand this table with a concise summary of the results for each hypothesis (Table 17).

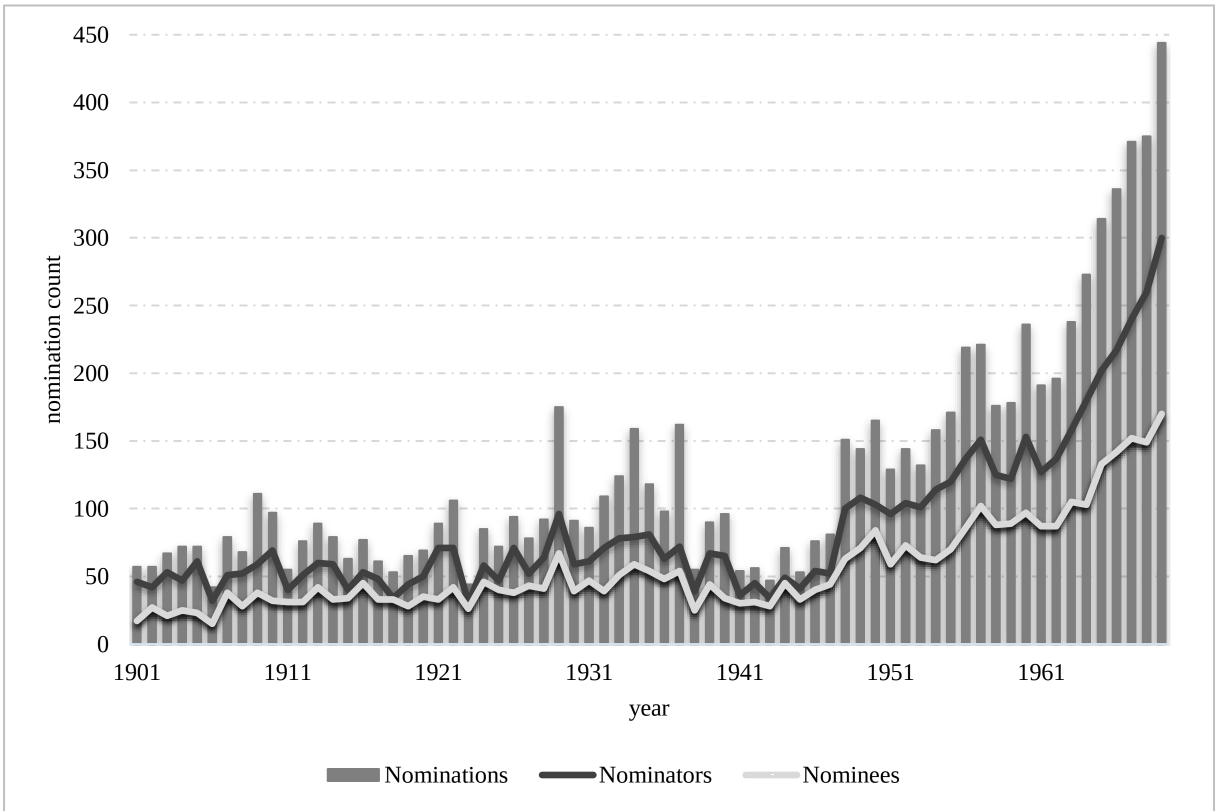
Table 2: Overview of research hypotheses

Hypothesis	Description	Chapter
H1a	Women are disadvantaged in the nomination network, resulting in fewer female nominators and nominees.	7.1
H1b	RSAS members are privileged in the nomination process, and thus dominate the nomination network.	7.1, 7.4
H2a	The global center of nomination power shifted from Germany to the United States in the first half of the 20th century.	7.1
H2b	The global center of placement power shifted from Germany to the United States in the first half of the 20th century.	7.4
H3a	The distribution of nominations is skewed among countries, resulting in a concentration of nominators from a small number of countries.	7.1
H3b	The distribution of nominations is skewed among organizations, resulting in a concentration of nominators from a small number of organizations.	7.1, 7.3
H3c	The distribution of self-nominations is skewed among organizations, resulting in a concentration of self-nominations in a small number of organizations.	7.2, 7.3
H3d	The distribution of placement power is skewed among organizations, resulting in a concentration of successfully placed nominations from a small number of organizations.	7.4
H3e	Nominators from newcomer organizations place fewer successful nominations than established organizations.	7.4

Before proceeding with analysis on nomination power, I will show the general growth of nominations and their network, present some basic characteristics, and visualize overall changes in the nearly 70 years observed.

Previous studies have already outlined the expansion of the nomination practice (Crawford, 2001; Seeman & Restrepo, 2023b), which is why I will discuss it only briefly in this section. As noted in chapter 3, other studies provide detailed examples of exceptional researchers as nominees and nominators operating at the individual level. Thus, there is no need to further compare the number of nominations or other details of individual scientists' cases. Instead, I focus on presenting general patterns.

Figure 1: Expansion of nomination counts 1901 - 1969



This graph depicts the growth of the nomination process by showing the number of nominations received (gray bars), nominators (black line), and nominees (light gray line) per year. The X-axis represents the progression over time, while the Y-axis represents counts.

From 1901 through 1969, the dataset contains 8832 nominations. Figure 1 displays the number of annual nominations in bars, showing historical fluctuations. Due to wartime, there is a small downward trend for World War I and a large dip for World War II, but the plot still reveals continuing growth up to the onset of the educational expansion in the 1960s. As of 1963, the number of nominations rises sharply to a maximum of 444 in the last year of observation.

The annual count of nominators (shown in dark gray) and nominees (shown in light gray) for each year is graphed via lines in the accompanying figure. In both instances, there is also an increasing pattern. The rise from an average of about 50 nominators per year in the 1910s to an average of nearly 200 nominators in the 1960s illustrates a significant growth in the number of involved actors. In 1969, the year with by far the largest number of nominations, a total of 300 nominators propose 170 nominees in 444 nominations.

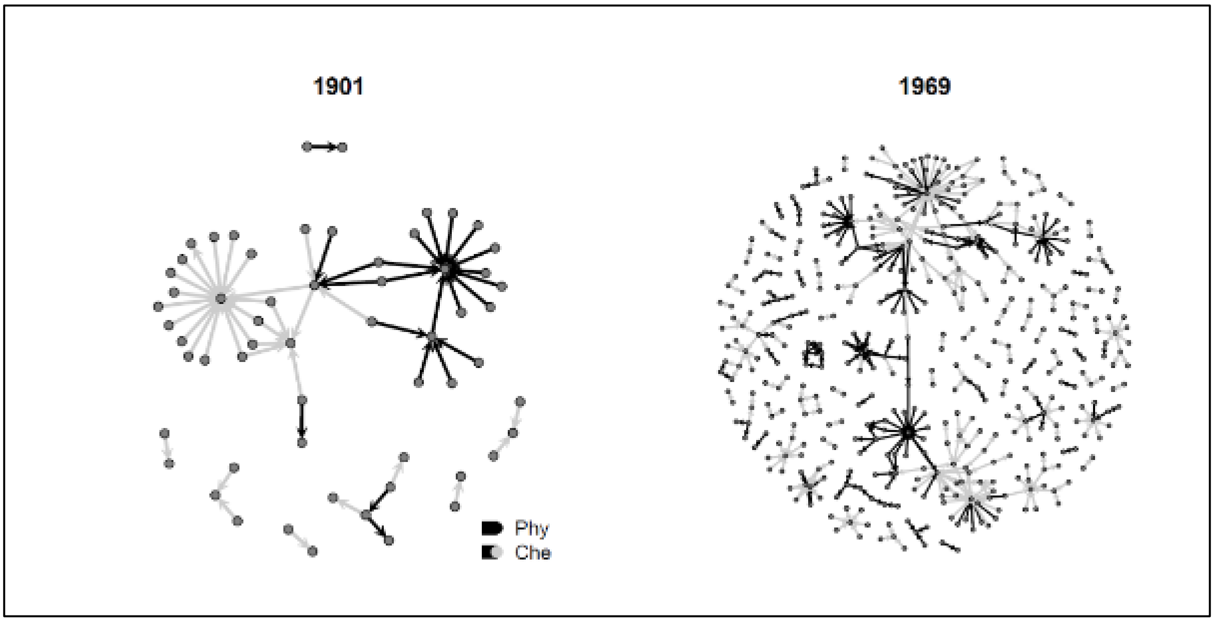
The disparity between the two lines presents intriguing findings: In years with a narrow margin, like 1923 (a year when there were only 44 nominations in general), there is no indication of a dominant agreement among nominators regarding a particular group of nominees (although there could be agreement in terms of the number of nominations that each nominee received). To clarify, 30 nominators collectively proposed 26 nominees.

During years with a wider gap between the two lines, the nominees chosen by the nominators were more consistent. For instance, in 1954, 114 nominators selected 62 nominees, resulting in a ratio of almost 1-to-2. This ratio remains steady for the remainder of the observation period, indicating that the nominees are genuinely selective and aligned with the nominators' typical choices. However, the nominations are widely dispersed, resulting in numerous candidates presented for selection. A common view of a large pool of candidates is that there is a lack of consensus among nominators (Seeman & Restrepo, 2023b), potentially hindering the selection process. But from the perspective of Swedish awarding bodies, this may not be accurate as the selection committees rely on numerous qualified candidates to choose a recipient from.

The nomination network also reflects this strong overall growth. Figure 2 illustrates the increase in individual actors within the network over time, demonstrated through a comparison of the years 1901 and 1969 as the first and last years of observation, respectively. Nodes represent actors within the network, functioning as nominators and/or nominees. Edges between them represent nominations directed towards the nominee. Nominations in the category of Physics are colored black, in Chemistry light gray.

Upon initial examination, it becomes apparent that the network has experienced significant growth. In 1901, the network consisted of 59 individuals, including a large cluster and various dyads or smaller groups of up to five actors. In 1969, a cohort of 455 individuals were involved in the nomination process. They also congregate in a spacious gathering with several detached subgroups, revealing that the configuration of the nomination network remains largely unchanged over time, but the magnitude has increased immensely.

Figure 2: Growth of the individual nomination network categorized as Physics or Chemistry



This figure displays the growth of individual actors in the nomination network over time, comparing the years 1901 and 1969 as the first and last years of observation. Nodes represent actors who function as nominators and/or nominees within the network. Edges between them (colored black for Physics, light gray for Chemistry) represent nominations directed towards the nominee.

It is notable that in both years there is one great cluster of actors, despite the data comprising the distinct disciplines Physics and Chemistry. This illustrates that individuals frequently nominate across multiple disciplines. For instance, nominators are invited to vote for both categories (including the node that links the two outposts of the main cluster in Figure 2), or nominees receive votes for both award categories. Those who operate across disciplines are often situated at the core of the network, and even though they operate at the margins of their respective fields, they are widely observable and possess considerable centrality in the network, highlighting the worth of an aggregate analysis for Physics and Chemistry.

Figure 2 and Figure 6 depict the same networks (1901 and 1969), highlighting the advantages of examining it from varying viewpoints. It is relevant to analyze the composition of individuals, including their RSAS affiliation, and the changes in scale over time. More details on this are given in the following chapter.

As explained in section 2.1, the Nobel Prize stems from an era when science was regarded as a catalyst for societal progress, and scientists were seen as inventors, innovating and uncovering knowledge for the betterment of humankind. This picture served as the initial inspiration for Alfred Nobel. During the time when the Nobel Prizes were established, this ideal began to show signs of weakness as both scientists and society at large began to question the impact and implications of their inventions. One notable example is the involvement of US scientists in the nuclear bombing of Hiroshima and Nagasaki. This occurrence affected not only the ethical principles of scientists, but also their esteem. There are conjectures that Robert Oppenheimer was (among other reasons) not granted the Nobel Prize due to his leading role within the Manhattan Project and his nickname that leaked into society: “father of the bomb” (Steeves, 2021). Oppenheimer received four Physics nominations between 1946 and 1967 (his death year).

This is just one example of societal changes that have occurred during almost 70 years of observation. The scientific landscapes of 1901 and 1969 exhibit notable distinctions, which also influenced the committees in charge of organizing Nobel Prize nominations in their decisions. These changes include important metrics of hegemonic power, such as gender disparities, organizational control exercised by RSAS members, and scientific leadership at the country level. I will provide a descriptive account of these elements, elucidating on the distribution of nomination power.

7.1 Nomination power of the Nobel Nominators

A substantial inquiry into Nobel Prize nominations concerns the nominators, who are the driving force behind the initial selection process. Nominators are either holders of permanent nomination rights (see Table 1 for a detailed overview) or are selected annually by the Nobel committees on the basis of their expertise in relevant fields, so that nominations cover a wide range of eligible candidates. Although the committees do not decide directly who is nominated for the prize, they do decide who is qualified to vote, and they select the winner from all candidates. Therefore, being a nominator is in itself associated with recognition and a pre-selection for potential prize recipients.

To ensure that committees obtain the best possible candidates, they distribute nomination rights throughout the international scientific community. Due to accusations that the Nobel Prize awards a disproportionately high number of male European and North American scientists (see chapter 3), neglecting women and scientists from peripheral regions, committees have come under pressure to improve their election process and to ensure sufficient diversity within their structures. Usually, these accusations focus on nominees or award decisions, but they rarely consider the nominators, who play a crucial role in presenting candidates.

The Nobel Foundation notes that scientists from several hundred organizations are invited each year, but provides no precise figures. Thus, initially, it should be noted that the population of invited nominators remains unknown. From 1901 to 1969, only the identities of those who submitted a nomination are available, but information is lacking on those who may have received an invitation but did not vote. This inconsistency can be elucidated by examining the laureates who, after receiving the prize, have been granted permanent nomination rights. Charles Glover Barkla received the Nobel Prize in Physics in 1918. This gave him the right to nominate for the Nobel Prizes in Chemistry and Physics for another 26 years until his death. However, he never made a nomination. While only a small number of laureates refrain from utilizing their voting privilege completely, many laureates do not exercise their right every year, indicating a moderate use to a certain degree.

Especially in assessing the variety of convened nominators, it is important to consider this blind spot in the data. Without details about the invitations sent, analysis can only rely on performing nominators. However, it is critical to note that this information could be valuable in precisely evaluating the use or withholding of nomination rights (and the reasons for doing so).

Thus, to assess how the Nobel Prize organization addresses diversity concerns, it is necessary to consider the possibility of an unknown number of unrecordable nominators. It is assumed that groups of individuals who are statistically underrepresented, such as those from countries outside the global scientific center, are more likely to utilize their right to nominate if it is offered to them, but this is a conjecture that cannot be confirmed by data.

Furthermore, it is worth noting that the call for more diverse selection processes, specifically regarding gender representation, did not arise until the late 20th century. As such, my period of observation cannot reflect this development. However, the development leading up to the 1970s demonstrates an expansion of the selection processes to involve larger groups of actors, as summarized in Figure 1 and Figure 2. This development will be thoroughly examined in this chapter.

The Nobel Prizes in science may perpetuate gender and racial inequalities by creating the unfounded impression that esteemed scientists are only old, white men in lab coats. Notably, junior researchers who emphasize the disadvantaged position of graduate students in attributing their contribution to discoveries, compared to esteemed tenured staff, strongly support this perspective. This position, which reflects a common concern, especially among the younger scientific community, is prominently featured in an online article by *Massive Science* (Mehta, 2017).

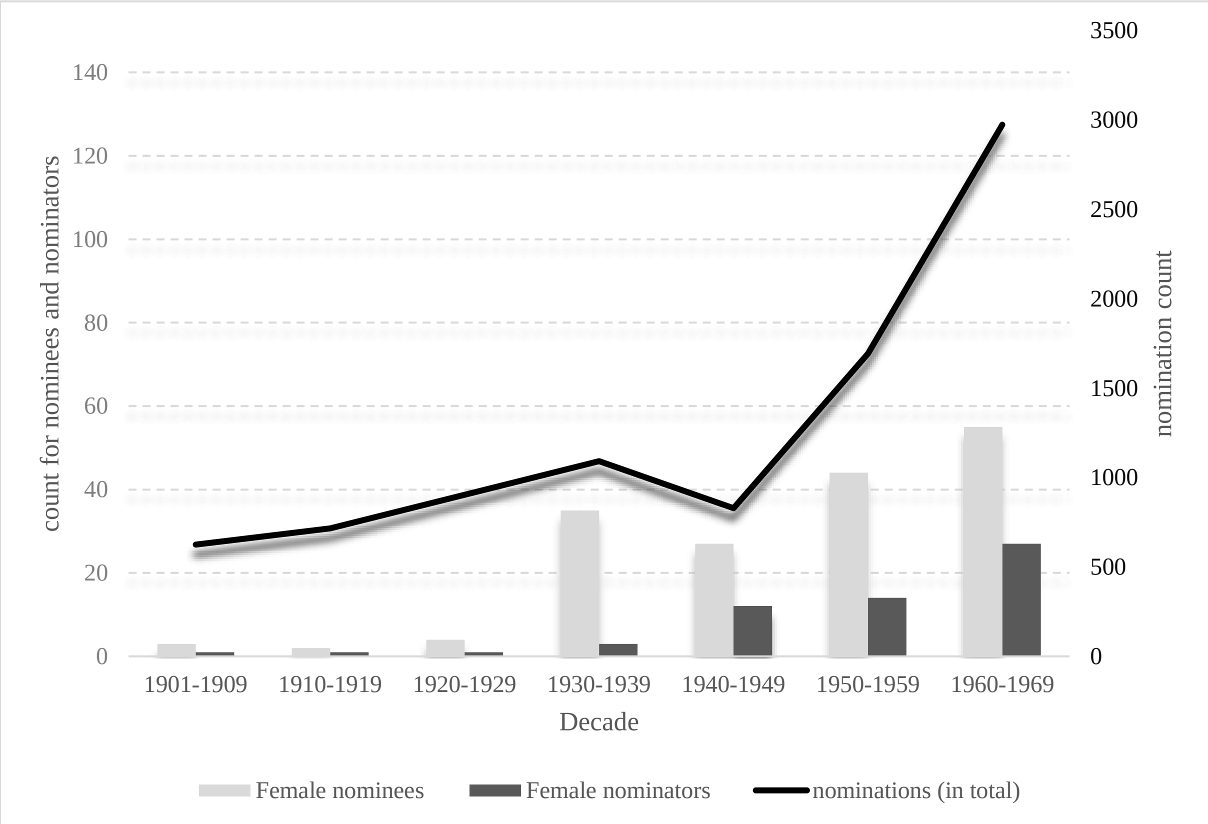
As mentioned earlier, studies have criticized the nomination process for its prevalent selection of middle-aged European/US American male candidates. The Nobel Foundation explicitly states its commitment to diversifying the pool of candidates and increasing representation for women and ethnic minorities among its laureates (Gibney, 2019). However, these critiques and pledges to improve tend to concentrate on the nominees' side. The gender bias against female nominees and laureates is a topic of widespread discussion (Charyton et al., 2011; Mahmoudi et al., 2019; Modgil et al., 2018), as it reflects other biases towards women in general academia (for example, Meho, 2021; Vasarhelyi et al., 2021), and especially within scientific fields such as chemistry (Tripathi & Goshisht, 2022).

Of the 168 NP laureates awarded in both categories up to 1969, only five were women, comprising approximately 0.3 percent of all laureates. The proportion of women nominees, on the other hand, is nearly two percent for the entire period, based on all 8832 nominations, which is the highest representation of women within the nomination process and its respective roles of nominators, nominees, and laureates. However, 49 of the 170 nominations go to Lise Meitner alone, who is one of the most nominated scientists in the data set (Top 1%). Together with Maria Goeppert-Mayer and Dorothy Crowfoot Hodgkin who both received a prize after 32 and 27 nominations, these three women alone account for more than half of the votes going to women scientists. Observed on the grounds of individual nominees, 18 out of 1094 nominated scientists were female, comprising about 1.6 percent of the nominated population.

Of the 474 well-connected scientists who serve as both nominators and nominees, only six are women: NP laureates Marie Curie, Irène Joliot-Curie, Dorothy Crowfoot Hodgkin, Maria Goeppert-Mayer, as well as French scientist from University of Strasbourg Marguerite Perey, and Erika Cremer, one of the first female chairholders of Innsbruck University in Austria.

Female nominators comprise about 0.8 percent of the dataset (47 out of 5952 nominators). Marie Curie and her namesake, Marie Reimer of Columbia University, were the first female nominators and the only two in the first three decades of nominations, Curie having nominated in two decades. There were two other female nominators in the 1930s, Curie's daughter Irène and Anna Chrzaszczewska of the Free Polish University. It appears that the nomination field opened up to more women during the 1950s. In sum, women have nominated 12 times in the 1940s with a clear upward trend for the next two decades.

Figure 3: Representation of women as nominators and nominees over decades



This figure displays the representation of women across the roles of nominees (light gray bars) and nominators (dark gray bars) over decades within my observation period 1901-1969. Counts are displayed on the left (primary) Y-axis. For comparison, overall nomination numbers are plotted as a black line, and the corresponding counts can be derived from the right (secondary) Y-axis.

Figure 3 displays the representation of women among nominators, in comparison to the nominees' development and the overall expansion of nominations aggregated by decades for improved readability. As anticipated from historical drifts, there is a clear upward trend in both columns due to processes of progressive emancipation. This trend highlights the selection process of nominees by nominators. In light of historical events, the proportion of women among nominees experienced a dip in the 1940s that might be a result of World War II, followed by gradual growth, as it follows the dip in general nomination numbers.

It should be noted that, despite the overall growth in nominations, women's share of these nominations, particularly among nominators, only experienced a relatively small increase. Women began representing 0.23 percent of nominators and remained at that level until the 1940s, when they rose to about 1.5 percent. Although the number of female nominators has increased, they still only represent about 0.8 percent (1950s) and 1 percent (1960s) of all nominations submitted. Despite a clear upward trend in women's participation in absolute numbers, the share of women as nominators only marginally increases within the observation period. However, this marginal increase does not display the overall share of women worldwide in academia, which was much higher, spanning from one percent in 1900 to 11 percent in 1969 (Iaria et al., 2022, last edited 2024).

Specifically, the rise in numbers is higher for nominees than for nominators. This suggests that there were capable female scientists, as they were nominated for the Nobel Prize, but they were less likely given the opportunity to serve as an expert and nominate others.

During the early nomination period, women faced significant challenges in obtaining nomination rights. This may have contributed to their underrepresentation as nominators and, in turn, as nominees. Obtaining permanent nomination rights for Nobel Prizes was more difficult for women than for men. Female professors were scarce during the first half of the 20th century, and the percentage of women holding professorships in Sweden consistently stayed below five percent until 1970 (Iaria et al., 2022, last edited 2024). This lack of representation among professorships in northern countries demonstrates that women did not have much nomination power through this opportunity. To confirm this case, there is only one nominating female professor of a northern country in my dataset, Salli Eskola.

There were very few female NP laureates and no women members of the RSAS during my observation period, with the exceptions of Marie Curie (RSAS member since 1910) and Lise Meitner (1945). As a result, permanent nomination rights were primarily exercised by men. NP laureates, including the Curies, Goeppert-Mayer, Crowfoot Hodgkin, and Gerty Cori, served solely as nominators following receipt of their awards and their permanent nomination rights, highlighting the limited opportunities for women in the domain of nominators.

Women during my observation period had to rely on annually distributed rights to attain invitations for nominating. However, these invitations are typically only given to chairholders, making them equally challenging for women to obtain. Distinguished female scientists were frequently denied regular staff positions at universities, such as Gerty Cori, who did not receive her professorship until late in her career, following her NP in Medicine in 1947.

Female nominators who successfully surpassed this obstacle include Pauline Ramart, née Lucas, who became the second woman after Curie to hold a chair at the University of Paris. She nominated five times between 1940 and 1950 and passed away shortly afterward. Ramart is one of the few examples of women who received an invitation to nominate by acquiring a university chair outside of the northern countries. Additionally, there is one woman who obtained a professorship within a northern country and, as a result, was eligible to nominate. Salli Eskola served as an associate professor at the University of Helsinki for multiple years, being Finland’s first female professor of chemistry. During my observation period in the 1950s and 1960s, she submitted five nominations.

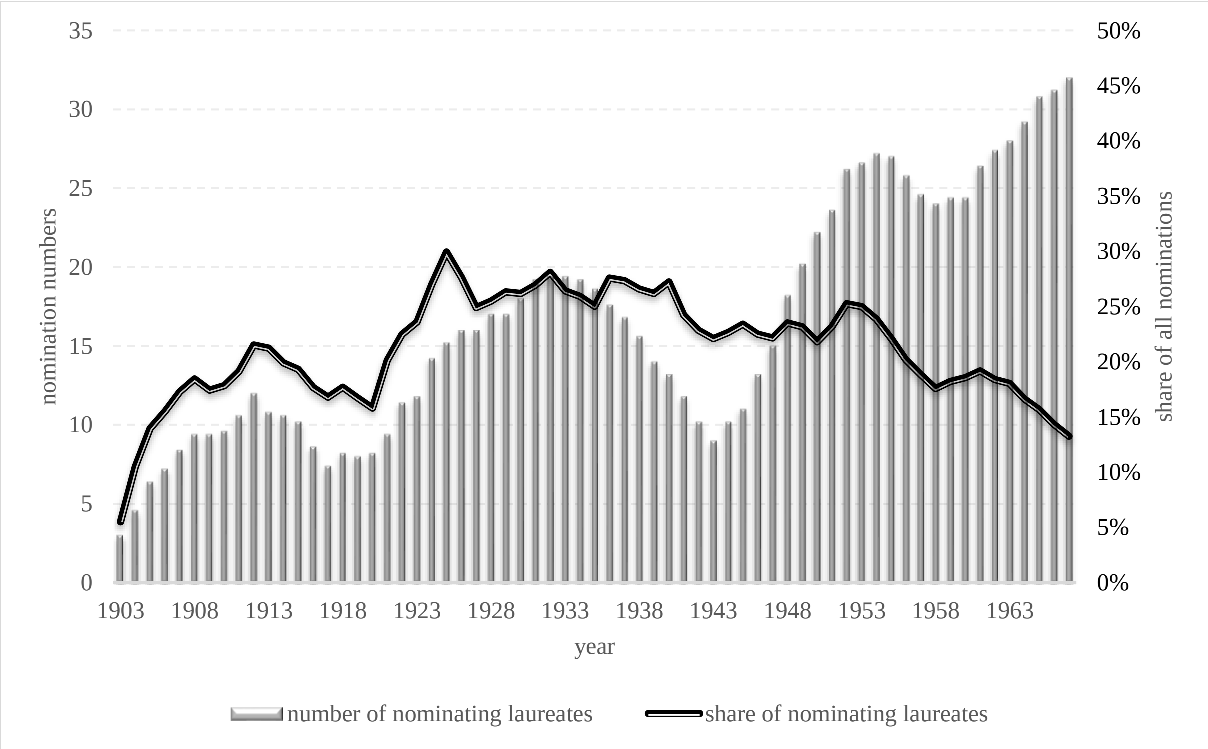
As shown in Figure 3, the proportion of female nominators has increased, albeit at a slow pace. This finding holds significance considering efforts to increase the number of female nominees and ultimately, female laureates. It is noteworthy that Gallotti and De Domenico (2019) discovered gender homophily in all five Nobel Prize categories, indicating that men tend to nominate other men while women tend to nominate other women. Prior to 1969, nomination rights served as an obstacle and hindered female scientists from participating in the nomination process as voter-givers. An increase in female nominators could potentially increase the representation of women as nominees. However, in the fields of Chemistry and Physics, only one nomination exists between two women, suggesting that the phenomenon of gender homophily observed by Gallotti and De Domenico may vary between sexes and across time or different academic disciplines. In 1950, Pauline Ramart nominated her fellow French scientists Thérèse Tréfouël and Jacques Tréfouël. It is worth mentioning that Ramart had previously nominated Jacques Tréfouël three times without his wife, and only included Thérèse in her final nomination.

In relation to hypothesis H1a, there is evidence of particularistic bias in the selection of nominators, resulting in the omission of female scientists as nominators. Despite the underrepresentation of women in academia overall within the observation period, female representation among nominators is substantially lower. This disadvantage may compound, assuming gender homophily in general nomination patterns, resulting in less representation of women in nominee and laureate statistics.

It will be informative to observe how the situation unfolds in subsequent years with the increasing number of female professors and their obtainment of permanent rights by way of laureate recognition, chairholding within a northern country or RSAS membership. These groups represent privileged and exclusive nominators who are authorized to nominate annually after obtaining their status. Of the 2699 nominators, 60 percent voted just once during the observation period. A further 20 percent voted twice, while the remaining 20 percent of nominating scientists delivered over half of all nominations. This demonstrates a heavily skewed distribution on the individual level, with a Gini coefficient of approximately 0.45. Nominations submitted by nominators who have previously nominated at least 10 times are more likely to come from a laureate (76%) and/or a member of the RSAS (55%).

In this context, it is crucial to examine the nomination patterns of individuals who are members of the RSAS and/or laureates, given their increased likelihood of multiple nominations during their lifetime. Considering that it is of secondary interest whether nominators submitted only one or several candidates in their nomination in a given year, I will argue with the reduced dataset of 5952 nominations as described in chapter 6 (pages 35-36).

Figure 4: Laureates as nominators in numbers and proportions (5-period moving average)

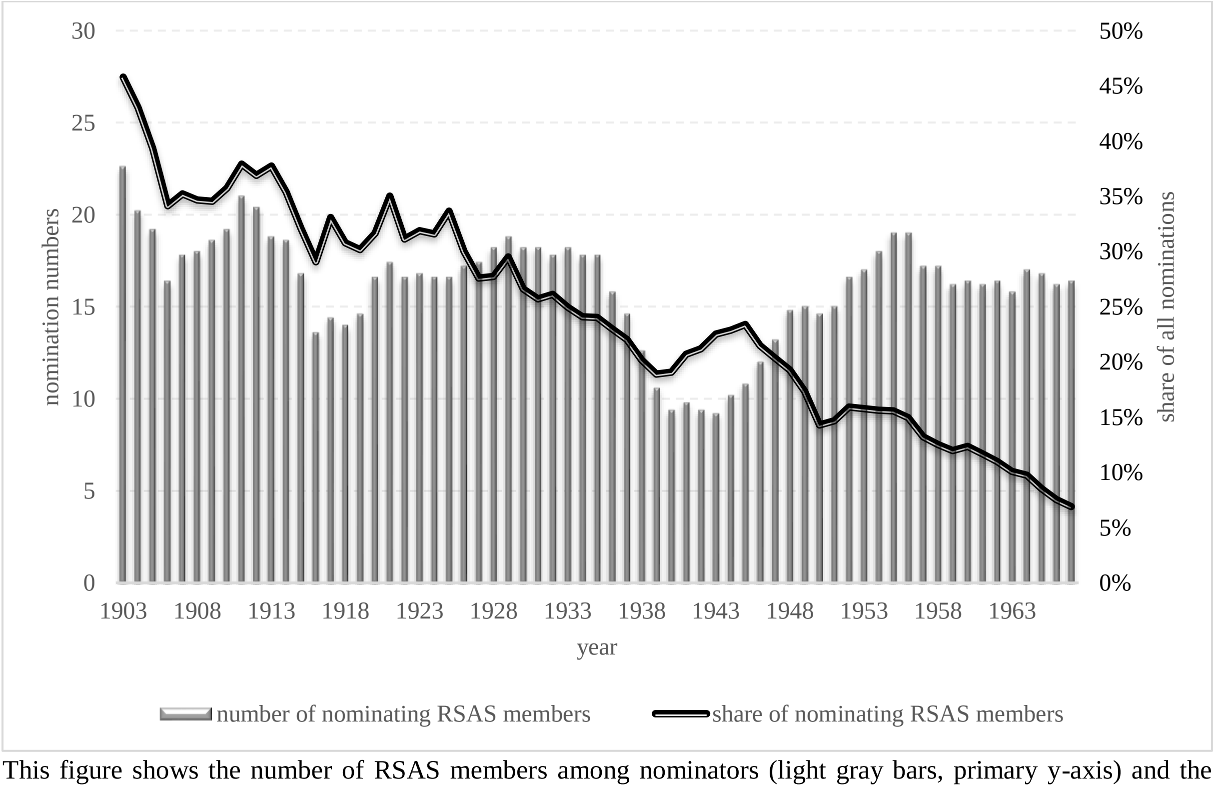


This figure shows the number of laureates among nominators (light gray bars, primary y-axis) and the percentage of laureates among nominators (black line, secondary y-axis) over time. Numbers and shares are presented as 5-period moving averages.

Figure 4 shows the annual count of nominating laureates, presented in a bar graph format. A trend towards growth is apparent, in addition to historical fluctuations due to events such as World War I and II. Notably in the 1960s, a substantial number of laureates were among the nominators, averaging 30 annually. These figures indicate that laureates comprise a substantial and increasingly critical group of nominators with growing numbers. However, the proportion of nominating laureates, shown as a black line, suggests that their numbers are not increasing as much as the overall increase in nominators. In order to smooth out historical fluctuations, a 5-period moving average was used to calculate the share of laureates among all nominators for the respective period, as the main focus here is on the overall development, and not on fluctuations between years. It is notable that the pinnacle of nominating laureates, accounting for a share of about 20 to 30 percent of all nominations, occurred in roughly equal measure from the 1920s to the early 1950s. Afterwards, the percentage declined to slightly over 10 percent for the first time since the initial years of nomination. This decrease suggests that the nomination process broadened to include a more diverse group of nominators, particularly in the late 1960s.

A similar trend is apparent when examining the number of nominating RSAS members. Figure 5, like Figure 4, displays the annual number of nominating members in bar graph form. This contrasts with the continually increasing numbers of laureates, as the number of nominating members remains relatively stable over time: a reasonable finding, since the number of laureates as a whole began to increase only at the beginning of the 20th century, while the RSAS, as an already established organization, has a certain quota of current members. The trend line in black portrays a notable decrease in the ratio of nominating members over time, calculated similar to the depiction of laureates with a 5-period moving average. The RSAS, as the leading Nobel Prize organization, has an advantageous position, with over 50% of all nominators accounted for in 1901, an exceptional feat for a relatively small group. This highlights the significance of examining such associations, particularly during the initial decades when RSAS was a driving force of the nomination process at multiple levels.

Figure 5: RSAS members as nominators in numbers and proportions (5-period moving average)

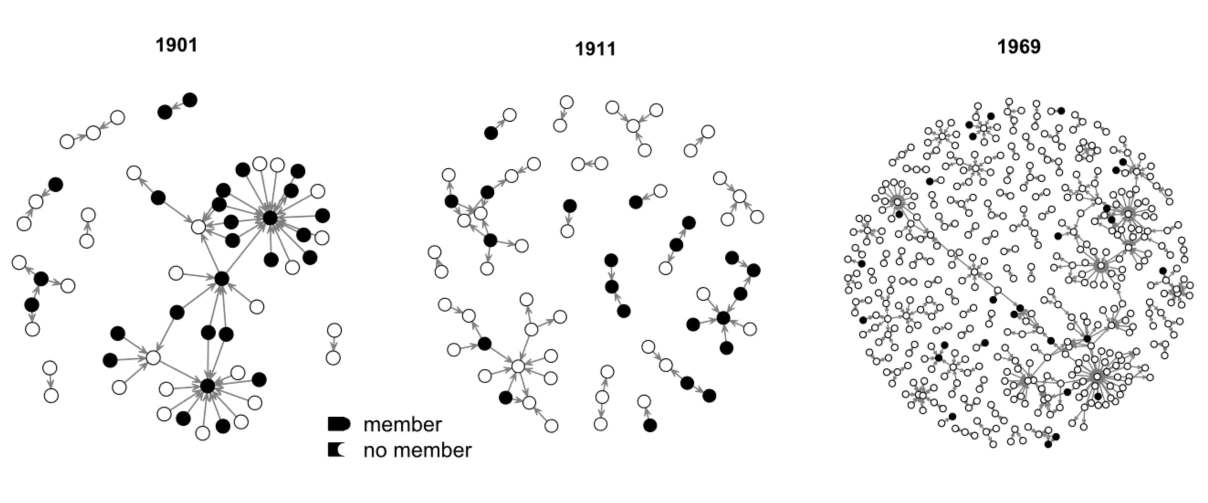


This figure shows the number of RSAS members among nominators (light gray bars, primary y-axis) and the percentage of RSAS members among nominators (black line, secondary y-axis) over time. Numbers and shares are presented as 5-period moving averages.

Over time, the nomination process has become more inclusive, with a greater variety of nominators involved in the selection process. This trend is particularly evident in recent years. In 1968, less than 5 percent of RSAS nominators were identified, and the following year only saw a slight increase.

A comparison of the years 1901, 1911 and 1969 is shown in Figure 6, which depicts the nomination network based on RSAS membership. This comparison demonstrates that the process has become more inclusive over time, and that the nomination power of RSAS members has decreased as a group.

Figure 6: Growth of the individual nomination network exemplified by RSAS membership

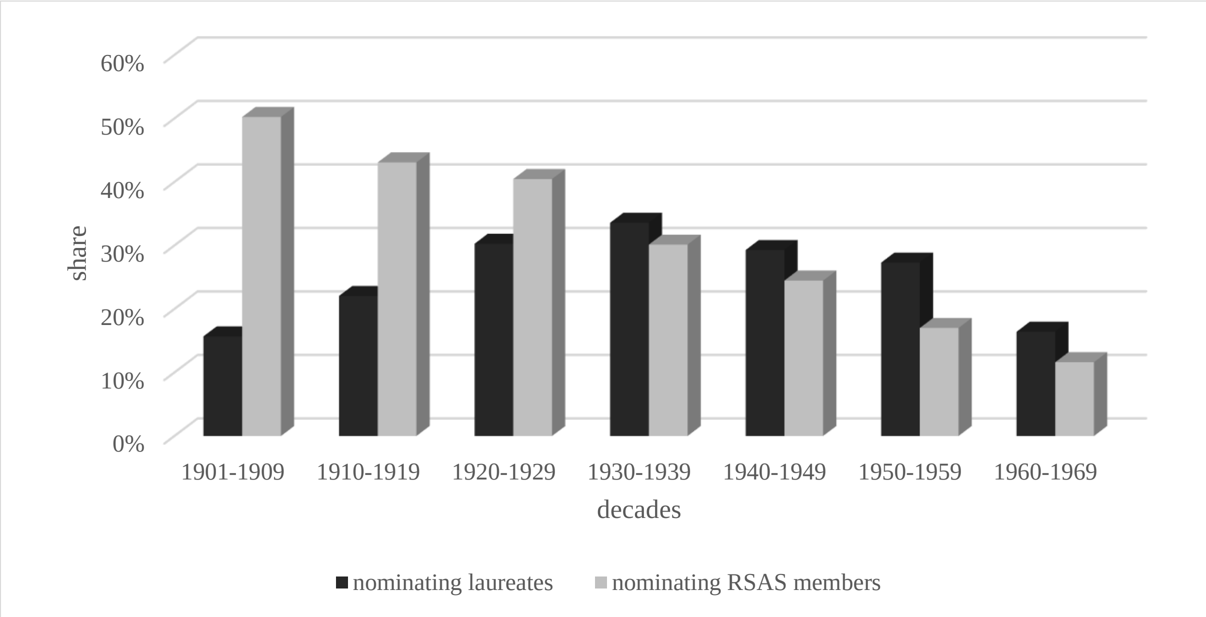


This figure illustrates the individual nomination network comparing the years 1901, 1911 and 1969. Nodes represent actors who function as nominators and/or nominees within the network. Black nodes represent RSAS members, while white nodes are non-members. Edges between the nodes represent nominations directed towards the nominee.

Figure 7 shows the percentage of nominating laureates and RSAS members in relation to all nominators in the field of Physics, while Figure 8 illustrates the same for Chemistry. Both disciplines exhibit a similar trend, supporting the decision to analyze them together. However, there is a slight difference in the share of laureates in the later decades. In Physics, the significance of laureates decreases over time, while in Chemistry, the proportion of laureates within the discipline follows more of a wave pattern, fluctuating slightly above and below a share of 20 percent without any notable decline. For RSAS members, there is a gradual decline in the proportion among nominators in both categories.

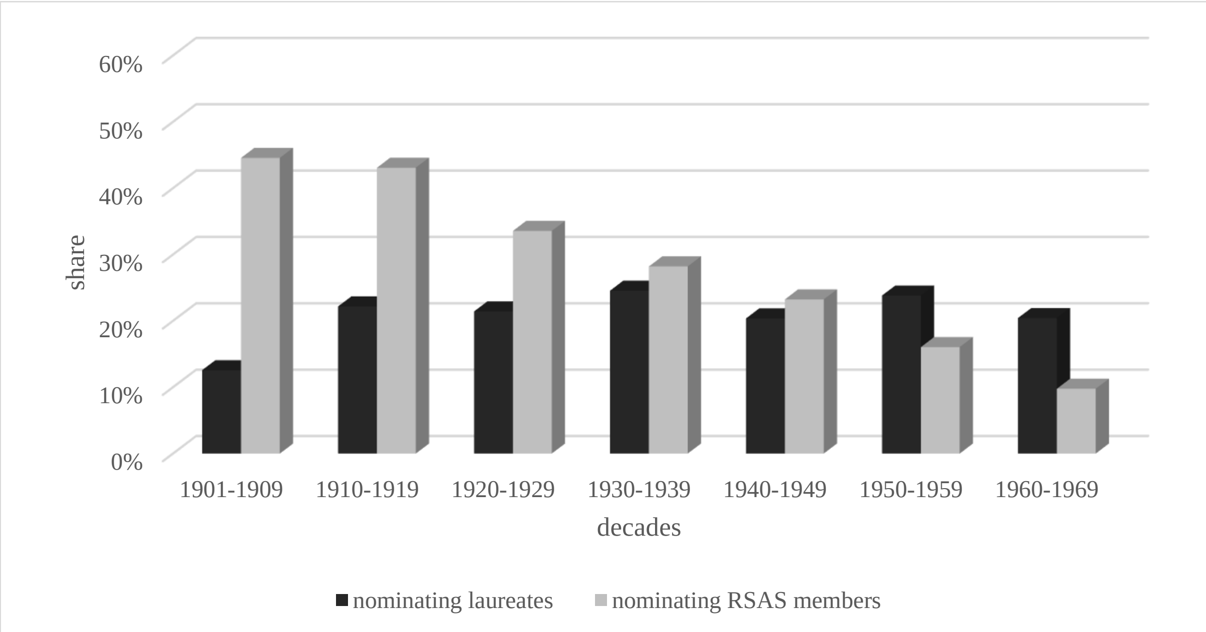
Figure 18 displays additional findings regarding the decline in RSAS members' domination of nominators. The self-nomination proportion among RSAS members, although fluctuating to a considerable extent, tends to shrink over time, as shown by the trend line. Over time, RSAS members have less control in selecting themselves as nominators, voting for other RSAS members as nominees, and ultimately choosing those members as laureates.

Figure 7: Proportion of nominating laureates and RSAS members in Physics (per decade)



This figure displays the proportion of two groups of nominators with special annual nomination rights for the nomination category of Physics per decade between the observation period 1901-1969. Laureates are depicted in black bars, RSAS members in light gray bars. Shares are displayed on the Y-axis.

Figure 8: Proportion of nominating laureates and RSAS members in Chemistry (per decade)



This figure displays the proportion of two groups of nominators with special annual nomination rights for the nomination category of Chemistry per decade between the observation period 1901-1969. Laureates are depicted in black bars, RSAS members in light gray bars. Shares are displayed on the Y-axis.

Regarding hypothesis H1b, this means that, predominantly within the first decades of nomination, RSAS members are a highly privileged group within the procedure, which extends its power over the entire process. However, this power is diminishing. A trend is noticeable, as the majority of nominators are becoming more distant from the executive institutions of the Nobel Prize. Consequently, the particularistic favoritism towards a small group with organizational control is diminishing, as new nominators without such affiliations enter the selection process.

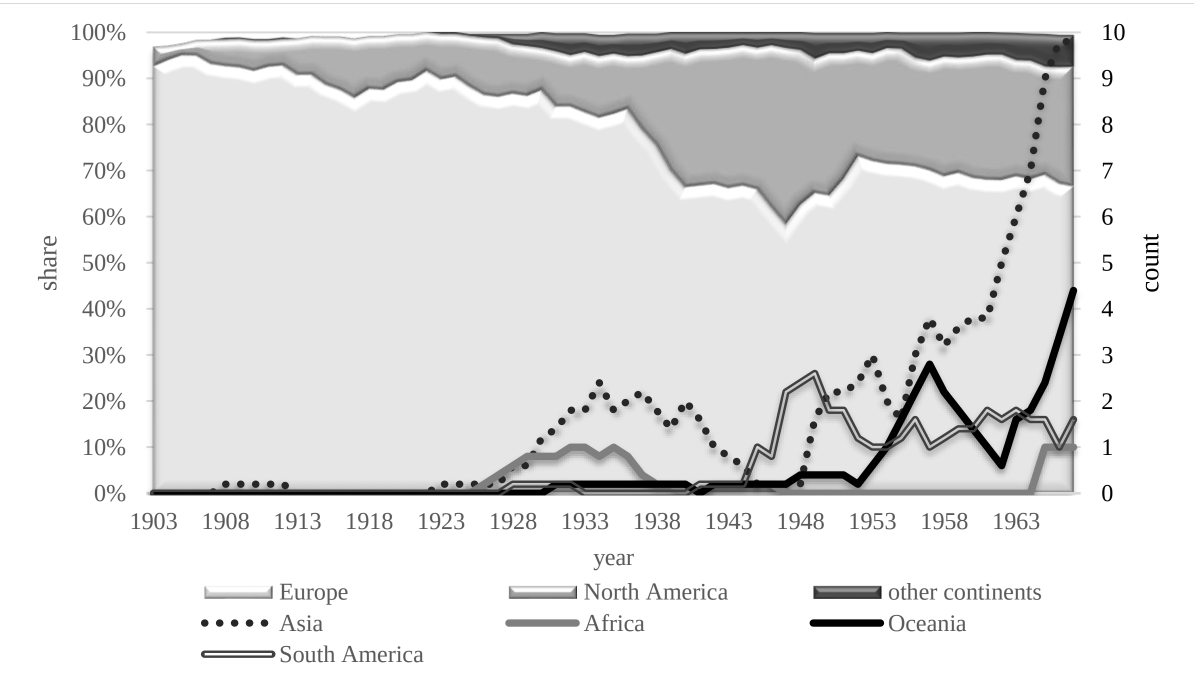
This may reflect the general increase in publicity surrounding the Nobel Prize. In the early years, it is reported that committee members encouraged RSAS colleagues to make nominations due to the limited number of nominators available (Friedman, 2001). However, in the later observation periods, there are significantly more individuals invited to make nominations. Furthermore, separating nominators from Swedish awarding bodies could enhance the reputation of the Nobel Prize. Decoupling actors involved in the election process within committees from candidate selection could make it less susceptible to scrutiny, as suggested by Friedman. He pointed out that individuals with significant influence in the committees are able to dictate the award decision, which would render the entire nomination process a farce. What contributes to this phenomenon is the composition of RSAS members according to their national affiliation. Sweden has the highest share of nominating members, as expected, with almost 30 percent. When combined with the next highest national affiliation, Germany, they collectively provide nearly 50 percent of RSAS members. In contrast, the United States only has a 10 percent share in nominating RSAS members.

Before proceeding with the analysis of the next hypotheses, I briefly summarize the results for hypotheses H1a and H1b from this chapter. Hypothesis H1a is supported by clear evidence of a particularistic bias in nominator selection, which leads to the underrepresentation of female scientists as nominators. Despite the overall underrepresentation of women in academia during the observed period, their presence among nominators is substantially lower, confirming hypothesis H1a. Assuming a general pattern of gender homophily in nominations, this disparity may amplify the gender imbalance in the distribution of nominees and laureates.

Concerning hypothesis H1b, the early decades of nominations demonstrate the considerable privilege enjoyed by members of the Royal Swedish Academy of Sciences (RSAS) in the nomination process, exerting considerable influence over it. However, this influence is decreasing over time. There is a noticeable trend indicating that an increasing number of nominators are becoming more distant from the executive bodies of the Nobel Prize. As a result, the particularistic favoritism towards a select group with organizational control is decreasing, as new nominators without such affiliations enter the selection process. Hypothesis H1b is therefore confirmed, though the decreasing trend shows that over time particularistic selection is diminishing regarding RSAS membership.

Next, I will assess hypothesis H2a, which states that the global center of nomination power shifted from Germany to the United States in the first half of the 20th century. The distribution of nominators across different levels of affiliation shows a progressive expansion. At the continental level, there is a clear preference for European (75%) and North American (21%) nominators over the observation period, which aligns with previous discussions on the background of nominees. Scientists originating from other continents represent just four percent of all nominators during the entire period. Asia (represented primarily by Japan, Israel, and India) first provided a nominator in 1910, Africa (represented primarily by Tunisia and Egypt) in 1928, South America (Argentina) in 1930, and Oceania (Australia) in 1933. Europe, however, has been dominant in nominating recipients with an average proportion of 90 percent in the first nomination decade and an average of 67 percent in the most recent decade.

Figure 9: Percentage of nominators by continent, with more detailed absolute numbers for "other continents" (5-period moving average)



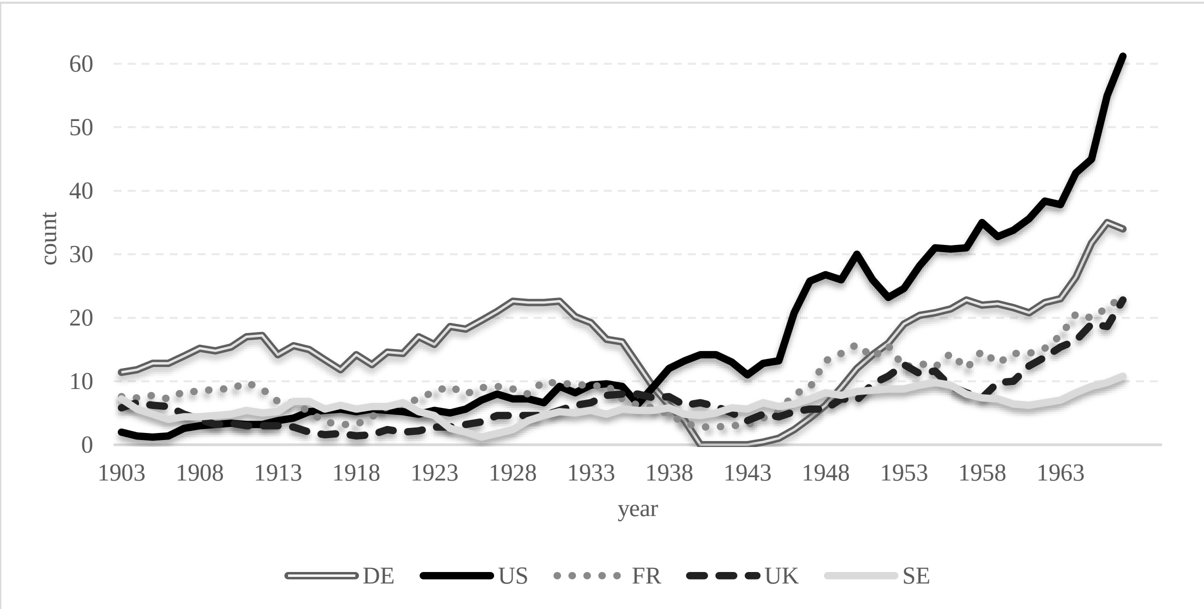
This figure displays the distribution of countries that submit nominators for the observation period 1901-1969. On the primary Y-axis, the shares of nominators between Europe (light gray space), North America (darker gray space) and other continents as residual category (black space) are shown. The nomination numbers of Asia (dotted black line), Afrika (gray line), Oceania (black line), and South America (white line with black frame) are shown on the secondary Y-axis. Both measures are presented in 5-period moving averages.

Nevertheless, there is evidence of increasing representation of other continents over time, both in absolute numbers and as a proportion, particularly in the 1960s, when the average was nearly 6 percent. Figure 9 shows a summary of this comparison. After all, the number of nominators per continent is quite uneven. Africa is the continent with the least representation, whereas Asia shows the third-highest number of nominators and a noticeable upward trend. Regarding the two disciplines, the distribution aligns in most aspects, but Chemistry displays greater openness towards nominators from South America (35 nominators in Chemistry, 5 in Physics) and Oceania (35 nominators in Chemistry, 9 in Physics).

It will be intriguing to see to what degree this process will solidify in the next decades, once available. The push for more varied nominees and awardees necessitates diversifying the field of nominators according to their continental as well as national affiliation.

The distribution of nominators is unevenly spread across countries, similarly to continents at a global level. Figures in the appendix provide an overview of the countries that submit the most nominators (Figure 32) and a visualization based on current national borders for data from the first (Figure 33) and last (Figure 34) nomination decades as a direct comparison. These distributions emphasize the dominance of Germany and the United States as global hegemonial actors.

Figure 10: 5-period moving average of leading countries for submission of nominators



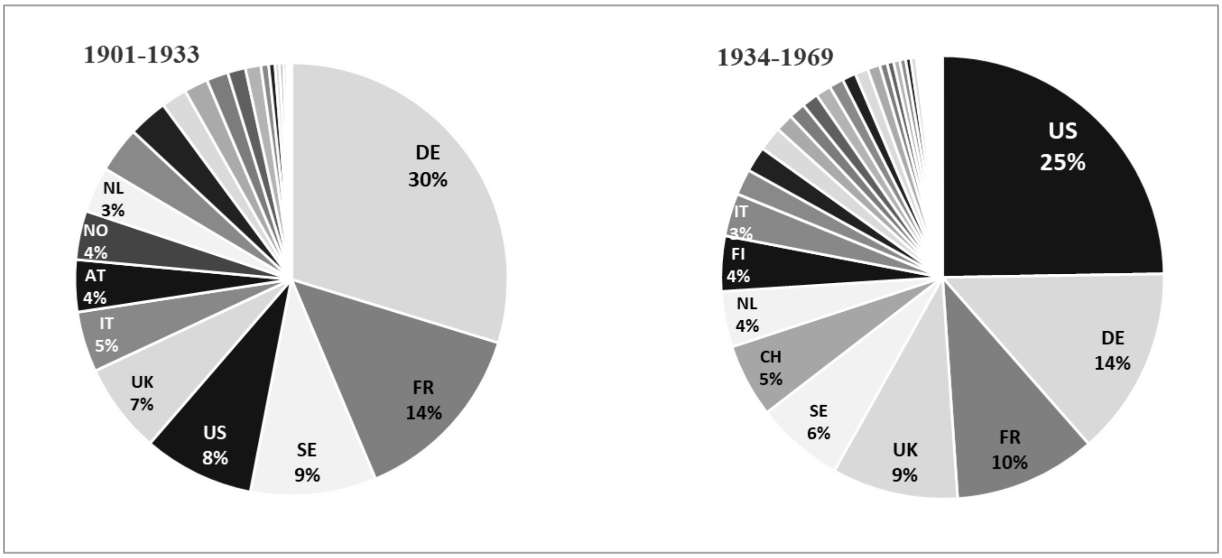
This figure displays the number of nominators from top nominating countries for the observation period 1901-1969. Counts are presented in 5-period moving averages for Germany (DE, white line with black frame), United States (US, black line), France (FR, gray dotted line), the UK (black dashed line), and Sweden (SE, gray line).

Descriptive findings for the most important countries in terms of submitting nominators have already been presented by Gallotti and De Domenico (2019). The thorough data collection presented in my study reinforces and extends the findings of Gallotti and De Domenico, because it relies on nominators' current workplaces at the time of nomination and on temporal national boundaries. Figure 10 illustrates a 5-period moving average for the number of nominators from countries in the lead, which include France, Germany, Sweden, the United Kingdom, and the United States. Collectively, they comprise 65 percent of all nominations, with Germany and the United States accounting for 40 percent on their own.

It is evident from the time series that Germany initially led in the number of nominators, submitting the highest fraction of nominators, with a small incline at the time of WW I. In the 1930s, German nominators declined heavily, dropping to zero near World War II, while US nominators increased and established themselves as the new leading nation. Gallotti and De Domenico interpret the decline of German nominators to zero as an active exclusion from the nominators' pool. It is uncertain, though, whether committees chose not to grant annual rights to German scientists (disregarding possible inhabitants of permanent nomination rights in Germany such as laureates and/or RSAS members), or if scientists stationed in Germany voluntarily excluded themselves after Adolf Hitler's explicit boycott of the Nobel Prize starting in 1937. Hitler sought to create a German National Prize for Art and Science to rival the Nobel Prize and even barred laureates from receiving Nobel Prizes. This may have impacted possible nominators. Moreover, numerous scientists were forced to migrate from Germany, resulting in a decrease in the pool of eligible nominators still residing in Germany (Waldinger, 2012; Waldinger, 2016). However, since there are no records of the invitations sent out by the committees, there is no definitive answer to this specific question.

Figure 11 demonstrates that German and US American scientific leadership alternated, with Germany leading the distribution of submitting nominators during the first half of the observation period (1901-1933) and the United States clearly taking the lead in the second half (1934-1969). This division of the observation period into two almost equal halves closely aligns with Germany's political course, which after 1933 forced many scientists to flee the country due to discriminatory laws such as the Law for the Restoration of the Professional Civil Service (Waldinger, 2010).

Figure 11: Proportion of countries submitting nominators 1901-1933 and 1934-1969



This figure shows the proportion of countries that submitted nominators during two time periods: the first half of the observation period (1901-1933) and the second half (1934-1969). Countries comprising less than 3 percent of nominators are not depicted in this figure. Country indicators are included in the list in chapter 12 Abbreviations.

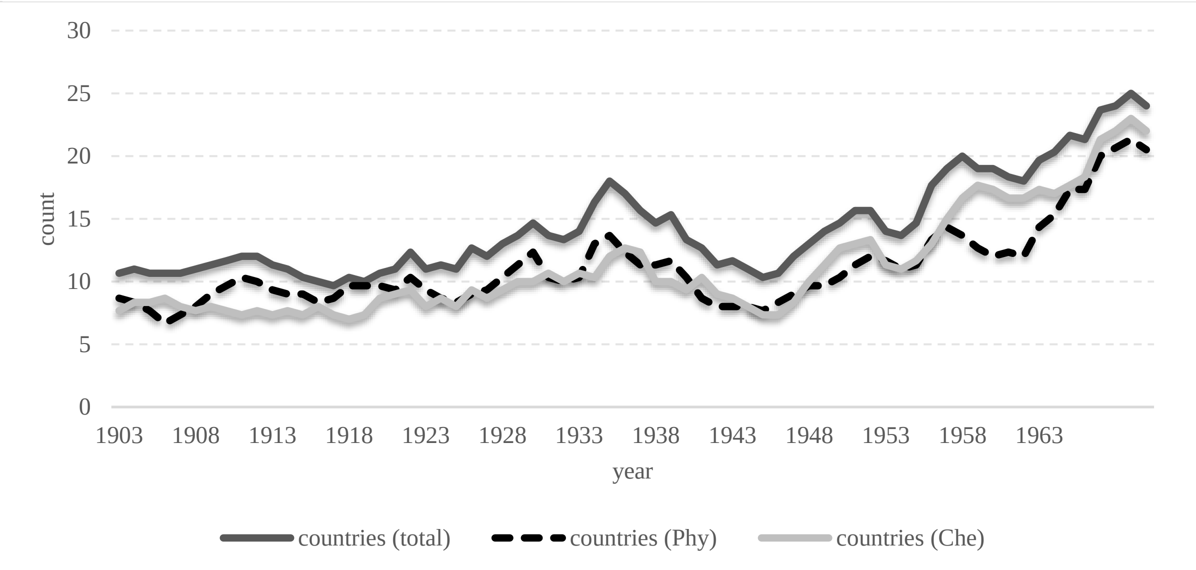
Both Figure 10 and Figure 11 reveal substantial evidence for the shift of scientific leadership within nomination power, thus, confirming hypothesis H2a that built up on the works of Ben-David (1960) and Hollingsworth (2004). The shift in nomination power occurred in the mid-1930s with a decrease in the number of nominators from Germany since the beginning of the decade. This development aligns with that of laureates (Heinze et al., 2020), confirming Ben-David's observation that although German science lacked structural components indispensable for scientific leadership since the beginning of the 20th century, its decline was a gradual process due to inertia within the science system and the international community, which was less affected by these structural deficiencies (e.g., tenure and power imbalances within universities) than German scientists. Similar to Ben-David’s argument, Swedish committees may have been slower to recognize the change in scientific leadership due to their established connections with Germany. After the post-WWII crash, Germany's number of submitted nominators began to rise again, as shown in Figure 10 and Figure 11, although they remain no match for the dominance of the United States.

Apart from the shifting power dynamic between the United States and Germany, Figure 10 shows that Sweden's nomination rates have remained relatively stable over time. France and the United Kingdom, on the other hand, have had similar, slightly increasing rates. Keeping in mind the overall growth of the nomination system since the 1960s, only the United States indicates growth nearly equal to that rate.

In relation to the broadening of the participation of the international scientific community within the nomination process, Figure 12 shows that the annual number of involved countries that submit nominators (smoothed with a 5-period moving average) increases over time, both in total and separately for the two disciplines Chemistry and Physics. This indicates progress in expanding the involvement of the international scientific community in the nomination process. Similar to other observed patterns on different dimensions, the war years, particularly WW II, resulted in a decline and concentration of only few participating countries. However, the process saw its most significant expansion during the 1950s and 1960s.

In total, more than 50 countries were involved in submitting nominators throughout the observation period, with over 20 countries participating each year in the 1960s, according to the historical expansion for each nomination year.

Figure 12: Number of countries involved in the submission of nominators (5-period moving averages)

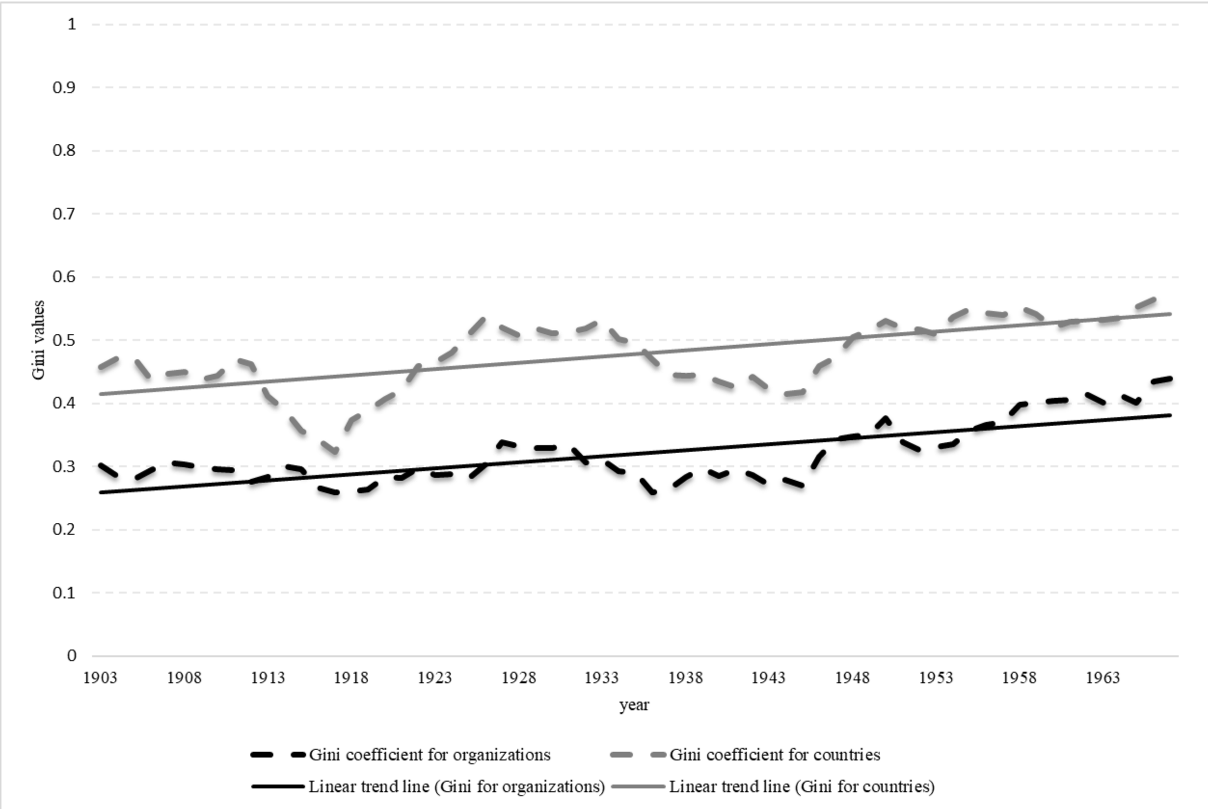


This figure shows the annual number of countries involved in the submission of nominators for the categories Physics (Phy, dashed black line) and Chemistry (Che, light gray line) separately, as well as combined (total, dark gray line). Counts were smoothed with 5-period moving averages.

To summarize hypothesis H2a, the presented data provides substantial support for the shift in scientific leadership in the area of nomination power. This validation is consistent with prior research indicating that the shift in nomination power became apparent during the mid-1930s, marked by a noticeable decline in the number of nominators from Germany since the early years of that decade. Although German science had structural inadequacies, its decline was gradual due to inertia within the science system and the international community, which were less affected by these deficiencies. With hypothesis H2a supported, I will now address hypotheses H3a and H3b.

The annually calculated Gini coefficients for countries demonstrate an immense inequality (Figure 13). Strikingly, values even increase over time, reflecting that although more countries are included within the process, the distribution of nomination rights among these countries is becoming more skewed. The Gini coefficients for organizations imply that there is a substantial inequality among organizations in terms of the distribution of nominations, though it is not as high as at the national level, indicating the nomination process is getting more decentralized across a variety of organizations.

Figure 13: Gini coefficients and numbers new organizations (5-period moving averages)



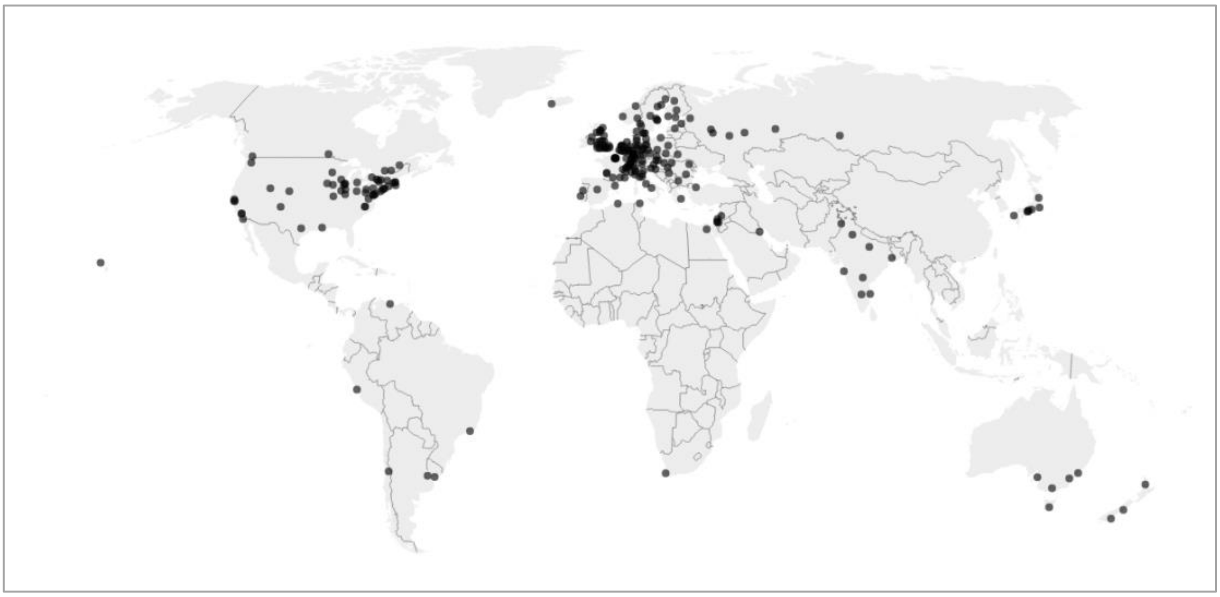
This figure shows the development of Gini coefficients on two levels over time (5-period moving averages), showing an unequal distribution of nomination rights among countries/ organizations. Values for the organizational distribution are plotted as black lines, for the distribution among countries as gray lines. The dashed lines represent 5-period moving averages, with corresponding trend lines in solid color.

When comparing these values with Gini coefficients for faculty placement in modern academia, it is important to note that those Gini coefficients range from 0.6 to 0.8 in different fields (Wapman et al., 2022), and are therefore even higher than values measured for the nomination process. However, these values refer specifically to faculty placement power within the United States, some 60 years later, and are therefore not directly comparable. Using the linear trend line in Figure 13 to predict nomination power in the 2020s, though, would yield more similar Gini values, ranging from 0.5 (for organizations) to nearly 0.7 (for countries).

This finding, together with the fact that the top nine countries account for almost 80 percent of all nominators, as observed in Figure 32, shows that there is a highly skewed distribution of nomination rights in favor of a few countries at the top. Although there have been attempts to diversify the process by involving more countries over the observed period, the skewed distribution has not been reduced, but has become increasingly unequal.

At the urban level, comparable patterns emerged. There are about 250 different cities in the dataset where nominators worked at the time of nomination. During the first decade, only about 20 cities participated in the nomination process, but this number tripled during the 1960s. Figure 14 illustrates which cities submit nominators throughout the observation period, indicating a high concentration of nominators in specific metropolises, mostly located in Europe and the United States, which exhibit strong nomination numbers, as previously discussed.

Figure 14: Visualization of cities submitting nominators, 1901-1969



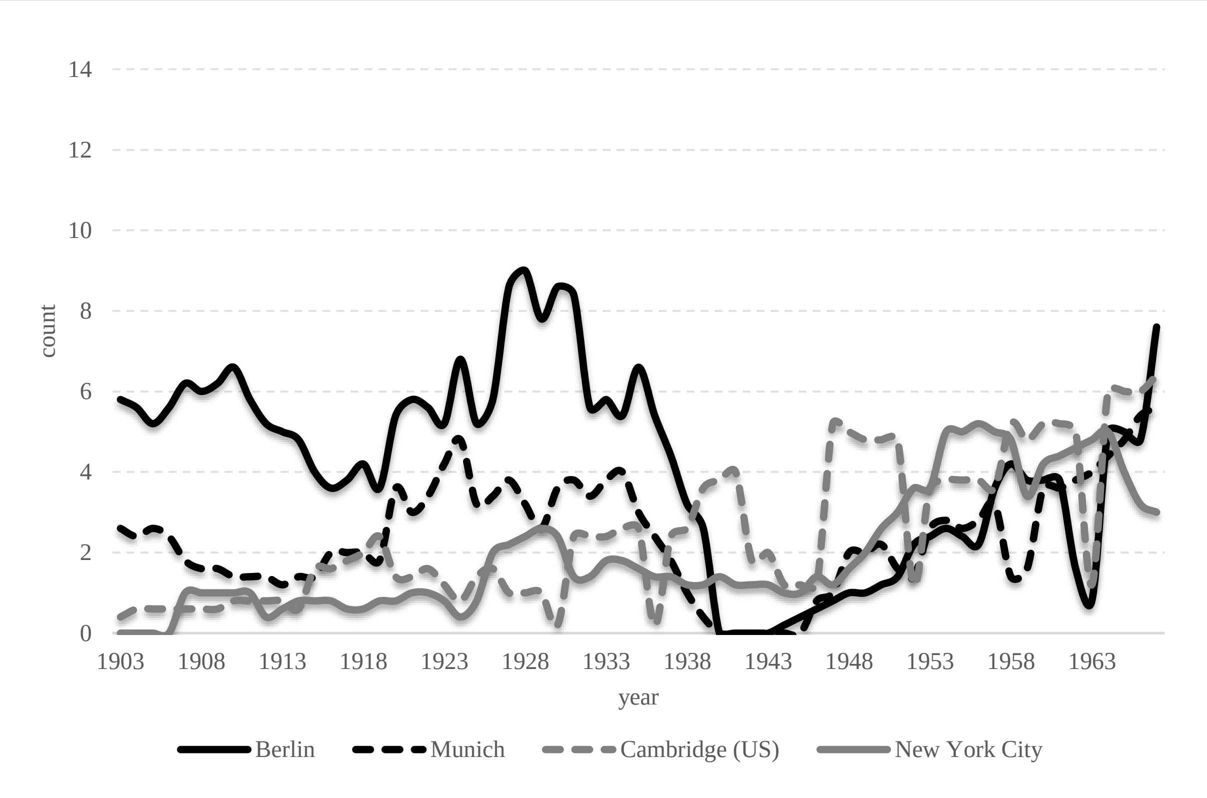
This figure (created with Datawrapper) visualizes cities that submit nominators within the observation period (1901-1969) as grey dots on a world map depicting their geographic location.

For a better overview, Figure 35 and Figure 36 in the appendix provide a magnified view of Europe and the United States, respectively, revealing the relationship between cities' size and the total number of nominators. Nominators in the United States are concentrated in metropolitan areas on both the East and West coasts, with the former being significantly more dominant. The top five metropolitan areas, in descending order, are Cambridge (15%), New York City (11%), Chicago (11%), Pasadena (8%), and Berkeley (7%). Together, they account for approximately 50 percent of all nominators in the United States but only about 10 percent of nominators worldwide.

Within Europe, it is apparent that nominators are concentrated in Central Europe, specifically in the metropolitan areas of northern countries (Sweden, Finland, Denmark, and Norway), the UK, France, the Netherlands, Belgium, Germany, Poland, Russia, the Czech Republic, Switzerland, Austria, and Italy. It is also noticeable that there are countries like France, which are rather centralized in one metropolis (namely Paris and its suburbs), and countries like Germany, which likewise have metropolises, but apart from that there are nominators from almost every region within Germany. The top seven nominating cities (in total as well as in Europe) are ranked in descending order as follows: Paris (10% of European nominators), Berlin (7%), Stockholm (6%), London (5%), Zurich (4%), Helsinki (4%), and Munich (4%). The top ten is completed by the US cities of Cambridge, New York City and Chicago.

A historical comparison of the two most significant cities in Germany and the United States is illustrated in Figure 15. From the distribution of countries, it is evident that Germany initially dominated in the first few decades of nominations before eventually yielding to the United States over time. During the observation period, Berlin experienced a significant decline during World War II but gradually recovered by the end of the period. In contrast, US cities showed an increase over the years, although this is not stable due to fluctuating numbers, especially for Cambridge, although the annual curve is smoothed by a 5-period moving average. This could be interpreted as a consequence of US nominators being predominantly selected on an annual basis rather than relying on permanent rights holders (such as RSAS members). As a result, the annual numbers tend to fluctuate more. The figure reveals that following WW II, US dominance is more evident at the country level than at the city level. This suggests that the advantage of capacity, rather than the number of nominators, is a main factor behind the dominance. Despite German metropolises submitting a comparable number of nominators, the United States has more available cities due to its larger size.

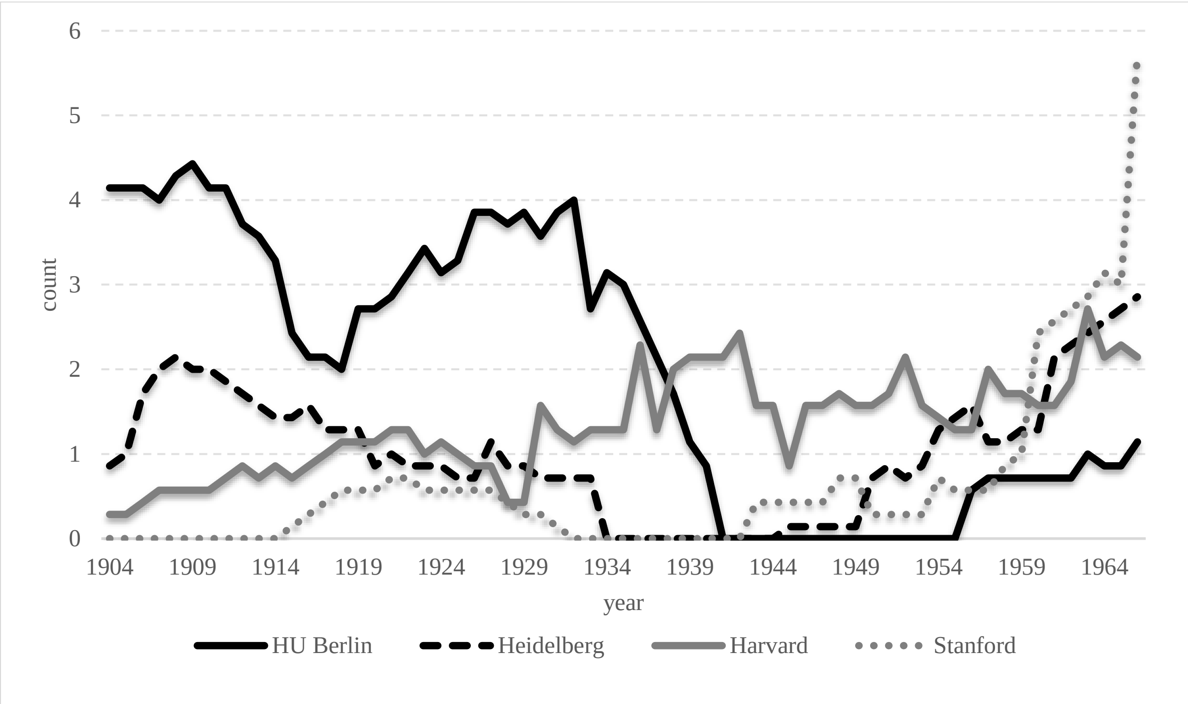
Figure 15: 5-period moving average of top German/US American cities submitting nominators



This figure shows the number of submitted nominators for the two most contributing German/ US American cities over time (smoothed with 5-period moving averages): The two German cities Berlin (solid) and Munich (dashed) are plotted with a black line, while the US American cities of Cambridge (dashed) and New York City (solid) are plotted with a gray line.

This trend is evident when analyzing the organizations that provide nominators. Figure 16 further highlights this pattern at the level of top organizations in submitting nominators, but also reveals that there are distinct types of German and US American organizations. As annual counts of universities fluctuate even more than on the national or metropolitan level, 7-period moving averages are applied for improved readability of Figure 16.

Figure 16: Numbers of nominators (7-period moving average) exemplified on US and German universities

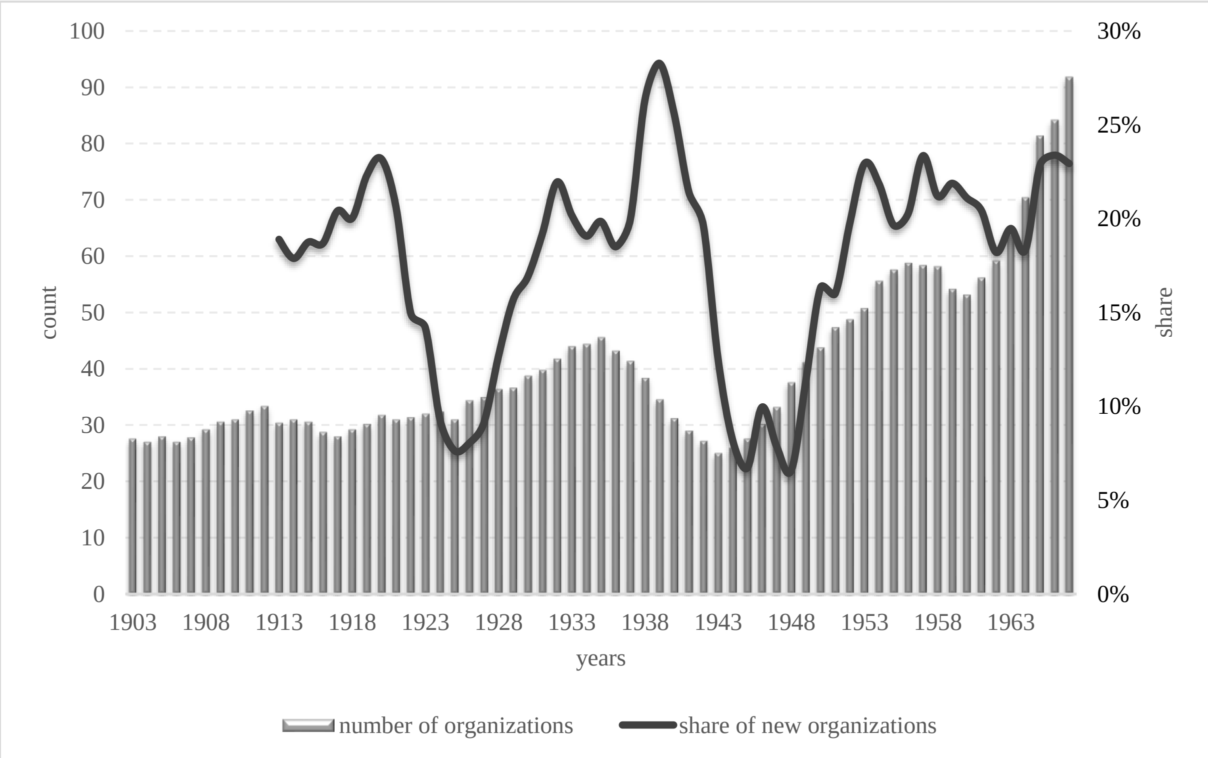


This figure shows the number of submitted nominators for two German and US American universities over time (smoothed with 7-period moving averages for increased readability): The two German universities HU Berlin (solid) and Heidelberg (dashed) are plotted with a black line, while the US American universities Harvard (solid) and Stanford (dashed) are plotted with a gray line.

The Humboldt University of Berlin (abbreviated HU Berlin) used to be a top-tier institution for nominators, but after a steady decline to zero after WW II, it has not been able to rebound. This could be attributed to Berlin's unique situation as a divided city. The HU Berlin was situated in East Berlin following its division, operating first under Soviet rule and subsequently under the Socialist Unity Party. The political environment may have impacted the institution's reputation, potentially affecting committee decisions regarding the allocation of nomination rights. Gallotti and De Domenico's research (2019) revealed that nominations usually occur between politically aligned countries. This illustrates the Eastern bloc’s isolated stance among western nominating nations. Similarly, the committees could potentially select nominators from countries or organizations that align with Sweden’s political system, thereby disempowering the HU Berlin following Germany's division. In West Berlin, the Free University of Berlin was created as a replacement for HU Berlin. Even so, during the 1960s, the Free University submitted as many nominators as HU Berlin, but did not succeed in forming a new hub for nominators like HU did during its initial nomination years. A contrary example from Heidelberg University illustrates that, despite a significant decline in the 1930s and 1940s, West German universities and science organizations were able to match American universities in securing nomination rights in the late 1950s and early 1960s.

Turning to US American organizations, there is a considerable number of universities that show an astonishing growth in submitting nominations, such as Stanford University, which has seen a sharp increase since the late 1950s. Similar to the case of the FU Berlin, there is evidence of organizational renewal in the nomination process. For instance, newly established organizations like Rockefeller University, founded in 1901, display relatively high numbers of nominators, showing that the nomination process is open to emerging organizations. On the other hand, there are more established universities like Harvard University that exhibit a moderate level of influence, yet still submit a relatively stable number of nominators over time.

Figure 17: 5-period moving average for number of organizations/shares of new organizations in terms of submitting nominators



This figure shows the number of organizations involved in nominator submissions over time, with the number of organizations on the primary Y-axis and shown as gray bars. The percentage of new organizations involved in nominator submissions over time is shown as a black graph on the secondary Y-axis.

The quantity of organizations participating in the nomination process is on the rise, as observed for other dimensions. Figure 17 displays a 5-period moving average of the annual number of organizations, with over 370 organizations submitting nominators represented throughout time. In order to contribute to the discussion on organizational renewal, I included the share of new organizations in the figure to show that times of war not only impede the diversity of nominating entities, but also hinder the inclusion of new organizations. Organizations are classified as "new" for a 3-year period after their first nominator submission.

For instance, in 1922, Robert Millikan, while a professor at the California Institute of Technology (Caltech), made the university’s first nomination, thus beginning the nominating process for Caltech. For the years 1923 and 1924, Caltech would also have been considered "new" but as there was a subsequent entry later in 1925, Caltech was already established and recognized as one of the top nominating organizations in the coming decades. The graph indicates that except for two considerable drops during or right after times of war, approximately 20 percent of the organizations are newcomers. However, in terms of quantity, newcomer organizations account for only a small portion of nominations.

The top 50 organizations in submitting nominators are listed in Table 3. The first five places are assigned to the countries that submit the most nominations: University of Paris (France), Humboldt University of Berlin (Germany), Stockholm University (Sweden), University of London (UK), and University of Chicago (USA). Among the top 50, the United States (12 organizations) and Germany (8 organizations) collectively claim almost half of the ranking positions, indicating the presence of multiple academic hubs within both countries. Next are the United Kingdom and France (5 organizations each), followed by the Netherlands, which has four universities in the top 50 (Leiden, Amsterdam, Utrecht and Delft). With the exception of the *Physikalisch-Technische Bundesanstalt*, only universities are represented, indicating that the nomination process heavily favors academic educational centers over industrial companies or non-university research institutes. This result aligns with previous findings on awarding prizes in favor of universities (Zhang & Zhang, 2023), indicating a consistent trend within the nomination process.

Table 3: Global Top 50 organizations in terms of submitting nominators, 1901-1969

Organization	country	count
University of Paris	FR	222
Humboldt University of Berlin	DE	144
Stockholm University	SE	135
University of London	UK	134
University of Chicago	US	129
ETH Zurich	CH	125
University of Helsinki	FI	124
Ludwig Maximilian University of Munich	DE	93
Collège de France	FR	92
Harvard University	US	92
California Institute of Technology (Caltech)	US	88
University of California, Berkeley	US	87
KTH Royal Institute of Technology	SE	86
University of Cambridge	UK	81
University of Oslo	NO	79
Massachusetts Institute of Technology (MIT)	US	76
Heidelberg University	DE	73
University of Göttingen	DE	72
Uppsala University	SE	70
University of Vienna	AT	69
Leipzig University	DE	60
Columbia University	US	60
Stanford University	US	60
Sapienza University of Rome	IT	57
Cornell University	US	56
Leiden University	NL	55
Technical University of Munich	DE	55
Rockefeller University	US	54
University of Amsterdam	NL	51
Imperial College London	UK	50
University of Strasbourg	FR	49
University of Basel	CH	49
University of Zurich	CH	48

Organization	country	count
Utrecht University	NL	46
University of Oxford	UK	45
Princeton University	US	45
Helsinki University of Technology	FI	44
University of Copenhagen	DK	42
University of Wisconsin-Madison	US	42
Technical University of Vienna	AT	41
Charles University	CZ	40
Technical University of Denmark	DK	39
University of Lyon	FR	39
Delft University of Technology	NL	39
University of Bologna	IT	37
Physikalisch-Technische Bundesanstalt	DE	36
University of Lorraine	FR	35
University of Illinois at Urbana-Champaign	US	35
University of Warsaw	PL	33
University of Jena	DE	32
University of Manchester	UK	32

Research institutes are often smaller than the relevant departments of large multidisciplinary universities. Therefore, I examined institutes that could be grouped under an umbrella organization, such as the Pasteur Institutes or countries' National Academies. Two umbrella organizations, once treated as one, would rank among the top 50: The Russian Academy of Sciences ranks at position 38 with 43 nominations and includes the Ioffe, Lebedev, and Kurchatov Institutes, for example. Institutes under the umbrella organization of Max Planck Society may indeed be considered as one organization, since they are not autonomous. With all institutes combined, the Max Planck Society ranks third with a total of 136 nominators, indicating an exception for non-university nominating organizations. Notable institutes within the Society include the Max Planck Institutes for Physics, Chemistry, and the Fritz Haber Institute.

When comparing this ranking of organizations that submit the most nominators with a ranking of organizations that excel in the number of affiliated laureates (for their career stages of highest degree, prize-winning research, and the awarding) presented by Heinze and Fuchs (2022), it appears that while half of both lists are congruent (about 56%), the top positions are distributed rather differently. For instance, the University of Cambridge, which is ranked 1st in the laureates' ranking, is only ranked 10th in terms of the submission of nominators. In contrast, the HU Berlin, which is ranked 2nd in terms of nominators, is placed 15th in the laureates' ranking. Paris, which is ranked 1st in terms of nominators, is placed in the second half of the top 50 list of laureates. However, it is important to note that single universities within the Paris University system are assessed separately for laureates, making comparisons more difficult.

Organizations listed in the laureates' ranking but not in the nominators' ranking typically are research institutes, such as Bell Labs, and universities from underrepresented continents in terms of nomination power, such as the University of Tokyo in Japan. Additionally, some universities from central countries with high nomination power, such as Yale in the United States, are also not listed among top nominating organizations, although to a lesser extent. Differences in rank between the lists can also be attributed to variations in category coverage: While this analysis only includes Physics and Chemistry, the laureates' ranking also encompasses Physiology or Medicine, resulting in significant differences for universities and research institutions that specialize in medical research, such as the Karolinska Institute. This factor, in addition to the varying time periods, may reduce the comparability of the lists, but makes the congruency of over 50 percent even more astonishing. Later, I will perform a more suitable ranking in terms of categories and timeframe with data on laureates.

Regarding universities listed among nominators but not among laureates, they are all European from countries that are among the overall top for the submission of nominators (Figure 32). These universities include Leipzig, Rome, Leiden, Basel, Prague, and Lyon. Northern universities from countries with special nomination rights, such as Stockholm, Helsinki, and Oslo, are also prominent in the submission of nominators, but do not appear in terms of affiliated laureates.

Table 22 in the appendix highlights disciplinary and temporal differences observable at the organizational level, presenting the top 5 organizations in terms of submitting nominators represented in each of the seven decades and in both prize categories of Physics and Chemistry. In the first few decades of nominations, certain prominent institutions consistently dominated both prize categories. LMU Munich, Stockholm University, and HU Berlin, which ranked second in both categories during the first decade, were among these organizations. The HU Berlin also held the top spot in both categories during the 1910s and 1920s before slipping to second and third place in Chemistry and Physics, respectively, in the 1930s and ultimately falling out of the top ranks. The University of Oslo's sole rank in Chemistry, rather than Physics, is an uncommon occurrence among top organizations as shown in Table 22 during the initial decades.

There is a shift in rankings during the ensuing decades with the top five not aligning as closely as before in both categories. Particularly in the 1960s, leading US organizations exhibit a growing trend towards specialization in one category. The Rockefeller University, which specializes in biomedicine, ranks second in Chemistry but is not even ranked in Physics within the 1960s. In contrast, the Massachusetts Institute of Technology (MIT) ranks fourth in Physics but only barely makes it into the top 50 for Chemistry. Although the percentage of organizations nominating in both categories during a decade increases over time (from around 37% in the first three decades to about 47% in the last three decades), the nomination system evolves to become more specialized among the top organizations, as demonstrated by the showcases.

This chapter confirms both hypothesis H3a and H3b by demonstrating that the distribution of nomination power is highly skewed among countries and organizations. The organizational level provides new insights into identifying prominent universities within the nomination process that align with macro trends. In agreement with Heinze and Fuchs (2022), who discovered similar patterns in data on laureates, there exists an *organizational ultra-elite* in terms of nomination power, drawing on Zuckerman's term. This ultra-elite aligns with Heinze and Fuchs' results to a large extent, although it also reflects the European-centric selection of nominators, particularly in the early nomination decades.

The change in scientific leadership from Germany to the United States (H2a) during my observation period is evident in both the nomination power of countries and the shift in organizational elites. In addition to the information presented for countries and organizations separately, I will demonstrate this change regarding a typical nominator within the first and last nomination decade using two case examples.

In the 1900s, Germany was viewed as a thriving scientific hub, with German being the language of academia. Metropolises such as Berlin and Munich were flourishing intellectual and technological hotspots, German researchers were celebrated as leading experts, and German universities served as exemplars of modern scientific organization with freedom of teaching and science as an organized occupation. After World War II, the United States, for whose scientists a German university education was a badge of prestige, became the hegemonic power in science. The academic center shifted to the United States with its modern research organizations that are decentrally organized and pluralistically funded (Ben-David, 1960; Heinze et al., 2020; Hollingsworth, 2006).

With about 40 percent coverage for US American nominators in the 1960s, nominations followed the shift in scientific hubs. While the typical characteristics of nominators, such as their common occupation as university professors, their distinct mid-50 age range, and male gender, remained consistent during the whole observation period, factors related to affiliation, for example on the national level, show the shift in scientific leadership.

Emil Warburg serves as a good example for a typical nominator in the first decade of awarding. He was a professor at Friedrich-Wilhelm University of Berlin (later HU Berlin) until 1905, then heading the Physikalisch-Technische Reichsanstalt (later Bundesanstalt). During the first nomination decade, the HU Berlin had the highest number of nominators overall, clearly ranking among the organizational ultra-elite of science, demonstrating also Germany's dominant role in the nomination process during the early 20th century.

Warburg was not a member of the RSAS, but he still exemplifies the close connections between German and Swedish academic elites. Nearly half of the nominators in the first decade were members of the RSAS at the time of their nomination, a particularly high number given the limited access for (foreign) scientists. Though not having a permanent right to nominate every year as a member, Emil Warburg was invited to nominate in every year of the first decade of awards, ultimately making 14 nominations for 9 nominees.

In the 1960s, nominators were mainly from the United States, and membership in the RSAS was a rarity among nominators (less than 10% of nominators were members). Regarding organizational affiliation, there is now a more distinct disciplinary differentiation between Physics and Chemistry compared to the early 20th century, when HU Berlin served as a leading institution in both fields, with over 20 nominators in each category during the 1910s. In the 1960s in the United States, organizations became more specialized in specific fields. To be considered a leading organization, representation in both fields was necessary.

Robert Hofstadter represents a common case of the 1960s as a scientist from Stanford University, which provides the highest number of nominators in the United States (in the top 3 for all countries). Hofstadter, a 1961 NP laureate in Physics, illustrates not only the committees' alignment with scientific hubs, but also the hubs' self-enforcement through permanent nomination rights for laureates. Despite the small number of active Nobel laureates, it is noteworthy that in the 1960s, approximately 30 percent of all US nominations came from previous NP laureates.

These cases demonstrate a shift from the traditional academic elite of German universities aligning with the Swedish awarding community to a more autonomous elite of US American scientists, clearly confirming hypothesis H2a.

7.2 Self-nominations

Knowing who has the right to nominate, a subsequent question is how these rights are exercised. In this subchapter, I extend the analysis beyond nominators to include the network resulting from nominations. According to the Nobel Prize Statutes, scientists are prohibited from nominating themselves, though nominators are able to self-nominate in aggregation to other levels.

In this analysis, I focus solely on work-related similarities between nominees and nominators, such as whether they both work on the same continent, country, or organization. For instance, if a nominator working in Europe nominates a nominee also working in Europe, it corresponds to a self-nomination at the continental level. My goal is not to draw any conclusions about meritocracy but rather to highlight structures that demonstrate nomination behaviors at the macro level. For analysis, the full dataset of nominations (8832) is used, instead of the reduced dataset of nominators (5952) that I employed in the last chapter.

Self-nominations at a continental level show that 75 percent of candidates are nominated from their own continent, with a decline over time (from around 90% in the first decade of nominations to approximately 65% in the 1960s). The decrease in this proportion is mainly due to European scientists nominating candidates from North America (over 90% of all European nominations for other continents) and, to a lesser extent (about 86%), vice versa. Although both continents have a similar proportion of self-nomination, around 75 percent, which is to be expected since they provide the majority of nominators, self-nomination is a negligible phenomenon for other continents. Asia has the highest share with almost 25 percent, followed by South America (18%), Oceania (13%) and Africa (4%). Without considering self-nominations, none of these continents has gained a single nomination from outside Europe or North America, except for two nominations from Asia to South America. This highlights the role played by Europe and North America in connecting all continents, while peripheral continents only have links to both central continents.

Regarding geographical distance, it is not unexpected then that nominations tend to occur between cities that are geographically close. Specifically, 16 percent of nominations are made between scientists who reside in the same city (not necessarily working for the same organization), while 25 percent of nominations are exchanged between locations no more than 200 kilometers apart (measured in a straight line). A distance of 200 kilometers corresponds to the distance between Groningen and Delft in the Netherlands or between Chicago and Urbana, Illinois in the United States, for example.

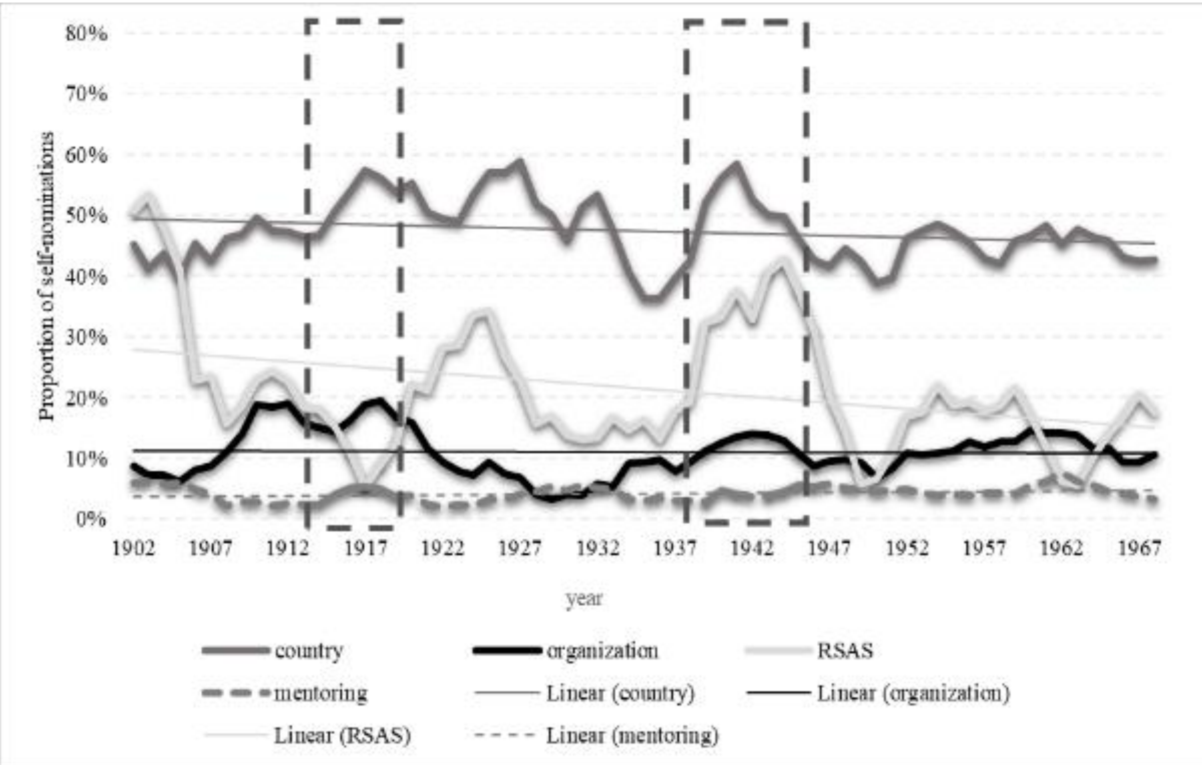
The median geographical distance between cities connected through nominations is about 700 kilometers, indicating that half of the cities within the geographical nomination network are closer to each other than Munich is to Kiel or Rome. The 75-percent-quartile is reached at a distance of approximately 4200 kilometers. This refers to a wide span that includes cities such as Cambridge (USA) and Pasadena, illustrating the different scale of distances within Europe and the United States, respectively. Overall, the distances between cities connected through nominations increased slightly over the covered time period.

Figure 18 illustrates the development of self-nominations as measured by several indicators. While annual self-nomination rates vary greatly, they accurately indicate when changes occur, such as during times of war. The graph's lines have been smoothed using 3-period moving averages, differing from the 5-period moving averages that I commonly used to strike a balance between these two demands. Furthermore, linear trend lines are provided for every indicator of self-nominations for improved clarity.

Self-nomination on a national level (dark gray line “country”) transpires when both nominator and nominee perform work in the same country at the time of nomination, accurately reflecting the historical spread of the respective country at that time. Robustness checks were conducted for today's country borders, and they confirmed the findings presented in Figure 18. The same procedure was conducted for the organizational level (black line, “organizations”), displaying self-nomination rates for nominations that pass between two scientists of the same organization in a strict sense, meaning that nominations among different institutes of one umbrella organization are not counted as self-nominating. Robustness checks have been carried out to ensure that this does not alter the results quantitatively. However, because of their interest, case examples are presented for the Max Planck Society, the Russian Academy of Sciences, and the Manhattan Project.

The light gray line shows self-nominations among members of the RSAS. The proportions refer to the total number of all nominations from the RSAS, whereby a similar course is found for curves referring to the total number of all nominations. Finally, the last dimension shows self-nomination in a mentoring-related context (dashed grey line), meaning that, since scientists cannot nominate themselves, they could nominate someone from "their lineage", i.e. mentors or mentees, thus picking up on the discussion of academic families and nepotistic tendencies. This dimension, too, is rather restrictive, since only direct relationships between mentor and mentee are considered (see chapter 6.2).

Figure 18: Proportion of self-nominations on different levels over time (3-period moving average)



This figure shows several indicators for the measurement of self-nominations (nominations that pass between scientists of the same entity) over time, using 3-period moving averages for a compromise between readability and historical accuracy. Linear trends (thinner lines) are presented for improved clarity. War years (1914-1918, 1939-1945) are outlined with a dashed frame. Indicators for self-nominations include the levels of individual scientists in a mentoring relation ("mentoring", dashed gray lines), RSAS members ("RSAS", light gray lines), organizations ("organization", black lines), and countries ("country", dark gray lines).

In general, self-nominations show a rather stable influence over time, with small but consistent effects at the organizational and mentoring levels. In particular, the rather low coverage of mentoring relationships shows that this phenomenon in a narrower sense is made larger by qualitative studies than its quantitative impact on all nominations justifies.

The trend line indicates a slight decrease in national self-nominations. However, it is noteworthy that self-nominations still comprise almost 50 percent of all nominations during the most recent nomination period. The only dimension that shows a substantial decline is self-nominations between RSAS members. The trend line shows a considerable decrease. Thus, not only are RSAS members less important in terms of their nominating power over time, they are also less likely to build self-nominating clusters.

When examining the fluctuations within the historical curves, peaks in self-nomination proportions are evident, particularly on a national level, in agreement with Crawford's (2001) research findings. Nevertheless, these peaks are not as apparent in the general course, and upward trends during times of war are subsequently followed by a downward period. Therefore, wartime fluctuations fit within the general course and are not particularly distinctive. On the organizational level, there is no striking difference from the national level, although there are smaller peaks during wartime.

When comparing the war years and non-war years, there is no significant difference in the distribution of self-nominations on any of the four levels shown in Figure 18. The Phi coefficient with the highest value of roughly 0.05 pertains to national affiliation, but the small value relativizes the correlation between war and self-nominations on a general national level.

Furthermore, Phi coefficients indicate no significant difference in self-nominations between the disciplines of Chemistry and Physics. Depending on the self-nomination measurement level, the coefficients range from -0.02 (RSAS membership) to 0.03 (national affiliation), centering around 0, which means that there is no statistical relationship.

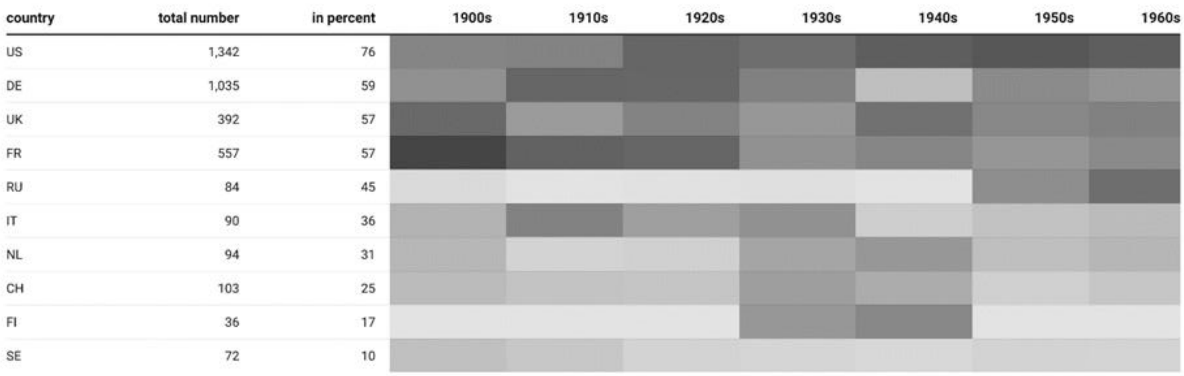
However, differences could pertain to the positioning of the individuals based on such criteria as laureate status, country, and organization. The bias of nominators towards self-nominations may be affected by their positions or roles within the nomination network.

One could, for example, assume that laureates represent a unique group in terms of self-nominations. As highly respected scientists, they may have more international contacts compared to non-laureated nominators. This may result in their nominations relying less on self-nominations, which occur between colleagues within the same organization or who share the same current national affiliation. To use Merton's terminology, they may view themselves as ‘exhibiters of meritocracy’ because of their special position, leading to more nominations that go, for instance, beyond country borders. I analyzed the nomination patterns of laureated nominators across various levels of self-nomination, including national affiliation, organizational affiliation, RSAS membership, and mentoring. However, I could not identify any apparent tendency to rely less on self-nomination. Based on Phi coefficient analysis, there is hardly any noticeable variation in the self-nomination behavior of laureated and non-laureated nominators. With a Phi coefficient of 0.15, the data shows that laureates nominating their own mentees/mentors is a slight tendency, providing support for Zuckerman’s (1977) idea of dense educational relationships among the Nobel elite.

The proportion of self-nominations by national affiliation varies based on countries, with the United States and France having higher rates than the United Kingdom or Sweden, confirming Crawford's descriptive results (1992). Figure 19 provides an overview of top 10 countries with the highest numbers of self-nominations overall, and a heatmap that shows whether this trend varies over decades. I rely on numerical values for ranking rather than ratios in order to demonstrate the countries that contribute the most to the phenomenon. There are countries such as Uruguay with 50 percent self-nominations that have a higher proportion compared to countries such as Sweden. In total, however, Uruguay only submits 8 nominations, making this more a question regarding the center and periphery of the nomination network, which will be addressed in the following chapter.

Upon a closer look at the countries in Figure 19 and the heatmap, it appears that self-nominations may be influenced by scientific hegemony, where countries with advanced innovative research, as opposed to those lacking it, tend to nominate more scientists from their own country.

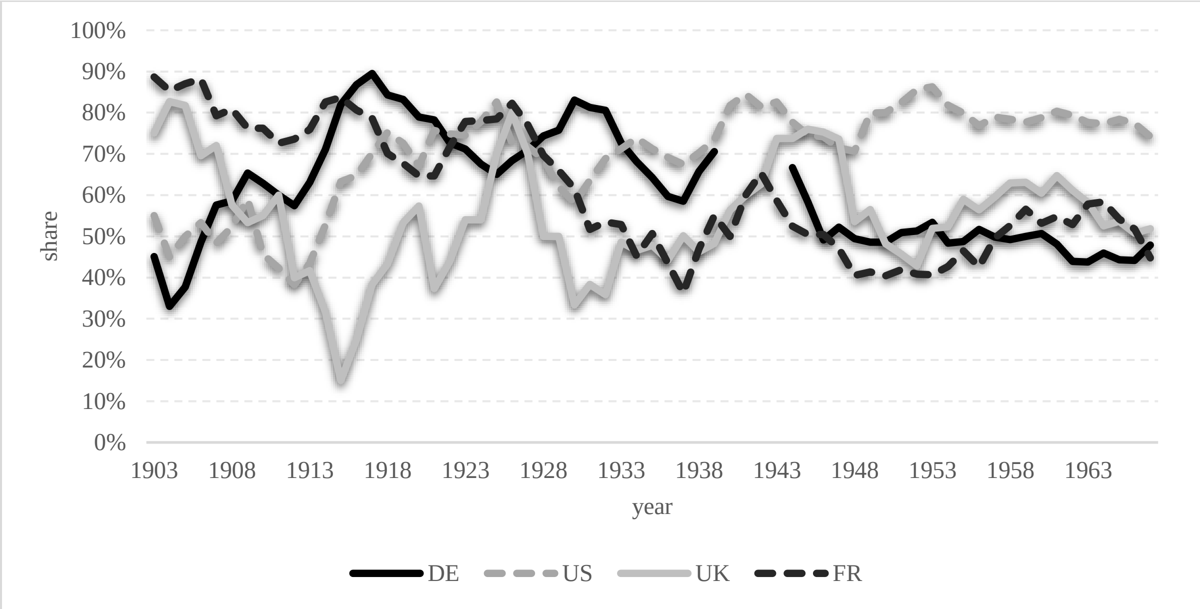
Figure 19: Heatmap of self-nomination rates for top 10 nominating countries in decades



This figure (created with Datawrapper) shows self-nomination rates for the ten countries that submit the most nominators within the observation period (displayed as total number, and converted to percentual shares). A heatmap visualizes a country’s self-nomination rate within decades between the 1900s and 1960s. Light gray squares signal low rates, while dark gray squares signal high rates.

Examining Figure 20, self-nomination rates (5-period moving averages) are plotted over time for Germany, the United States, the UK, and France to provide an illustrative comparison on this issue. As demonstrated, during the first and second halves of the observation period, Germany and the United States were scientific centers, respectively. In terms of self-nominations, they experienced lower proportions outside of their hegemonic phase, while the proportions increased within their respective hegemonic phases: However, the German graph fluctuated greatly until WWII. It first rose sharply to its peak in 1917, nearly reaching a 90 percent share of self-nominations. It fell slightly until 1924 (65%), rose again to a peak of 81 percent in 1931, and then fell to 58 percent in 1937. Between 1939 and 1944, no German nominators submitted votes. After that, self-nomination rates stabilized between 50 and 40 percent.

Figure 20: Proportion of self-nominations for Germany, USA, UK, and France



This figure illustrates self-nomination rates over time (using 5-period moving averages) for the four countries exerting the highest overall shares of self-nominations: Germany (“DE”, solid black line), United States (“US”, dotted gray line), UK (solid gray line), and France (“FR”, dashed black line). Missing values (1939-1944 for the German graph) result from a country submitting no nominations, which differs in interpretation from a value of 0%.

In the United States, rates fluctuate during the first few decades and stabilize in the 1930s, remaining between 70 and 85 percent. This suggests that a country's scientific standing may play a role in the variation of their self-nominations, which contrasts with Crawford's perspective of self-nominations as a marker of chauvinism. A comparison of self-nominations in Germany and the United States during the periods of German dominance (1901-1933) and US dominance (1934-1969) shows a slight tendency towards influence. The time spans were chosen to align with the descriptive findings from chapter 7.1 and Germany's political situation after 1933. Robustness checks were performed for time periods of 1901-1938 and 1939-1944, reflecting a division regarding WWII. Compared to the Phi coefficients for all other countries in the two time periods, which was close to zero with -0.04, both the US (0.1) and German (-0.2) coefficients demonstrate that this, at the very least, is an explanatory approach that suggests self-nominations may to some degree be influenced by scientific hegemony.

However, Figure 20 also reveals that the UK and France, which do not shift into/out of a leading role like Germany and the United States, also experience large fluctuations in the early nomination decades and stabilize their self-nomination rates after World War II at levels comparable to Germany. This suggests that these rates required time to stabilize after two world wars and in the 1950s and 1960s, they show a more pronounced alignment with scientific leadership.

Changing the analysis to the organizational level reveals a growing fluctuation among entities. Like countries, some organizations exhibit minimal self-nominations. For instance, Stockholm University's rate is less than one percent, which is remarkable given that it submitted more than 250 nominations in total. This enhances Sweden's image and that of the "host" university in Stockholm as impartial organizers, who seem to nominate with an international perspective.

Conversely, certain universities demonstrate a high degree of self-nominations. The average rate for self-nominations on the organizational level is approximately 11 percent. Numerous universities surpass this average: Examples of organizations that submit relatively few nominations, but have high rates of self-nominations (over 60%), include the Commonwealth Scientific and Industrial Research Organisation (CSIRO) from Australia with six nominations (four self-nominations) and Grenoble Alpes University from France with ten nominations (eight self-nominations).

The Rockefeller University submitted approximately 60 nominations, with half of them directed towards itself, making it the organization with the highest self-nomination rate among organizations.

Turning to umbrella organizations with multiple opportunities for self-nomination, it becomes clear that nominators from these entities are often employees of science administrations, such as the Russian Academy of Sciences, and direct their nominations to the individual institutes affiliated within the umbrella organization, such as the Landau or Lebedev Institutes. The presidents of the Max Planck Society, Otto Hahn (1946-1960) and Adolf Butenandt (1960-1972), frequently served as nominators during their tenure and showed a tendency to vote for German scientists, particularly those affiliated with MPIs. This resulted in several successful Nobel Prize nominations, including Walther Bothe (Phy 1954), Karl Ziegler (Che 1963), Feodor Lynen (Med 1964), and Manfred Eigen (Che 1967).

Self-nomination is present in 40 percent of nominations from the Russian Academy of Sciences and its affiliated institutes. This practice was prominent in the 1950s and 1960s, as these organizations were rarely selected to nominate in earlier decades. An exemplifying instance occurred in 1957, with seven out of nine nominations directed towards scientists within the umbrella organization. For the MPIs, rates are generally lower, at about 25 percent, which is still significantly higher than the average self-nomination rate of organizations that is around 10 percent (tested using chi-square analysis). Self-nomination rates fluctuated in the 1930s, with more solid concentrations in the 1950s and 1960s. This aligns with the Max Planck

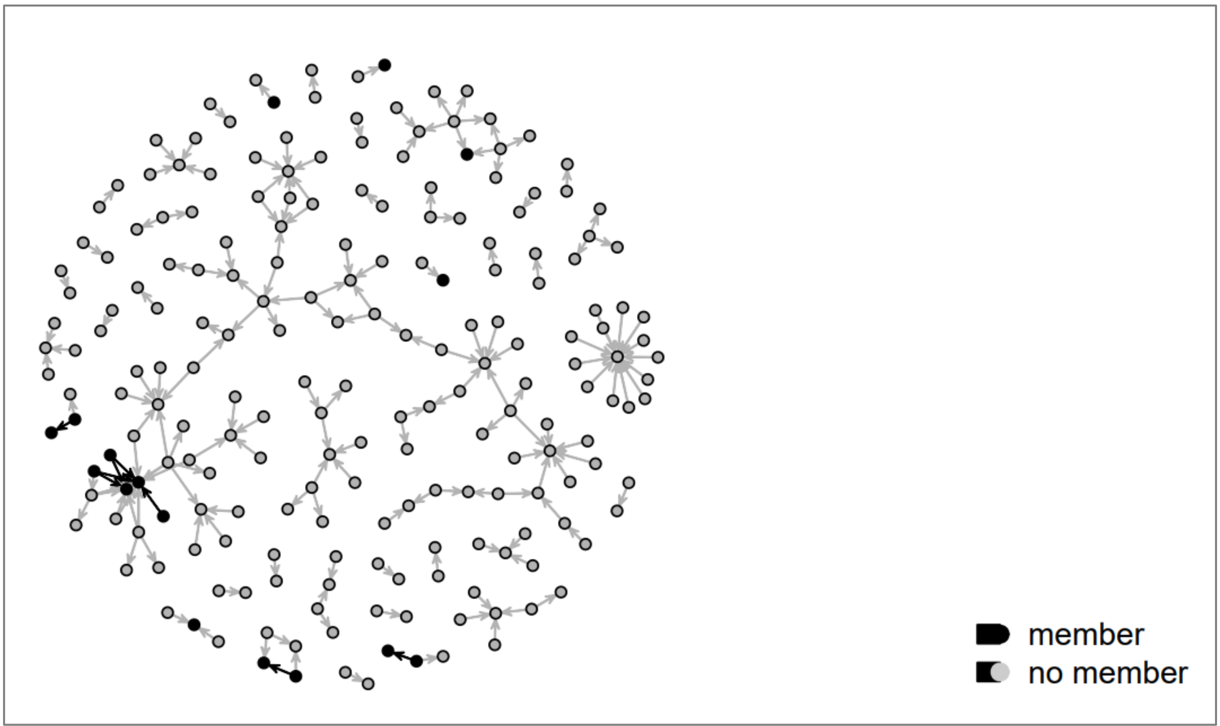
Society's reputation as a promoter of postwar basic research in Germany, which has often led to Nobel Prizes.

The Manhattan Project, a temporary research project involving numerous scientists in addition to their regular employment, is of interest for the study of nomination behavior among former colleagues after 1945. Although there may be a thematic focus on atomic research and related fields, over 40 percent of nominators who worked within the project voted for their former Manhattan colleagues. To minimize the likelihood of thematic convergence accounting for the high proportion of nominations, I took a closer look at the project's main site, Los Alamos, where most of the nominators worked, followed by other sites such as Oak Ridge or university-based sites such as Chicago MetLab and MIT RadLab.

On average, between 1901 and 1969, former Los Alamos employees nominated their colleagues in approximately 30 percent of cases (significantly higher than the organizational average, measured by a chi-square test). Self-nomination rates vary widely between years, as is typical in nomination data, ranging for example from 100 to 0 percent in two consecutive years (1943 and 1944). On average, however, there is a clear tendency towards self-nominations, which illustrates how participation in temporary projects, in addition to regular workplace activities, can impact the nomination patterns of scientists on an organizational level.

To provide an example of this phenomenon, I will examine the nomination network in the year 1959. The self-nomination rate among coworkers at Los Alamos was high in 1959 (about 60%), and as a noteworthy fact, two former Los Alamos scientists shared the Nobel Prize in Physics. In Figure 21, it is apparent that membership in the Manhattan Project is fairly selective, even for elite scientists within this nomination network, and has a rather negligible quantitative impact. However, regarding the black cluster on the left, there are five nominations among the members of the Los Alamos site. The laureates of 1959, Emilio Segré and Owen Chamberlain, received numerous nominations from both inside and outside of the Manhatten Project.

Figure 21: Depiction of the individual nomination network in 1959 characterized after Manhattan Project membership



This figure shows the individual nomination network of the year 1959. Nodes represent individual scientists, colored after membership within the Manhattan Project (only Los Alamos site). Black nodes were members of Manhattan Project, while white nodes are non-members. Edges represent nominations directing towards the nominee.

As with countries, it is worthwhile to focus on the organizations that submit most nominations. Table 4 presents the self-nomination rates for the leading 50 organizations in terms of submitting nominators (differences in counts/organizations compared to Table 3 are due to the use of different datasets for nominators (5952) and nominations (8832).

Table 4: Top 50 organizations of submitting nominations ranked after proportion of self-nominations

Organization	Country	Count	Proportion of self-nominations
Rockefeller University	US	61	50.82%
California Institute of Technology (Caltech)	US	131	43.51%
Princeton University	US	69	39.13%
Charles University	CZ	42	33.33%
University of Illinois at Urbana-Champaign	US	55	32.73%
Harvard University	US	151	29.80%
University of Bologna	IT	48	29.17%
University of California, Berkeley	US	174	28.74%
University of Cambridge	UK	130	27.69%
Utrecht University	NL	56	26.79%
Technical University of Denmark	DK	62	25.81%
Cornell University	US	66	25.76%
University of Chicago	US	207	23.67%
Heidelberg University	DE	186	22.04%
University of Paris	FR	344	20.93%
Stanford University	US	89	20.22%
University of Oxford	UK	69	18.84%
Imperial College London	UK	81	18.52%
Humboldt University of Berlin	DE	216	17.13%
Columbia University	US	89	15.73%
University of London	UK	168	15.48%
Technical University of Vienna	AT	60	15.00%
University of Oslo	NO	126	11.90%
University of Wisconsin-Madison	US	52	11.54%
Technical University of Munich	DE	92	10.87%
University of Warsaw	PL	57	10.53%
Massachusetts Institute of Technology (MIT)	US	104	9.62%
ETH Zurich	CH	186	9.14%
University of Helsinki	FI	133	9.02%
Leiden University	NL	67	8.96%
University of Groningen	NL	47	8.51%
Sapienza University of Rome	IT	73	8.22%
Northwestern University	US	50	8.00%
University of Göttingen	DE	115	7.83%
University of Basel	CH	68	7.35%
Delft University of Technology	NL	55	7.27%

Organization	Country	Count	Proportion of self-nominations
University of Copenhagen	DK	69	7.25%
KTH Royal Institute of Technology	SE	133	6.02%
Ludwig Maximilian University of Munich	DE	141	5.67%
Collège de France	FR	148	5.41%
University of Jena	DE	68	4.41%
Lund University	SE	56	3.57%
University of Amsterdam	NL	62	3.23%
University of Zurich	CH	73	2.74%
Technical University of Berlin	DE	42	2.38%
Leipzig University	DE	89	2.25%
University of Manchester	UK	45	2.22%
Uppsala University	SE	119	1.68%
University of Strasbourg	FR	61	1.64%
University of Vienna	AT	189	1.59%
Stockholm University	SE	256	0.39%

The top places in the ranking are filled by US organizations (with the exception of Charles University), both established universities with a long tradition such as Harvard University (about 30% self-nominations) and relatively new universities such as Caltech (about 44%). Only two of the top American universities, MIT and Northwestern University, fall below the average rate of self-nomination, with just under 10 percent, only slightly under the average. Apparently, the scientific elite in the United States tends to self-nominate, with renowned British universities in Cambridge (28%), Oxford (19%), and London (Imperial College 19%, University of London 16%) following closely behind. Top nominating universities from Germany and France are situated in the upper half of the table, indicating higher rates of self-nomination (Heidelberg at 22%, Paris at 21%, and HU Berlin at 17%). On the other hand, universities like LMU Munich and Collège de France have self-nomination rates below average, with only 6 percent each. Universities in Leipzig, Jena, Berlin (TU) and Strasbourg all score below 5 percent.

Few universities outside of the US, UK, France, and Germany, which are the leading countries in nominating candidates as well as receiving awards, belong to the group of top organizations in terms of submitting nominations with above-average self-nomination rates: Charles University (33%) is followed by Bologna (29%), Utrecht (27%), TU Denmark (26%), TU Vienna (15%), and Oslo University. However, Oslo only slightly surpasses the average with approximately 12 percent. All other leading organizations from northern countries (Helsinki, Copenhagen, Royal Institute of Technology, Lund, Uppsala, and Stockholm) have lower self-nomination rates than the average of all organizations. This may be due to their special connection to the prize, but is more likely speculation.

In contrast, universities with high self-nomination rates are predominantly from countries that are also prominent in receiving Nobel Prizes. This observation could be interpreted as self-nomination rates on the whole being a sign of scientific quality, thus marking differences between organizations' display of self-nominations a form of stratification.

To analyze this assumption, I once again rely on data by Heinze and Fuchs (2022) providing information about the most successful universities in terms of acquiring laureates in their staff. Ranking of universities is based on three substantial career stages for laureates: completion of highest degree (HD), conduction of NP-related research, and awarding of the NP. As I have already laid out, results from this paper extend beyond my observation period and encompass the category of Physiology or Medicine. I use their specific dataset to replicate the results, matching to my selection of categories and time period. A table showing the top 50 organizations in Physics and Chemistry for the years 1901-1969 ranked after affiliation numbers for laureates within the three career stages is provided within the appendix (Table 23).

To compare these results with organizations' self-nomination rates, a Spearman correlation is performed between the top 50 ranks of laureate affiliation and the ranks of self-nominations. Only a reduced set of laureates was used, as the ranks within this set are very close to each other in the periphery. Specifically, 17 organizations have a score of 3, 33 have a score of 2, and 46 have a score of 1.

A correlation coefficient of 0.5 demonstrates a strong relationship, which supports the idea that self-nomination rates of organizations can be used as an indicator of scientific achievements. This finding suggests that organizations that attract laureates tend to self-nominate more frequently. In support of hypothesis H3c, it indicates that self-nominations are more common in organizations that excel in research production and laureate education as well as employment. Consequently, there is a stratification of self-nomination rates over the period 1901-1969.

7.3 Organizational network components

Table 5 presents the ranking of the top 50 organizations within the nomination process, considering now all four stages of nomination: The first stage is based on an organization's nominators and the extent of their nomination power. The data is derived from nominations sorted by nominators (see chapter 6 for details on the dataset and its variables).

The second and third stages pertain to an organization's nominees. The former refers to the organization's ability to employ top-notch scientists who are nominated for the Nobel Prize, and the latter refers to the organization's ability to educate nominees in the first place. Education is defined as the university where a nominee received his or her highest academic degree (HD), typically, but not always, a doctoral degree, such as the PhD (and equivalent degrees, including for example Dr.). Particularly, the distribution of candidates' higher degrees is highly hierarchical, with only about half of the organizations included in this study providing education for candidates. The ten most important universities in training candidates (in order) are: Paris, Cambridge, LMU Munich, MIT, HU Berlin, Caltech, Harvard, Göttingen, Columbia, and Berkeley. Together, they constitute almost 40 percent of the total HD distribution.

The last nomination stage is based only on nominations resulting in the nominee being awarded a Nobel Prize which are 1128 in total and have been portrayed as successful nominations in chapter 6.2. The number of successful nominations is relatively small and the distribution rather skewed. Only just over 90 organizations achieve a successful nomination and make it into the rankings. Other organizations are marked with a dash.

The overall ranking in the final column of Table 5, which also determines the sorting of organizations, is determined by summing up all stations weighted by the number of cases in each column, which corresponds to an organization’s share for that category. The columns in Table 5 show the rankings of organizations in each of the four nomination stages as well as their overall rank, providing an overview at first glance rather than exact numbers.

For clarification, I calculate two examples of Caltech and HU Berlin, which end up in the second and third position (total rank). For employing the most nominators, HU Berlin ranks second with a share of 2.5 percent of the total nominator distribution. Caltech ranks eleventh (share of 1.5%). Within the next three categories, Caltech’s shares are four percent for employing the most nominees (second rank in this category), three percent for educating the most nominees (rank 6), and 7.6 percent for employing the most nominees in their NP award year (first rank). Calculating the average from the four categories, Caltech’s overall share is about four percent, second only to Paris (4.7%). This calculation leads to the overall rank in Table 5.

For comparison, values for HU Berlin (in the same order as in Table 5) are about 2.5, 3, 3.6, and 6.4 percent, resulting in an average coverage of about 3.9 percent, which places it just behind Caltech on third rank. In general, the top 25 organizations account for 50 percent coverage of the four categories. For individual categories, the distribution becomes more skewed with each stage of the nomination process, as depicted in Table 5.

Table 5: Top 50 organizations ranked after all nomination stages

Organizations	Ranking position for employing the most **nominators**	Ranking position for employing the most **candidates**	Ranking position for educating **(HD)** the most **candidates**	Ranking position for employing the most **candidates in their NP award year**	**Total rank**
University of Paris	1	1	1	4	**1**
Caltech	11	2	6	1	**2**
Humboldt University of Berlin	2	5	5	2	**3**
University of Cambridge	14	6	2	7	**4**
University of California, Berkeley	12	4	10	3	**5**
Harvard University	9	3	7	5	**6**
LMU Munich	8	11	3	10	**7**
MIT	16	8	4	11	**8**
University of London	4	7	25	6	**9**
University of Chicago	5	9	14	17	**10**
University of Göttingen	18	20	8	16	**11**
Leiden University	26	13	11	23	**12**
Yale University	64	24	21	8	**13**
Imperial College London	30	15	18	13	**14**
Stockholm University	3	35	81	12	**15**
ETH Zurich	6	16	30	35	**16**
Leipzig University	22	29	19	14	**17**
Heidelberg University	17	10	29	34	**18**
Columbia University	21	30	9	48	**19**
University of Zurich	33	14	16	32	**20**

Organizations	Ranking position for employing the most **nominators**	Ranking position for employing the most **candidates**	Ranking position for educating **(HD)** the most **candidates**	Ranking position for employing the most **candidates in their NP award year**	**Total rank**
Uppsala University	19	62	15	31	**21**
Cornell University	25	19	62	15	**22**
University of Oxford	36	12	38	25	**23**
Princeton University	35	21	20	42	**24**
University of Copenhagen	38	22	23	33	**25**
Max Planck Society (Institute for Physics)	54	38	143	9	**26**
Stanford University	23	18	118	20	**27**
University of Vienna	20	106	12	-	**28**
University of Helsinki	7	72	55	50	**29**
University of Freiburg	57	27	35	24	**30**
University of Strasbourg	31	64	13	82	**31**
University of Oslo	15	44	31	53	**32**
University of Manchester	50	45	37	18	**33**
Charles University	41	42	40	26	**34**
Sapienza University of Rome	24	51	50	36	**35**
Collège de France	10	40	53	-	**36**
Technical University of Munich	27	56	41	49	**37**
École normale supérieure (ENS)	60	36	34	43	**38**
Rockefeller University	28	17	193	59	**39**
University of Marburg	103	47	17	-	**40**
Polytechnic University of Milan	131	52	51	21	**41**
Max Planck Society (Institute for Chemistry)	104	25	195	28	**42**
University of Bologna	45	41	24	-	**43**
University of Wisconsin-Madison	39	83	36	45	**44**
KTH Royal Institute of Technology	13	31	132	-	**45**
University of Illinois at Urbana-Champaign	47	28	57	62	**46**
Bell Labs	158	23	194	30	**47**

Organizations	Ranking position for employing the most **nominators**	Ranking position for employing the most **candidates**	Ranking position for educating **(HD)** the most **candidates**	Ranking position for employing the most **candidates in their NP award year**	**Total rank**
Russian Academy of Sciences (Lebedev Physical Institute)	159	59	82	19	**48**
Utrecht University	34	33	43	-	**49**
University of Bristol	126	78	95	22	**50**

While it is true that organizations that excel in one dimension are likely to excel in others, there are tendencies among top-tier universities to excel in specific dimensions. For instance, the University of Paris ranks first among all organizations, excelling in three nomination stages - nominating, being nominated, and educating nominated scientists. Nevertheless, the large number of candidates does not translate into an equal number of Nobel Prizes. The University of Paris ranks fourth in successful nominations, indicating that among the number of nominations received by scientists from this university, many do not result in a prize.

Caltech ranks highly in successful nominations, but its number of submitting nominators is comparatively mediocre in comparison to other top universities. This trend is most likely a result of US American universities entering the ranks of nominators rather late after the first decades of nominations, as I have shown in the last chapters. Quite a few US universities at the top display a weakness at nomination power (e.g. Harvard, MIT, Yale) compared to European organizations that rather excel at this nomination stage (London, ETH Zurich, Collège de France, Oslo, and Helsinki). Though, there are US American top universities that are ranked better for submitting nominators than for (successful) nominees, for instance the University of Chicago.

Interesting are also organizations that exhibit a discrepancy in candidate submissions and successful nominations. Some organizations receive fewer nominations than others but are more successful in pushing them through. An apparent example for this are the universities of Stockholm, Uppsala and the Karolinska Institute (ranks on position 54), which might imply that strong candidates from Sweden are more easily selected than those from other countries. But this interpretation must be treated with caution, as there are plenty of other examples from outside the northern countries that display this pattern (e.g. Yale, Leipzig, Cornell, MPI Institutes, Manchester, Prague, Milan, and Russian Academy Institutes).

On the other hand, some universities may have a higher number of nominees but are limited in receiving awards compared to other organizations. This is for instance the case for universities in Leiden, Heidelberg, Zurich, Oxford, Princeton, and Urbana-Champaign.

The top organizations are mainly universities authorized to confer doctoral degrees. Nevertheless, these universities display considerable variation in their capacity to educate candidates. Some universities excel in training candidates even more than in recruiting (successful) nominees. Examples of highly successful universities in this regard include LMU Munich, Cambridge, MIT, Columbia, and Strasbourg. On the other hand, there are institutions that place more emphasis on employing successful candidates but may not be as proficient in educating future nominees and laureates, such as the University of London, Cornell, and Stanford.

Displaying a quantitative perspective, Spearman correlations were computed for comparisons between all four nomination stages, respectively. Results show that rankings align to a great degree, confirming the notion of an organizational elite that excels within the whole nomination process, as all correlations performed lie above a correlation coefficient of 0.3. Especially interesting is which stage's ranking correlates the most with the ranking for employing the most candidates in their NP award year. Based on their correlation coefficients, all three stages have relatively high coefficients, in ascending order, starting with the submission of nominators (0.35), followed by the education of laureates (0.41), and finally, with a high coefficient of 0.6, the employment of candidates. This order may seem intuitive as it reflects a systematic nomination system operating at the organizational level. However, considering studies that emphasize the uncertain outcome of nominations (Seeman & Restrepo, 2023a, 2023b), this result shows that, at least for top organizations, employing the most candidates is a solid predictor of success.

Ranking universities is a prevalent practice in the academic world that is both demanded as well as criticized by academics. Organizations with favorable rankings attract a greater number of students, including those who are highly qualified, thus strengthening the already exceptional quality that led to their high ranking. Regarding the Nobel Prize, which is a key determinant in common rankings like the Shanghai Ranking, university-affiliated recipients of the prize benefit future students by inspiring higher levels of expertise and motivation, thus fostering mentoring networks, as explained by Zuckerman (1977). This process can be understood as a cumulative effect of success (Merton, 1968a).

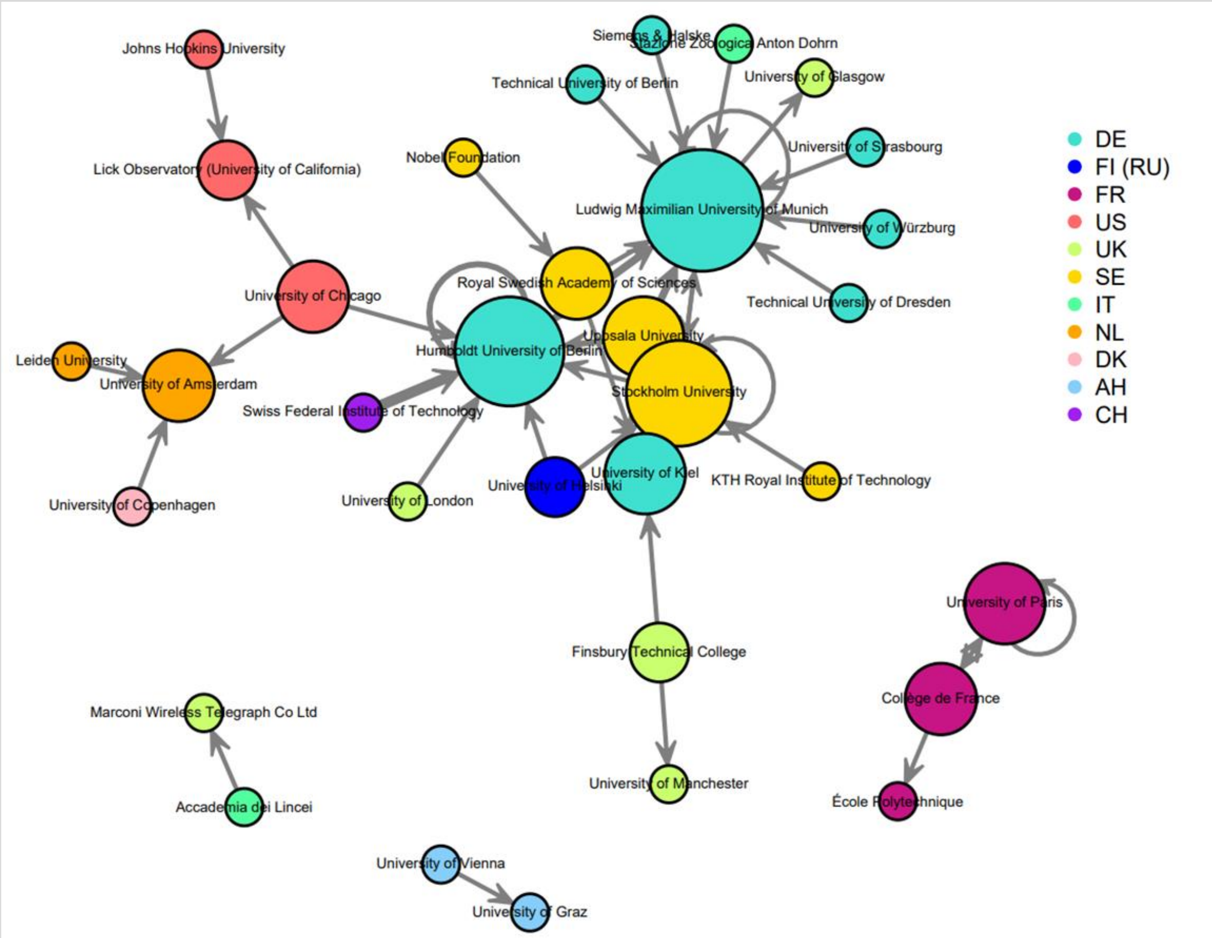
To gain a better understanding of organizational stratifications within the nomination network, consulting reputational rankings of universities would be beneficial. However, these rankings did not exist during my observation period and are therefore not a suitable measure of organizational reputation.

A preliminary assessment of universities' positions within the scientific organizational hierarchy was conducted in the previous chapter. The comparison measured top nominating organizations against a list of top-prize-winning organizations, indicating potential benefits of nomination power as well as signaling a stratification within self-nominations. Subsequently, it is revealed that some universities have high proficiency in both nominating and achieving, while others excel more in one of these domains.

From a network perspective, certain universities may function as hubs by exerting their nomination power, while others serve as authorities by consolidating multiple nominations. An exemplary network depiction of 1901 displays this on the level of organizations. In Figure 22, each node (circle) corresponds to a single organization with directed edges (lines) going from the nominating organization to the nominated organization. The width of the edges signifies the number of individual nominations exchanged between the organizations. Edges with arrows on both ends indicate a mutual relationship where the organizations nominate each other. Edges that encircle a node (loops) and point to itself represent self-nominations, as seen at the University of Paris (the largest pink node). Nodes are named for clarity, as the 1901 network is relatively small. A node's size is determined by its degree, which is the total number of nominations it sends and receives. A node's color reflects its national affiliation at the time of nomination in 1901, representing its historical association (for example, the University of Strasbourg is affiliated with Germany at this time period).

The depiction confirms pre-existing findings that nominations tend to cluster based on national affiliation, as is immediately apparent. German hegemony is also visible, with two authorities, HU Berlin and LMU Munich, frequently being nominated by other (German) universities and nominating each other. Swedish organizations, on the other hand, act as hubs in emphasizing the significance of German authorities. Other organizations such as Finsbury Technical College, University of Chicago, and Swiss Federal Institute also serve as hubs.

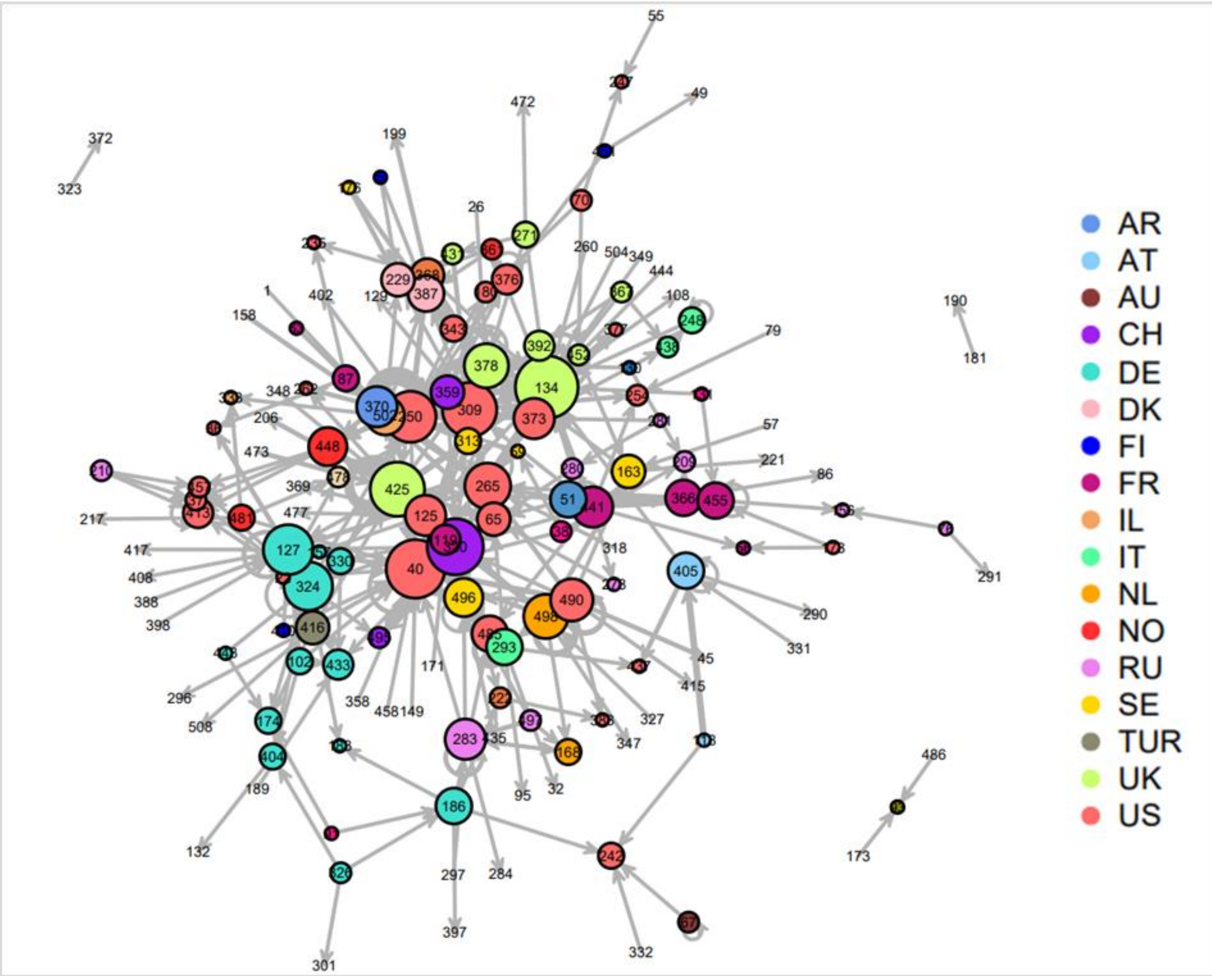
Figure 22: Nomination network of 1901 on organizational level



This figure displays the organizational nomination network of 1901. Nodes are labeled with the names of organizations and colored according to their respective national affiliations, dating back to 1901. A node's size is determined by its degree, which is the total number of nominations it sends and receives. The edges represent nominations and are directed towards the receiving organization. The width of the edges represents the number of nominations between the two connected organizations. Edges with arrows on both ends indicate a mutual relationship where organizations nominate each other. Loops indicate self-nominations, where scientists nominate their colleagues from the same organization.

As nomination networks continue to expand each year, it becomes challenging to depict all organization names. To provide an overview with enhanced details, every organization is assigned a number, listed in Table 24 in the appendix, to ensure readability of dense network graphs henceforth. An example that reinforces the findings of network growth is the network graph of the year 1969 in Figure 23, which corresponds to that of 1901. Although the graph is much harder to read because of the many edges between nodes, it is clearly visible that organizations with the same national affiliation are close together. Central organizations come from dominant countries such as the United States, Germany, France, the UK, and Switzerland, with the most central organizations by degree being Stanford University (number 309), Imperial College London (134), Technical University of Berlin (324), University of Montpellier (441), and Swiss Federal Institute of Technology (320). Analogous to Figure 22, the top universities often specialize in being a central hub or authority. The size of the University of Montpellier in Figure 23 is due to its frequency in submitting nominators, which fits the role of a hub. Other universities, such as Imperial College London, are more likely to be nominated than to nominate others.

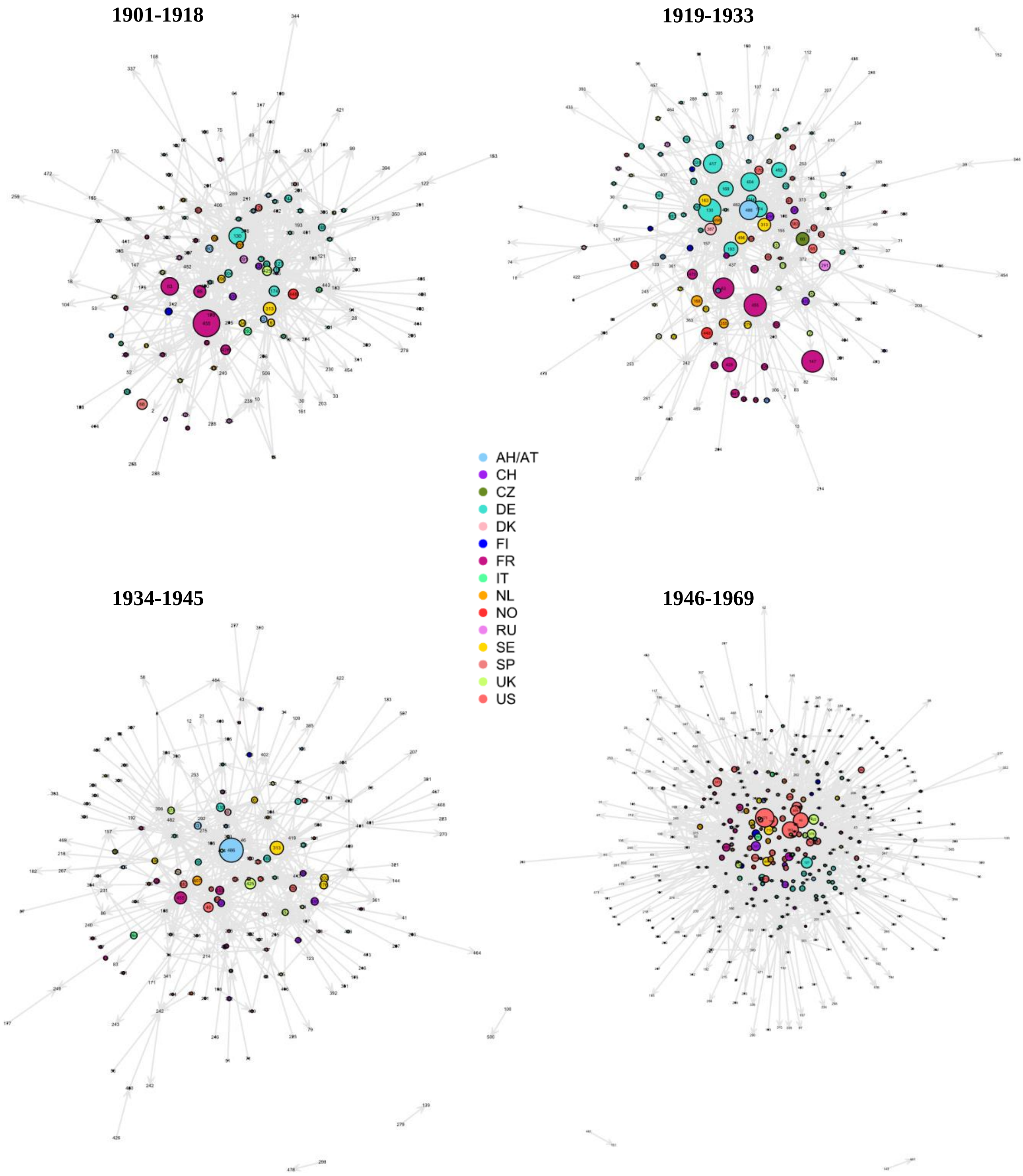
Figure 23: Nomination network of 1969 on organizational level



This figure displays the organizational nomination network of 1969. Nodes are labeled with numbers (see Table 24) and colored according to their respective national affiliations, dating back to 1969. A node's size is determined by its degree, which is the total number of nominations it sends and receives. The edges represent nominations and are directed towards the receiving organization. The width of the edges represents the number of nominations between the two connected organizations. Edges with arrows on both ends indicate a mutual relationship where organizations nominate each other. Loops indicate self-nominations, where scientists nominate their colleagues from the same organization.

To get an overview of this disparity, I plotted the networks over a broader time series and set the size of the organizations (nodes) to Kleinberg's hub and authority centrality scores, respectively. The individual periods in Figures 24 and 25 can be viewed in higher resolution in Figure 37 and Figure 38 in the appendix. Figure 24 displays the results for Kleinberg's hub centrality.

Figure 24: Organizational hubs within time periods



This figure displays the organizational nomination network in four subsequent time periods. Nodes are labeled with numbers (see Table 24) and colored according to their respective national affiliations. A node's size is determined by its Kleinberg's hub centrality score. Country labels are only displayed for the largest hubs.

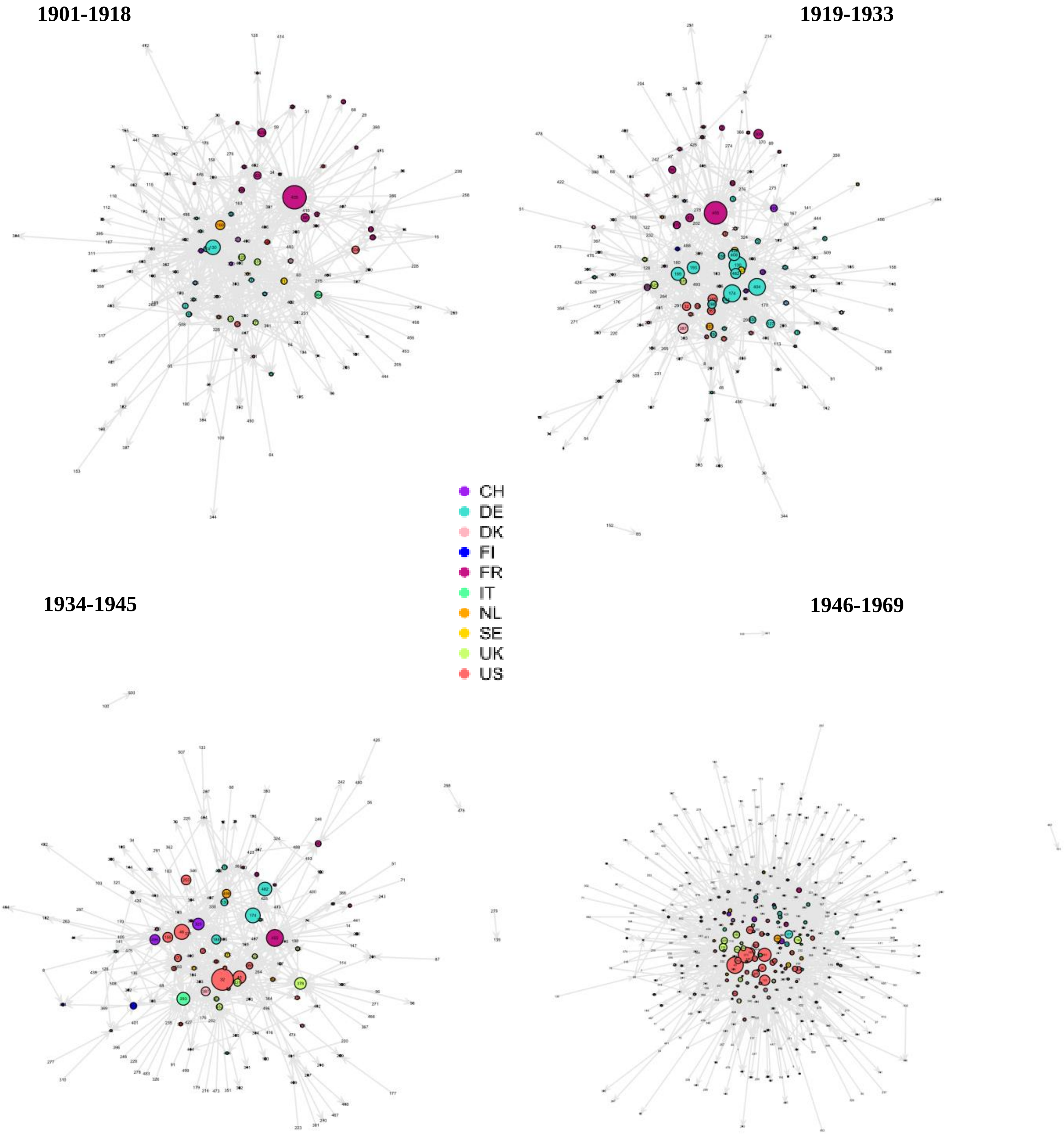
The first observed period starts in 1901 and ends with World War I in 1918. As emphasized earlier, hubs represent important countries in submitting nominators, such as France, Germany, and Sweden, each of which has several organizational hubs, such as the University of Paris (number 455), HU Berlin (130), and Stockholm University (313). To a lesser extent, Italy, the UK, Norway, and Spain each have at least one hub with a relatively high centrality score, often the university of the capital city, such as Madrid (68), London (425), Rome (293), and Oslo (448).

The second period extends to 1933, marking a period between the two world wars, and ends with the Nazi rise to power, resulting in the third period to the end of World War II in 1945.

Following results for the shift in scientific leadership from Germany to the United States ((Ben-David, 1960; Hollingsworth, 2006) already found within the descriptive analysis of nomination power, we see a similar pattern here. In the second period, Central and Northern European hubs predominate with Germany in the lead, but also expanding to hubs such as Charles University (60), as well as including the eastern border of Europe, such as St. Petersburg State University (291). In the third period, hubs concentrate on fewer organizations, and formerly flourishing hubs in Germany and France shrink significantly. For instance, HU Berlin (130), which was once a pivotal organization, is now small compared to powerful hubs such as the University of Vienna (486). Meanwhile, hubs in the United States, such as Caltech (40), are experiencing gradual growth. This trend continues into the next time period, which covers post-war nominations up to the end of the observation period in 1969. The United States holds a hegemonic position, with several hubs including Chicago (383), MIT (180), Stanford (309), and Berkeley (373).

Figure 25 demonstrates consistent findings for time periods related to Kleinberg's authority centrality, denoting frequently nominated organizations. Similar to hub centrality results, the change from German to US American prevalence becomes noticeable in the time period 1934-1945 and amplifies within the time period 1945-1969: Germany's number of authorities reduces intensely between 1919-1933 and 1934-1945. Organizations that last the longest within the center of nominations are the University of Tübingen (482), LMU Munich (174), and MPI for Chemistry (188).

Figure 25: Organizational authorities within time periods



This figure displays the organizational nomination network in four subsequent time periods. Nodes are labeled with numbers (see Table 24) and colored according to their respective national affiliations. A node's size is determined by its Kleinberg's authority centrality score. Country labels are only displayed for the largest authorities.

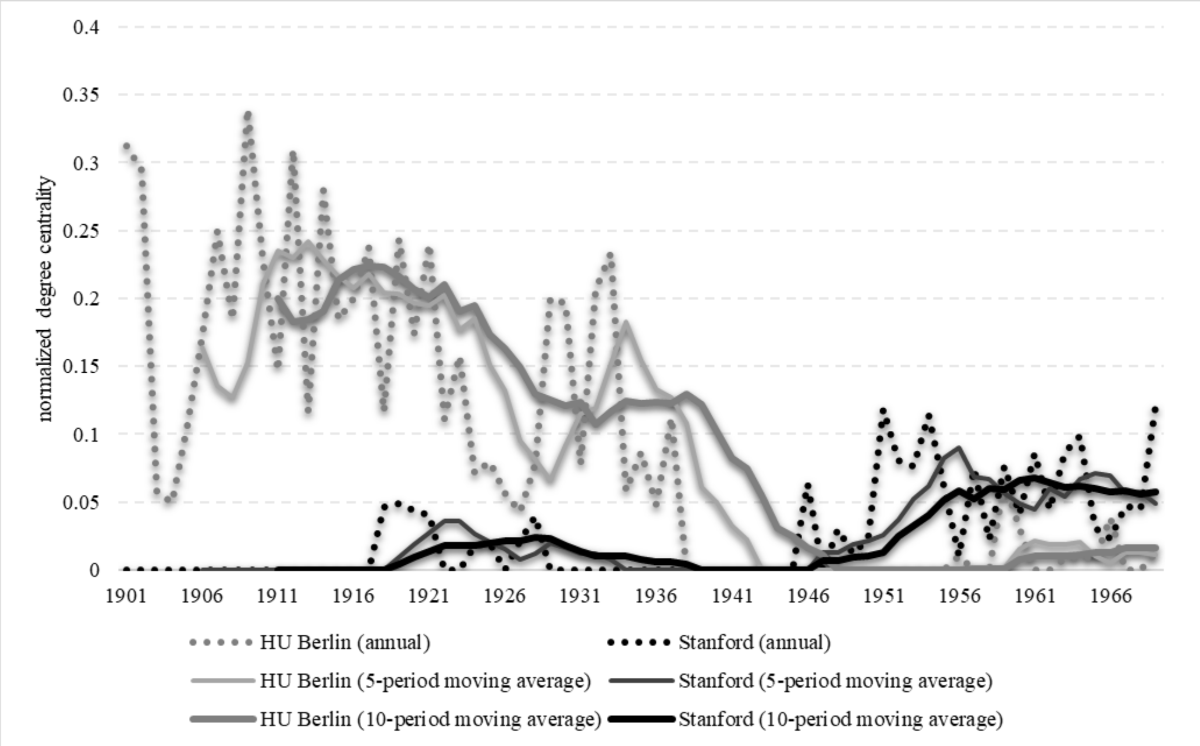
US American authorities after 1945 include Caltech (40), Berkeley (373), Princeton (250), Rockefeller (265), Bell Labs (32), Carnegie Mellon University (46), and Argonne National Laboratory (22), among a multitude of other organizations. This indicates that the shift was not driven solely by state-governed universities (as was the situation in Germany), but also by industry and private funding, which emphasizes structural advantages of the United States because plurality in funding as well as multiple organizational types foster productive competition within the scientific system (Ben-David, 1971; Hollingsworth, 2006). At the individual level, many nominees of US organizations have a migration history, such as Otto Stern, who fled from Germany to the United States and worked at Carnegie Mellon University.

To examine the structural characteristics of organizational nodes in the nomination network over time, I analyze their degree centrality - the number of adjacent edges. High degree values indicate centrality in the nomination process, while low values correspond to limited influence and a positioning in the periphery of the network. I calculate values annually, resulting in 69 values per organization. As networks grow larger over time, their degrees also increase. Therefore, I utilize normalized degree centrality, which involves dividing the degree value by n-1, where n represents the number of nodes in the respective graph. This approach guarantees comparability of annual values throughout the entire observation period. In order to concentrate on the organizational impact of submitting nominators (hubs) and nominees (authorities), indegrees and outdegrees are calculated separately. High indegree values (directed edges pointing towards the respective organization) are indicative of organizations that employ numerous nominees and rather serve as an authority, while high outdegree values (directed edges pointing away from the respective organization) suggest that they employ many nominators and serve as a hub.

Figure 26 displays annual degree values for HU Berlin (dotted grey line) and Stanford University (dotted black line) as an example, for their historical courses are already known to the reader. Annual values fluctuate frequently during the nomination process, making them difficult to interpret and unsuitable for analysis. For instance, the significant decrease in HU Berlin's graph in 1903 is more likely due to random fluctuation than to a sudden decline in influence.

To account for these fluctuations, moving averages have been calculated that cover the last five and ten annual degree values of the organizations (for all three degree measurements), as shown in the graph as thin and thick solid lines. Accordingly, these scores start after 5 and 10 years, respectively.

Figure 26: Degree centrality 1901-1969, exemplified for HU Berlin and Stanford



This figure shows a comparison of different presentations of degree centrality for HU Berlin (gray graphs) and Stanford University (black graphs). Annual degree values are shown as dotted lines, 5-period moving averages as thin solid lines, and 10-period moving averages as thick solid lines.

These averages serve as a reputational benchmark, showing how organizations' structural characteristics have evolved over the past years. Organizations can be categorized based on their prior network position, which reveals the potential impact of their reputation.

The various degree measurement calculations produce nine annual values for each organization. These comprise annually calculated values and 5-period and 10-period moving averages of previous measurements for degree centrality, indegree centrality, and outdegree centrality (all based on normalized calculations). Table 6 displays a comparison of these values for HU Berlin as an example. Considering this variety of measurements, I focus on 10-period moving averages because they show the smoothest positioning of organizations over time and are best suited for a long-term reputational benchmark. I only use annual values and 5-period moving averages to conduct robustness checks. To obtain an overview, I utilize degree centrality, while indegree and outdegree measurements are used to answer specific questions about the roles of nominees (and organizational authorities) as well as nominators (organizational hubs).

Table 6: Comparison of centrality values exemplified for HU Berlin

Measurement	Values for 1911	Values for 1969
Annual degree	0.15	0.01
Annual indegree	0.07	0.00
Annual outdegree	0.07	0.01
5-period moving average (degree)	0.24	0.01
5-period moving average (indegree)	0.07	0.01
5-period moving average (outdegree)	0.09	0.01
10-period moving average (degree)	0.20	0.02
10-period moving average (indegree)	0.11	0.01
10-period moving average (outdegree)	0.09	0.01

This table shows a comparison of centrality measures using HU Berlin as an example. Different calculations refer to annual values or moving averages (5 or 10 periods) as well as to degree, indegree or outdegree values (normalized).

To enhance the insight into the structure of the nomination network, I assign organizations to quartiles based on their 10-period moving average degree. This enables tracking of nomination patterns for peripheral, middle-low, middle-high, and central organizations regarding a prestige-driven stratification. Each quartile corresponds to 25 percent of the entries with central organizations having the highest degrees and peripheral organizations having the lowest. For instance, HU Berlin’s organizational status would be classified as central in 1911 and as middle-low in 1969. For both indegree and outdegree measurements in particular, there are no differences in the classification of HU Berlin, except that the 1969 indegree organizational status is peripheral instead of middle-low.

Once the hierarchical positioning of organizations within the nomination network over time is clear, another interesting question arises as to whether nominations cluster more frequently within the same category or if nominations do not show any pattern among hierarchical categories. As there are two sides of a nomination with the nominating organizations (those that submit the nominator) as the active part, it is interesting to see if there is a tendency to nominate universities from an equally high or low structural position. Nomination patterns showing social closure, where nominations are favorably exchanged within categories of organizational status, would suggest a hierarchy within the network and be consistent with patterns of social closure (Weber, 1946 [1916]) found in other social networks within academia (Burris, 2004). Table 7 is a crosstab that shows on a descriptive level how nominations are distributed among the four quartiles of organizational status.

Table 7: Nomination patterns according to organizational status measured with degree centrality

	Nominees' side				
Nominators' side		**Periphery**	**Middle-low**	**Middle-high**	**Center**
	Periphery	582	446	445	426
	Middle-low	497	575	397	428
	Middle-high	441	466	580	407
	Center	370	410	464	647

This crosstabulation displays the distribution of nominations between organizational status groups. The rows represent nominators' status, while the columns represent nominees' status. Counts show the magnitude of nominations passing between each pair of status groups. The measurement of organizational status is based on degree centrality.

On initial inspection, it is evident that nominators (on the left, vertically) show a preference for candidates whose workplace organizational status aligns with their own. For instance, nominators from peripheral organizations (based on their degree centrality in the past decade) submit the highest number of nominations for other scientists from peripheral organizations. Most nominations occur within the category of nominators from central organizations voting for scientists from similarly central organizations, supporting the notion of a highly-connected organizational elite within the network. A chi-square test was conducted to determine if differences between categories were statistically significant, and showed that they do differ at a significant level.

As a robustness check, specialized degree values were used to see if differences persisted, with the result that for the extreme groups of peripheral and central organizations, the contrast increases, and for the intermediate status groups, the differences tend to diminish when utilizing indegree and outdegree centrality.

The previous chapter discussed whether organizations differ in their propensity to self-nominate. Results showed that high self-nomination rates are correlated with producing high-quality research as well as educating and employing laureates. Table 8 and Table 9 enhance this finding with crosstabulations of organizational status categories and the propensity to self-nominate, showing that prestige drives self-nominations. After conducting chi-square tests to confirm significant differences between the four categories in both tables, Phi coefficients were calculated for peripheral and central organizations separately. The coefficients showed reasonably substantial differences, with 0.18 and 0.2 for national and institutional self-nominations, respectively.

Table 8: Distribution of self-nominations regarding national affiliation for organizational status

	Periphery	Middle-low	Middle-high	Center
No self-nomination	1184	1095	1063	830
Self-nomination	761	851	878	1114
Self-nomination rate	39.13%	43.73%	45.23%	57.3%

This crosstabulation displays the distribution of self-nominations between organizational status groups. The rows represent nominations categorized as either no self-nominations or self-nominations as well as self-nomination rates, while the columns represent nominators' organizational status groups. The measurement of organizational status is based on degree centrality. Self-nominations are assessed on national level (nominating within country borders).

Table 8 shows that central organizations nominate within their own country borders for nearly 60 percent, while peripheral organizations have below-average self-nomination rate (40%) on the national level.

Table 9: Distribution of self-nominations regarding organizational affiliation for organizational status

	Periphery	Middle-low	Middle-high	Center
No self-nomination	1846	1751	1695	1593
Self-nomination	99	195	246	351
Self-nomination rate	5.09%	10.02%	12.67%	18.06%

This crosstabulation displays the distribution of self-nominations between organizational status groups. The rows represent nominations categorized as either no self-nominations or self-nominations as well as self-nomination rates, while the columns represent organizational status groups. The measurement of organizational status is based on degree centrality. Self-nominations are assessed on organizational level (nominating colleagues from the same organization).

Table 9 shows the distribution of self-nominations based on organizational affiliation. In central organizations, self-nominations are more frequent than in peripheral organizations, resulting in higher rates that are above average for central organizations (18%) and below average for peripheral organizations (5%). In terms of organizational self-nominations, i.e. scientists nominating their current colleagues from the same organization, this implies that central organizations use their nomination power to a greater extent to promote their own achievements. This observation is consistent with the findings in chapter 7.2. It highlights a hierarchy based on scientific excellence, indicating an organizational elite.

Examining the visible indications of hierarchy in the nomination network raises the question of who initiates change within it, especially by nominating organizations that have not been previously recognized, thus demonstrating an exploratory approach (March, 1991). March's research emphasizes the importance of investigating the processes of change and renewal within organizational systems. Identifying the agents responsible for nominating previously unrecognized organizations sheds light on the dynamics of innovation and the introduction of new actors into the nomination process.

A specific variable is used to classify newcomer organizations (refer to chapter 6.2 for calculation details), as according to their organizational status, they cannot be distinguished from organizations with a degree measurement of zero (category of peripheral organizations).

Data revealed that new organizations represent only a small fraction of all organizations. As for their nomination behavior, it is indistinguishable whether new nominating organizations nominate new candidates' organizations at a higher proportion than others. Therefore, the renewal of organizations within the nomination process is not driven by new organizations per se but comes from established organizations.

Table 10 shows the descriptive results, which indicate that the periphery of the nomination network plays a substantial role in promoting organizational renewal, which is consistent with the presence of social closure and the distinction between status categories (Bourdieu, 1986; Weber, 1999 [1922]). Differences between the four categories of organizational status are found to be significant based on the results of a chi-squared test. A Phi coefficient of -0.06 indicates a rather small effect size.

Central organizations often nominate other central organizations, perpetuating the existing hierarchy and acting as drivers of inertia. The lower share of nominations given to newcomer organizations is consistent with this exploitative pattern.

In contrast, peripheral organizations have a higher rate of nominating newcomers, which aligns with status distinctions but also allows for organizational renewal by introducing new actors. Newcomers can initially disrupt stratification and in the end become elitist organizations themselves, as occurred in the case of Caltech, which entered the network in the early 1920s and became one of the top five nominating organizations in the 1940s (Table 22).

Table 10: cross tabulation between organizational status and newcomer organizations

	Nominees' side			
Nominators' side		**Established Organizations**	**Newcomer Organizations**	**Share of Newcomers**
	Periphery	1738	207	10.64%
	Middle-low	1789	157	8.07%
	Middle-high	1767	174	8.96%
	Center	1802	142	7.3%

This crosstabulation displays the distribution nominating newcomer organizations between organizational status groups. The rows represent nominators' organizational status groups, while the columns represent the counts of nominated established and newcomer organizations. The measurement of organizational status is based on degree centrality.

This chapter has deepened the understanding of organizational hierarchies within the nomination network. Regarding hypothesis H3c, it proved that, firstly, high-prestige organizations of the network's center self-nominate more frequently, showing patterns of social closure, prestige-sensitive reproduction and exploitation of the existing stratification, and, secondly, that peripheral organizations show fewer self-nominations, but serve as drivers of organizational renewal by introducing new actors that potentially rattle the existing stratification. Self-nominations are therefore skewed across organizations, resulting in a concentration of self-nominations in a selective group of organizations, confirming hypothesis H3c.

7.4 Regression analysis of Nobel Nominators' Placement Power

In the previous chapters, I introduced nomination power as a potent, yet understudied factor in the nomination process. In this chapter, I aim to expand on the extent to which nominators succeed in securing acceptance for their candidates, as well as the factors that impact the outcome of award selection. The capacity to submit successful nominations is referred to as placement power, in line with studies that analyze graduate placement within academia (Clauset et al., 2015; Wapman et al., 2022). These studies have revealed stark hierarchies, in which prestigious universities succeed in placing their own PhDs among the whole stratum, while less prestigious universities rarely achieve upward mobility for their graduates (see chapter 4.3 for details).

The question at hand is complex because many factors may influence the selection of high-caliber nominees who will receive an award in a given year and who will not. Therefore, various factors are applied, not only depicting nominators' placement power but also investigating how nominees' characteristics determine their likelihood of winning an award. Regarding hypotheses H1b, H2b, H3d, and H3e (refer to Table 2), I expect nominators to vary in their placement power, that is their capability to successfully nominate, for example regarding RSAS membership. Specifically, placement power is expected to be unevenly distributed among organizations, resulting in a concentration of successfully placed nominations from a small number of organizations at the top of the prestige hierarchy, resembling encrusted hierarchies. Newcomer organizations, which represent organizational renewal, accordingly are expected to exhibit lower placement power than established organizations.

At the organizational level, there is a tendency to accumulate the benefits of a good ranking regarding nomination power, which has already been observed descriptively. This investigation aims to determine whether these benefits also apply to placement power. In relation to the previously confirmed shift in scientific hegemony, I anticipate to find a corresponding shift in placement power during the first half of the 20th century from Germany towards the United States.

Logistic regression models are used in the following to investigate various factors that impact award-winning. First, analysis grounds on the basis of nominations with models comprising effects for both nominees and nominators. In a second steps, the two roles are investigated separately, with special emphasis on nominators' placement power. Variable selection and modeling are based on the three core theoretical approaches and the hypotheses derived from them, resulting in three model frameworks. Model 1 covers particularistic influences on the selection process, referring to individual-based variables that identify influential actors with special nomination rights (laureates and RSAS members), a personal self-nomination pattern of mentoring ties, and individual nomination frequencies, as permanent nomination rights are linked to greater nomination opportunities. In model 1, special emphasis lies on investigating hypothesis H1b (influence of RSAS). Hypothesis H1a, which analyzes a bias towards male representation within the nomination process, is not included in the model due to the lack of female representation among nominators (only two nominations by female nominators were successful which is just not enough data for quantitative analysis).

Model 2 depicts global scientific leadership, and thus focuses on H2b, which expects placement power to be distributed in favor of the leading countries, Germany and the United States, and thus shows a time variance as leadership shifts historically.

Model 3 focuses on the organizational level, with an emphasis on effects that show stratification in favor of highly prestigious universities and social closure demonstrated by self-nominations. First and foremost, I expect to find that prestigious organizations at the top of the hierarchy exhibit a high degree of placement power, as the analysis of nomination power revealed the existence of an organizational elite that descriptively dominates the process. In particular, placement power is expected to be concentrated in central organizational hubs (H3d). In contrast, newcomer organizations are disadvantaged in terms of placement power (H3e). Different operationalizations and results for models 1 to 3 will be discussed in detail in the following chapters.

7.4.1 Focus on successful nominations

Using my dataset on Nobel Prize nominations, which analyzes the roles of nominators and nominees at various levels, I present many variables that could potentially affect award decisions. Variables represent three levels of analysis (individual, organizational, and national). A question arises as to which of these levels show meaningful effects on awarding. A previous approach relied on anecdotal evidence and individual-level arguments, focusing on highly influential individuals within the Nobel committees and awarding bodies (Friedman, 2001).

First quantitative models that emphasize chances of winning work with data on nominees' candidacies (Chen et al., 2023). The perspective is therefore person-driven, asking why certain candidates receive a prize while others do not. In my analysis, I enhance this perspective with a nomination-driven approach, focusing on the question what makes a nomination successful while others are not. In a second step within the next chapter (7.4.2), I edit data to present distinct cases for nominees and nominators, respectively, while maintaining the general viewpoint of nomination-based claims.

Initially, I will investigate possible variables and their impact on general regression models on the basis of all nominations, with the dependent variable of winning the Nobel Prize. Successful nominations, as outlined in chapter 6.2, are those that result directly in a Nobel Prize in a given year, regardless of whether the nomination was submitted for Physics or Chemistry. The only exception is if the award ceremony was postponed for a year (often due to war), and laureates were honored in the subsequent year. Chapter 6.2 includes detailed examples on categorization. The original set of 8832 nominations is reduced to 8110 due to the ten-year observation period for the organizational affiliation status variable as well as missing values. Therefore, data for analysis starts in 1911, which is appropriate for long-term observation of nomination data. The first ten years were fluctuating and unpredictable, as indicated by the descriptive data, but after this period, the process smoothed out. Thus, I begin with analysis thereafter.

Variables as well as results for the logistic regression models 1 to 3 are listed in Table 11. First, I will describe the variables in the table in the order in which they appear, starting with the nominees' variables. The number of nominations a nominee has received in the past is used as a numerical variable in the analysis. As a robustness check, the variable was divided into categories (four categories, chosen to be relatively equally distributed). The assumption behind this frequency variable is that nominations may become more pressing over time and demonstrate to committees that candidates are receiving attention over a wider time frame.

Nominees' affiliation with the RSAS is analyzed as a binary variable of membership within the RSAS at the time of nomination, assuming that membership has a positive impact on candidates' chances of winning.

On an organizational level, the nominees' chances could potentially be influenced by their affiliation status. Initially, their alma mater (the university where they received their highest degree) is examined. The variable 'HD in high-status university' analyzes if nominations going to graduates from the eight universities that trained the most candidates (Paris, HU Berlin, LMU Munich, Cambridge, MIT, Caltech, Göttingen, and Harvard) have higher chances of success than those going to graduates of other universities.

Furthermore, the analysis considers the current workplace status of each nominee, ranging from peripheral to central organizations based on their performance within the nomination network in the last ten years. The crucial factor observed for nominees' organizational status is indegree centrality, which characterizes high-performing organizations as authorities.

Newcomer organizations are distinguished from other peripheral-level organizations with an indegree centrality of zero. For this reason, I analyze them in a special variable that captures newcomer organizations.

National affiliation indicates the country of the nominee's current employment at the time of nomination. Countries of special interest are compared to the reference category of all other countries combined. The most frequently affiliated nations, Germany, the United States, the United Kingdom, and France receive special emphasis. Northern countries (Sweden, Finland, Denmark, Iceland, and Norway) are also emphasized because of their special role within the nomination process. As a Nobel laureate once advised young, ambitious researchers: “Always be nice to Swedish scientists” (Roberts, 2015). This brief account focuses on the potential impact that nominators (as well as nominees) from northern countries may exert on the nomination process.

In the second part of Table 11, factors that might influence the chances of winning an NP are added from the perspective of the nominators, assessing whether they have some kind of power to place candidates that positively or negatively affects nominations’ success. To ensure comparability, most of the variables chosen match those of the nominee variables. This consists of RSAS membership, past nomination frequency (in the role of *submitting* nominations as a numerical variable as well as a categorical for robustness checks), organizational status (determined by outdegree centrality), affiliation with newcomer organizations, and national affiliation. Notably, nominators' highest degree information is unavailable and thus not part of the analysis. However, the laureate status of nominators is being examined as a variable to ascertain whether being nominated by a former laureate influences a nominee's chances.

Two variables were included in the study to examine the effect of self-nominations on award decisions on both national and organizational level. Additionally, the mentoring variable was utilized to evaluate the impact of nominations exchanged between mentors and mentees on the probability of winning.

The comparison of the three models shows that model 1, which examines only individual-level effects, provides a considerable amount of explanatory power, with pseudo R-squared values of about 0.08 to 0.12, which is equal to model 3, which considers organizational factors. Model 2, representing the country level, has a low explanatory power with a pseudo R-squared value of about 0.02. This implies that macro-level factors, especially at the organizational level, should be considered in addition to individual-level factors affecting individual scientists, supporting the expanded use of multilevel models to ensure that the complex mechanisms and their interrelationships are adequately captured.

Regression coefficients across the three models indicate that all variables, except national affiliation and nominators' organizational status, have a significant impact on making successful nominations. Significance values are reported even though the study is not a random sample, as it represents all nominations in physics and chemistry.

Model 1 indicates that there are particularistic elements within the nomination process that increase the success of a nomination. Findings from literature suggesting that nominations endorsed by laureates are increasingly successful are confirmed in this model. On top, RSAS membership has a positive effect on nomination success for both nominees and nominators, providing further support for Hypothesis H1b, which expected RSAS members to play a prominent role in the nomination process.

It is worth noting that the number of previous nominations of nominators has a negative effect on the probability of winning. This finding suggests that privileged individuals who frequently nominate candidates do not necessarily increase their chances of success.

Table 11: Logistic regression models for chances of making a successful nomination

	(1)	(2)	(3)
Nominees' variables			
Number of past nominations (numerical)	0.04*** (0.00)	-	-
Membership in the RSAS	0.25** (0.10)	-	-
HD in high-status Uni	-	-	0.36*** (0.07)
Organizational status Reference category: peripheral			
Middle-low	-	-	1.11*** (0.17)
Middle-high	-	-	1.55*** (0.17)
Central	-	-	2.20*** (0.16)
Newcomer organizations	-	-	0.78*** (0.20)
Country Reference category: all other countries			
Germany	-	0.62*** (0.13)	-
USA	-	0.59*** (0.12)	-
Northern countries	-	-0.15 (0.18)	-
UK	-	0.70*** (0.14)	-
France	-	-0.08 (0.18)	-

	(1)	(2)	(3)
Nominators‘ variables			
Number of past nominations (numerical)	-0.04*** (0.01)	-	-
Membership in the RSAS	0.44*** (0.09)	-	-
Laureates	0.41** (0.09)	-	-
Organizational status Reference category: peripheral			
Middle-low	-	-	0.21 (0.12)
Middle-high	-	-	0.29* (0.12)
Central	-	-	0.15 (0.12)
Newcomer organizations	-	-	0.53*** (0.14)
Country Reference category: all other countries			
Germany	-	-0.22 (0.12)	-
USA	-	-0.13 (0.11)	-
Northern countries	-	0.56*** (0.11)	-
UK	-	-0.18 (0.15)	-
France	-	0.17 (0.14)	-
Self-nominations (national level)	-	-	-0.48*** (0.08)
Self-nominations (organizational level)	-	-	-0.98*** (0.15)
Mentoring-relation	-0.68** (0.23)	-	-
N	8110	8110	8110
McFadden Pseudo R^2	0.08	0.02	0.08
Nagelkerke Pseudo R^2	0.12	0.02	0.11
BIC	5483	5919	5548
AIC	5433	5842	5463

Standard errors in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In terms of model 2 which shows results at the country level, Germany, the United States, and the United Kingdom stand out as successful nominee countries compared to the reference group of other countries. The only region that has a positive effect on its residential nominators is that of northern countries. These results require further examination to determine potential effects over time. To achieve this, model 2 will be enriched with a time variable that captures the shift in scientific hegemony and possible effects on placement power, especially taking into account the development of Germany and the United States as scientific hegemons in the early 20th century (Table 13).

At the organizational level (model 3), graduating from a top university that trains Nobel candidates has a positive influence on the probability of becoming a laureate. Central organizational authorities are more likely to produce laureates from their current staff than peripheral organizations, which at first glance supports the notion of a stratification within the selection process.

However, a select group of peripheral organizations, which are new to the network, also enhance the likelihood of success for their employees. On top, nominators' current place of employment shows no sign of an organizational status hierarchy. In this model, central organizational hubs do not exhibit increased placement power. Although each category has a higher likelihood of success than peripheral organizations, it is noteworthy that the coefficient for central organizations is minimal and insignificant. To validate this finding, outdegree centrality was replaced with the more general degree centrality, but the results remained stable. Only newcomer organizations have a clear impact on success, which contradicts H3d and H3e, stating that new organizations are disadvantaged compared to established organizations. This observation is consistent with a related finding, which shows that self-nominations have a negative impact on the chances of success. Self-nominations are a form of status-matching nomination behavior that supports social closure of the nomination process and is more prevalent in central organizations. They are one mechanism for reinforcing the nomination power of elitist organizations that represent the top of a hierarchy that became apparent at the descriptive level. However, regarding placement power, self-nominations seem to be sanctioned.

To support these interpretations, Table 12 displays the marginal effects for variables used in model 1-3. In general, most significant effects are rather small, such as nominations endorsed by RSAS members have a five percent higher chance to be successful than for non-members. Though the effect is rather small, it still supports hypothesis H1b.

The highest categorical effects for models 1 to 3 are at the organizational level: Nominees from central organizations have a nearly 20 percent higher chance of being successfully nominated compared to those from peripheral organizations. Yet, there is further evidence to reject hypothesis H3d, which states that nominators’ placement power is unevenly distributed by organizational status, with advantages for central organizations. The effects of nominators' organizational status are not significant, as indicated by the upper and lower limits of the 95 percent confidence interval of the AME passing through zero and into negative values. The small AMEs ranging from 0.03 to 0.01 are inconsistent, providing additional evidence for rejecting H3d. Additionally, newcomer organizations have higher placement power than established organizations, with a six percent higher chance of a successful nomination on average. This finding also rejects hypothesis H3e, which posits that established organizations exhibit higher placement power than newcomers.

Table 12: Average marginal effects (AME) for variables used in Table 11 (model 1-3)

	AME	StE	p-value	Lower limit	Upper limit
Nominees‘ variables					
Number of past nominations (numerical)	0.00	0.00	0.00	0.00	0.00
Membership in the RSAS	0.03	0.01	0.01	0.01	0.05
HD in high-status Uni	0.04	0.008	0.00	0.02	0.05
Organizational status					
Reference category: peripheral					
Middle-low	0.06	0.01	0.00	0.05	0.08
Middle-high	0.10	0.01	0.00	0.08	0.12
Central	0.20	0.01	0.00	0.17	0.22
Newcomer organizations	0.10	0.03	0.00	0.04	0.15
Country					
Reference category: all other countries					
Germany	0.06	0.01	0.00	0.04	0.08
USA	0.06	0.01	0.00	0.04	0.08
Northern countries	-0.01	0.01	0.42	-0.04	0.02
UK	0.07	0.02	0.00	0.04	0.10
France	-0.01	0.01	0.67	-0.03	0.02
Nominators‘ variables					
Number of past nominations (numerical)	-0.00	0.00	0.00	-0.01	-0.00
Membership in the RSAS	0.05	0.01	0.00	0.03	0.07
Laureates	0.04	0.01	0.00	0.02	0.06
Organizational status					
Reference category: peripheral					
Middle-low	0.02	0.01	0.07	-0.00	0.04
Middle-high	0.03	0.01	0.01	0.01	0.05
Central	0.01	0.01	0.19	-0.01	0.04
Newcomer organizations	0.06	0.03	0.00	0.03	0.10
Country					
Reference category: all other countries					
Germany	-0.02	0.01	0.57	-0.04	0.00
USA	-0.01	0.01	0.21	-0.03	0.01
Northern countries	0.07	0.02	0.00	0.04	0.10
UK	-0.01	0.01	0.23	-0.05	0.01
France	0.01	0.02	0.24	-0.01	0.05
Self-nominations (national level)	-0.05	0.01	0.00	-0.06	-0.03
Self-nominations (organizational level)	-0.08	0.01	0.00	-0.10	-0.06
Mentoring-relation	-0.07	0.02	0.00	-0.01	-0.00

This table shows average marginal effects (AME) for variables used in Table 11 (model 1-3). AMEs are presented with corresponding standard errors, p-values and lower as well as upper limits of the 95% confidence interval.

Robustness checks were conducted to determine if the results presented in models 1 to 3 are dependent on either the discipline, showing changes for Physics and Chemistry separately, and to look for effects that may be time-dependent, showing different effects for certain time periods. The regression analyses of the full models 1-3 was performed for reduced data samples regarding decades, and overlapping 20-year periods. For clearer presentation, data was categorized into two periods that have represented the shift in scientific hegemony well within descriptive data on nomination power. The first period covers data until 1933, marking Germany's dominant phase. From 1934 onwards until the end of the observation period, the United States dominated in terms of nomination power.

Table 13 displays the robustness check regarding time periods, having three models analogous to Table 11. Table 25 in the appendix displays the same models for Chemistry and Physics, separately. Regarding variances between Physics and Chemistry, there are several variables that show concrete differences. In Physics, the organizational hierarchy based on status variables (such as HD and current workplace of nominators) appears to be more stratified than in Chemistry, which aligns with existing literature in science of science that emphasizes a more pronounced disciplinary core in Physics (Cole, 1983). However, effects that demonstrate a positive influence of new organizations (nominees' side) are only found for Physics, indicating at the same time more openness for organizational renewal in terms of organizational authorities (while in Chemistry, this effect is more pronounced for hubs).

One notable difference between the disciplines is the impact of RSAS membership. Model 1 in Table 11 showed a positive influence on success for both nominees and nominators who are RSAS members. However, this trend is not apparent for Physics nominees, where membership has a small negative influence, in contrast to Chemistry, and is less pronounced in terms of Physics RSAS nominators' placement power. Additionally, there are minor differences between the disciplines at the country level regarding national affiliation. Some countries show greater discrepancies, implying specialization in one discipline.

Table 13: Robustness check for models 1-3 for time periods

	1911-1933			1934-1969		
	(1)	(2)	(3)	(1)	(2)	(3)
Nominees' variables						
Number of past nominations (numerical)	0.05*** (0.00)	-	-	0.03*** (0.00)	-	-
Membership in the RSAS	0.27 (0.17)	-	-	0.17 (0.13)	-	-
HD in high-status Uni	-	-	0.16 (0.14)	-	-	0.45*** (0.09)
Organizational status Reference category: peripheral						
Middle-low	-	-	0.72* (0.31)	-	-	1.30*** (0.20)
Middle-high	-	-	1.45*** (0.30)	-	-	1.60*** (0.20)
Central	-	-	2.03*** (0.29)	-	-	2.24*** (0.20)
Newcomer organizations	-	-	0.39 (0.36)	-	-	0.92*** (0.24)
Country Reference category: all other countries						
Germany	-	0.91*** (0.24)	-	-	-0.08 (0.19)	-
USA	-	-0.07 (0.33)	-	-	0.65*** (0.13)	-
Northern countries	-	0.19 (0.34)	-	-	-0.41 (0.23)	-
UK	-	0.56 (0.34)	-	-	0.70*** (0.15)	-
France	-	-0.01 (0.31)	-	-	-0.26 (0.25)	-
Nominators' variables						
Number of past nominations (numerical)	-0.03 (0.02)	-	-	-0.04*** (0.01)	-	-
Membership in the RSAS	0.17 (0.15)	-	-	0.46*** (0.12)	-	-
Laureates	0.23 (0.17)	-	-	0.47*** (0.11)	-	-
Organizational status Reference category: peripheral						
Middle-low	-	-	0.26 (0.26)	-	-	0.15 (0.13)
Middle-high	-	-	0.35 (0.26)	-	-	0.20 (0.13)
Central	-	-	0.32 (0.27)	-	-	0.03 (0.14)
Newcomer organizations	-	-	0.42 (0.29)	-	-	0.53** (0.16)

	1911-1933			1934-1969		
	(1)	(2)	(3)	(1)	(2)	(3)
Country Reference category: all other countries						
Germany	-	-0.08 (0.20)	-	-	-0.30 (0.16)	-
USA	-	0.02 (0.31)	-	-	-0.13 (0.12)	-
Northern countries	-	0.74*** (0.22)	-	-	0.52*** (0.13)	-
UK	-	0.82* (0.35)	-	-	-0.37* (0.18)	-
France	-	0.18 (0.28)	-	-	0.21 (0.17)	-
Self-nominations (national level)	-	-	-0.81*** (0.15)	-	-	-0.38*** (0.09)
Self-nominations (organizational level)	-	-	-1.45*** (0.29)	-	-	-0.91*** (0.17)
Mentoring-relation	-0.08 (0.36)	-	-	-1.09*** (0.32)	-	-
N	1932	1932	1932	6178	6178	6178
McFadden Pseudo R^2	0.09	0.04	0.10	0.09	0.03	0.08
Nagelkerke Pseudo R^2	0.13	0.06	0.14	0.12	0.03	0.10
AIC	1496	1593	1498	3904	4181	3958
BIC	1534	1654	1564	3951	4255	4039

Standard errors in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13 shows that some variables have changing effects when comparing time periods, indicating that the nomination system needed time to consolidate for variables to show robust effects. For example, the positive influence of laureates on successful nominations is not apparent in the initial period, possibly due to the lower number of laureates at that time in history. In terms of RSAS membership, a comparable pattern is evident, which is surprising given that the proportion of RSAS members among nominators, and thus their nomination power, declined in the second time period. However, there is a slight but increasing positive impact of nominators' RSAS membership on successful nominations over time, which supports hypothesis H1b, indicating that the RSAS still has some influence, including placement power.

Similarly, some effects on the organizational level found for model 3 in Table 11 become more pronounced over time. Specifically, the advantage of newcomer organizations, as compared to established ones, becomes more pronounced over time, for both hubs and authorities. This provides additional evidence for rejecting H3e, which posited that established organizations would have an advantage in placement power. Moreover, the impact of organizational hubs remains insignificant and small.

With regard to nominators' placement power over the two time periods, Germany and the United States show no clear changes that can be interpreted as an adaptation to the shift in scientific leadership. Although German nominators are less unsuccessful than the residual category of other countries in the first period, both values show a negative influence. The same pattern can be observed for the United States, which overall does not fit hypothesis H2b.

Regarding nominees' national affiliation, however, Germany shows a development that is consistent with the shift in scientific leadership: In the first period, German nominees were significantly more successful than the residual category of other countries. In the second period, German nominees were less successful, with a small negative effect, while US nominees experienced a reversed pattern, with a negative coefficient for the first period and a significantly positive coefficient for the second.

This chapter has presented small evidence of a shift in scientific leadership that is consistent with the data on successful nominations, showing that over time Germany has lost its lead as an authority to the United States. However, national hubs do not emerge as being strongly associated with successful nominations, making H2b unlikely to be confirmed. Furthermore, placement power does not emerge as a strong predictor of success in terms of an organizational elite that is advantaged in successfully placing nominations, providing further evidence to reject H3d, while positive effects were found for newcomer organizations, rejecting H3e. Interestingly, placement power emerges as an advantage for RSAS members, who decline in nomination power but retain a small but positive effect on successful nominations over time (H1b).

7.4.2 Focus on separate nomination roles

The analysis in the previous chapter showed that factors determining successful nominations are complex to assess because they are multi-level and include aspects that apply to both nominees and nominators, implying that to some extent the candidates' claim is decisive for a successful nomination, but that the nominators' standing also plays a role. To address these questions in more detail, I separated entries for the two groups of nominees and nominators and edited the dataset of nominations accordingly. This puts the focus on candidates' claims and nominators' placement power, respectively.

For nominees, data is aggregated in a way that each candidate only appears once per year, reflecting their individual eligibility to the prize, their *claim*. As a result, double entries for scientists in a respective year are omitted, reducing the dataset to 3490 observations. Cases no longer represent all nominations, but instead they are designed to showcase the candidates' distinctive claim for a given year. With regards to this, scientists may still have multiple entries, pertaining to the data on nominations. However, they are restricted to one entry per year for which they received a nomination.

Albert Einstein, for instance, received a total of 62 nominations, although many of these were submitted in the same years. For the data structured through claims, Einstein has ten entries, one in each year between 1912 and 1922 (with the exception of 1915). Of these claims, two were successful, as he received the 1921 Physics Nobel Prize in 1922, which is a special case explained in chapter 6.2.

I use a limited set of variables to investigate which factors affect the success of candidates. Most of these variables were introduced in the initial regression model shown in Table 11. Two individual-level factors, namely membership in the RSAS and the frequency of received nominations within the given year, are analyzed in model 1. This variable of nomination counts differs from the one utilized in chapter 7.4.1 to supply details about a nominee's present assertion in a specific year and to enhance the distinction between scientists' claims. Nominees' national affiliation is covered in model 2, though in contrast to chapter 7.4.1, it concentrates on Germany, the United States and the United Kingdom in comparison to the residual category of all other countries (which now also contain northern countries and France), as the reduced dataset with less cases leads to otherwise unstable results. This also allows for a dedicated look at the issue of scientific leadership between the United States and Germany, with the UK as a successful country that is not affected by this change. A second adjustment is the addition of an interaction term of national affiliation and nomination year, as the previous analysis has shown that country variables are highly time-dependent. Three organizational factors relate to candidates' education and their current workplaces' organizational status and apply to model 3. I conduct a logistic regression on nominees' success with these data. Results are shown in the first model of Table 14.

To ensure the reliability of my results, I further summarized annual claims in the dataset into 3-year periods, which reduces the number of cases to 2218 but still enables a viewpoint of individual scientists' having multiple claims if they get nominated in various periods. This analysis contributes to the ongoing conversation regarding top-tier scientists' eligibility for the Nobel Prize, highlighting that the year of the award may be coincidental within a few years' time frame. For Albert Einstein's showcase, his ten annual claims are condensed into four periods: 1913-1915, 1916-1918, 1919-1921, and 1922-1924. Two of these claims are considered successful, with the latter two periods incorporating his Nobel Prize years of 1921 and 1922. Once a successful year is identified within a particular three-year period, that entire period is deemed successful. The same approach is taken for other categorical variables, including membership in RSAS and newcomer organizations. Metric variables, such as the frequency of nominations and indegree centrality, will be averaged over the 3-year period. Following this, organizational status will be separated into quartiles. Results are also shown in in Table 14.

Table 14: Logistic regression models for nominees' chances of success

	Annual models			3-year period models		
	(1)	(2)	(3)	(1)	(2)	(3)
Number of nominations received in the present candidacy	0.27*** (0.02)	-	-	0.45*** (0.04)	-	-
Membership in the RSAS	0.42 (0.23)	-	-	0.22 (0.26)	-	-
year	-	-0.01 (0.01)	-	-	-0.01 (0.01)	-
Country Reference category: all other countries						
Germany	-	28.76 (25.57)	-	-	34.40 (27.78)	-
USA	-	-18.82 (25.13)	-	-	-15.39 (26.56)	-
UK	-	13.99 (26.24)	-	-	6.98 (27.62)	-
Interaction terms:						
Germany X year	-	-0.02 (0.01)	-	-	-0.02 (0.01)	-
USA X year	-	0.01 (0.01)	-	-	0.01 (0.01)	-
UK X year	-	-0.01 (0.01)	-	-	0.00 (0.01)	-
HD in high-status Uni	-	-	0.11 (0.16)	-	-	0.26 (0.17)
Organizational status Reference category: peripheral						
Middle-low	-	-	0.65 (0.35)	-	-	1.37*** (0.41)
Middle-high	-	-	1.19*** (0.34)	-	-	2.14*** (0.41)
Central	-	-	1.50*** (0.33)	-	-	2.44*** (0.41)
Newcomer organizations	-	-	0.08 (0.40)	-	-	0.77* (0.33)
N	3490	3490	3490	2218	2218	2218
AIC	1200	1348	1328	1008	1133	1082
BIC	1218	1397	1365	1025	1178	1116
McFadden Pseudo R^2	0.12	0.02	0.03	0.12	0.02	0.06
Nagelkerke Pseudo R^2	0.14	0.02	0.04	0.15	0.02	0.08

Standard errors in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The best model fit is reached by model 1 with the best predictor for nominees’ success as the number of nominations a nominee has received within the current claim, which represents a very merit-based view of selection policy. Each nomination a nominee obtains in a given year strengthens their claim, resulting in every further nomination increasing chances on average by about one to three percent. Studies have highlighted the convoluted selection process of the Nobel Prize (see for example Seeman & Restrepo, 2023b) and the unclear significance of nominations. Despite the committees' emphasis on not relying solely on the quantity of support, this finding does indicate that a high number of nominations increases the chances of success.

At the organizational level, central and middle-high organizations present the strongest predictors, offering a six to twelve percent increase in chances (AMEs) compared to peripheral organizations. Additionally, education obtained from a high-status university and holding a middle-low organizational or newcomer status increase the likelihood of success, albeit to a smaller and not consistently significant degree.

The impact of most variables increases when candidacies are viewed in periods rather than years. This is particularly true for the number of nominations and organizational status.

Overall, the number of nominations received within the current claim remains the most crucial predictor for nominees' success. This fact emphasizes the significance of scrutinizing nominations, while also pointing out that awardees may rely heavily on broad support within the nomination network. In relation to this finding, it is surprising that organizational status seems to play a less pronounced role. Although there is a slight stratification in favor of all other categories compared to peripheral organizations, with AMEs between 0.04 and 0.12, the success advantage ranging from four to twelve percent, it turns out that even for organizational authorities, hierarchies are not as crystalline and entrenched as previously expected.

This perspective on nominees will be extended by setting up a comparable regression model for nominators based on their respective claims to success, where success is defined as placement power, in the sense of submitting nominations that result in a Nobel Prize. For annual claims, the condensed dataset for nominators described in chapter 6.1 is utilized to provide descriptive data on nominators. This ensures that each nominator only has one entry per year, as in the nominees' set. As an example, for Albert Einstein as a nominator, this results in a reduction of his original twelve nominations to nine claims from the years 1919 to 1954.

The annual dataset contains 5195 entries due to an omission of data on organizational status prior to 1910 and missing values. The success variable aggregates entries so that once a nominator submits a successful candidate, their entry for that year is counted as successful, regardless of the total number of nominations they submitted (and which may not have been successful). Nominators' frequency is controlled for in a separate variable, measured as the total number of nominations they submit in a given year. Other variables included in analysis are individual-level factors such as RSAS membership and laureate status, organizational status (determined by outdegree centrality) and newcomer organizations as well as national affiliation with an interaction term for the nomination year.

For a robustness check, data on nominators is aggregated into 3-year periods, similar to data and depiction on nominees. Variables are aggregated using the same logic as for success variables, i.e., if a nominator becomes a laureate in any year within the 3-year period, the corresponding record is set accordingly. This final step brings the data to 4274 cases.

To provide an overview of how data structure affects successful nomination counts, Table 15 employs the examples of Albert Einstein and Victor Weisskopf for illustration. The table illustrates differences in data structure, highlighting the unique aspects of my approach. Previous literature has quantitatively measured factors that determine success within the nomination network. However, these measurements have been restricted to nominees. For instance, Chen et al. (2023) measured the time duration between a nominee's first nomination and their award using survival analysis. My focus is on nominations as the primary tool of pre-selection, rather than on nominees as the product of pre-selection. By aggregating nominations to match annual or periodical claims of nominees and nominators, this perspective highlights the two sides of a nomination, respectively.

Table 15: Overview over dataset structure with two individual examples

	nominations (nominees)	nominees' annual claims	nominees' claims, 3-year-periods	nominations (nominators)	nominators' annual claims	nominators' claims, 3-year-periods
Dataset size	8832	3490	2218	8832	5195	4274
Case example of Albert Einstein						
Number of nominations	62	10	4	12	9	8
Successful nominations	2	2	2	5	5	4
Case example of Victor Weisskopf						
Number of nominations	6	4	3	14	7	6
success	0	0	0	3	3	3

This table gives an overview over dataset structure used for the regression models regarding nomination roles for two case examples, Albert Einstein and Victor Weisskopf who both performed as nominee and nominator.

Results for regression analysis on nominators' placement power for both annual as well as 3-year period models 1 to 3 are shown in Table 16.

Table 16: Logistic regression models for nominators' ability to execute placement power

	Annual models			3-year period models		
	(1)	(2)	(3)	(1)	(2)	(3)
Number of nominations submitted in the present year/period	0.22*** (0.03)	-	-	0.60*** (0.07)	-	-
Laureates	0.23* (0.09)	-	-	0.38*** (0.11)	-	-
Membership in the RSAS	0.04*** (0.10)	-	-	0.50*** (0.11)	-	-
year	-	-0.01*** (0.00)	-	-	-0.01*** (0.00)	-
Country Reference category: all other countries						
Germany	-	10.16 (10.98)	-	-	16.78 (11.52)	-
USA	-	-56.63*** (14.02)	-	-	-61.55*** (14.79)	-
UK	-	9.37 (17.22)	-	-	-0.22 (18.48)	-
Interaction terms:						
Germany X year	-	-0.01 (0.01)	-	-	-0.01 (0.01)	-
USA X year	-	0.03*** (0.01)	-	-	0.03*** (0.01)	-
UK X year	-	0.00 (0.01)	-	-	0.00 (0.01)	-
Organizational status Reference category: peripheral						
Middle-low	-	-	0.52*** (0.14)	-	-	0.54*** (0.15)
Middle-high	-	-	0.71*** (0.14)	-	-	0.84*** (0.15)
Central	-	-	0.71*** (0.14)	-	-	1.07*** (0.14)
Newcomer organizations	-	-	0.77*** (0.15)	-	-	0.81*** (0.16)
N	5195	5195	5195	4274	4274	4274
AIC	4366	4413	4410	3779	3925	3892
BIC	4393	4465	4443	3805	3976	3924
McFadden Pseudo R^2	0.02	0.01	0.01	0.05	0.01	0.02
Nagelkerke Pseudo R^2	0.03	0.01	0.01	0.07	0.02	0.03

Standard errors in brackets. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Similar to the findings on nominees, consolidating data from annual observations into 3-year periods enhances the model's effects and explanatory power, resulting in Pseudo-R-square values ranging from 0.01 to 0.07. These values are low, indeed even lower than those for nominees (0.2 to 0.14), but they still reveal factors that affect nominators' success in placing their candidates on a small scale.

While all variables in model 1 and 3 exhibit a significant influence, individual-level variables, namely the number of nominations submitted by nominators during a specific time interval, exhibit a substantial impact on placement power. Each additional nomination submitted results in a 3 percent (annual model) to 8 percent (3-year model) higher chance of successful placement. This is an interesting discovery. In the model based on nominations, the past frequency of nominations by nominators correlated with a lower likelihood of success. Conversely, submitting a greater number of nominations within the set timeframe positively impacts success. This could be analogous to “shooting several arrows at the same time hoping that at least one will hit the target” (Korom, 2020, p. 261), a practice that seems to be tolerated by the committees and, on top, reflects a strategy to increase placement power.

Both other individual-level variables depict small but substantial effects as laureates as well as RSAS members have a higher chance to successfully place their candidates, confirming findings from case studies presented in chapter 3, for example from Gallotti and De Domenico (2019), as well as adding further substance to hypothesis H1b, which expected RSAS members to exhibit substantial control over the nomination process.

The effects in model 2 show the smallest (mostly insignificant) effects as well as explanatory power. While the shift in scientific hegemony was observed for nomination power on a large scale, this does not show up as a significant effect for placement power, although the addition of a time-dependent perspective reveals a minor tendency: on the basis of the interaction term between countries and nomination year, there is a very slight alignment with the hegemonic shift from Germany to the United States (also observed for nominees’ model 2). While the UK is not affected by time, US placement power increases slightly (significantly) over time, while for Germany it decreases. This finding is congruent with the results of time period models in Table 13, showing that both nations' success in placements are particularly time-dependent. However, there is no profound advantage that leads to a substantially higher placement power than other countries have, which still supports a rejection of hypothesis H2b, but with the consideration that the US and German course changes are consistent with hegemonic trends.

Regarding model 3, high organizational status increases the likelihood of successful candidate placement. In comparison to peripheral organizations, central organizations have on average an 8 (annual model) to 14 percent (3-year period model) higher chance of success, directly followed by middle-high status organizations (8 and 10%). Apparently, this indicates to a greater extend that there is at least some reputational advantage based on the past centrality of nominating organizations within the network. However, similar to the organizational status for nominees' claims, a much more stratified and strict hierarchy was expected in hypothesis H3d and H3e. Placement advantages as measured by AMEs are very close for middle-low to central organizations, with only a few percentage points of difference. These placement effects are minor compared to the highly stratified hierarchies found within literature (Wapman et al., 2022), regarding graduate exchange networks within academia.

Further arguing against a prestige hierarchy is the fact that newcomer organizations exhibit higher placement power than established ones. On average, newcomer organizations have a 14 percent higher chance of success. In addition to the lack of stratification in terms of placement power, this is profound evidence of organizational renewal within the nomination system.

To compare the effects found for nominees and nominators more discernably, Figure 27 represents a forest plot of AMEs for the variables listed in the three annual regression models (Table 14 and Table 16) with 95 percent confidence intervals as whiskers. The forest plot Figure 28 shows that these findings in general hold for the regression models based on 3-year nomination periods.

The effects for the number of nominations a nominee received and a nominator submitted within a year are not directly comparable, because the scale is higher for nominees than for nominators. Murray Gell-Mann received the highest number of nominations in his award year 1969 (with 36 nominations). Ferdinand Franz Cap by far submitted the highest number of nominees within one year (17 nominees in 1967, but none received the award). It is important to note that both frequency effects are comparably high for nominators as well as for nominees.

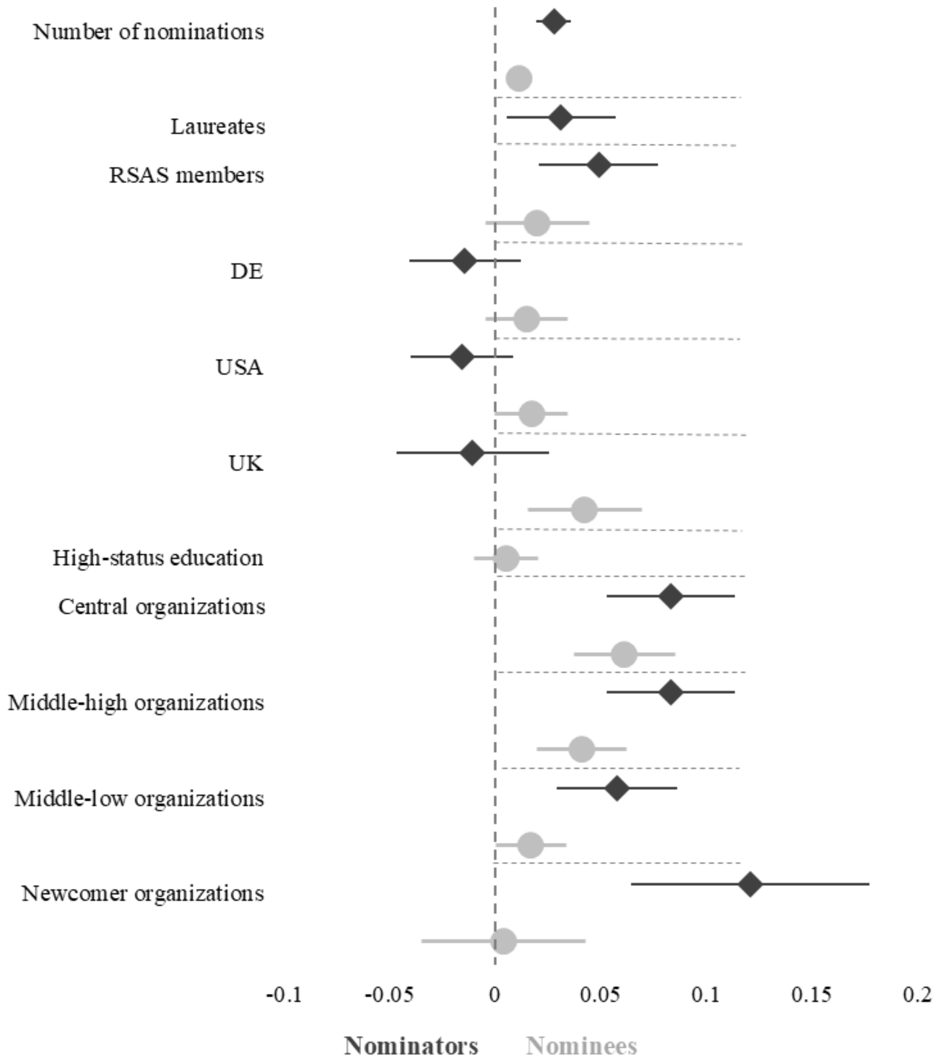
Membership in the RSAS seems to especially benefit nominators, increasing their placement power on average by five to eight percent, which fits interpretation in the regression model on the basis of nominations.

National affiliation effects are small and often insignificant, with no clear positive or negative effect, as indicated by the wide whiskers between positive and negative values. Again, an alternative model that includes a comparison over time is provided (Figure 29 and Figure 30).

In terms of hierarchical stratification among organizations, the three-year period model in particular shows the largest and most stratified results, with central organizational hubs (nominator's workplace) having the highest measured advantage over peripheral organizations (AME of 14%), followed by middle-high and middle-low status organizations with four and ten percentage points difference, respectively.

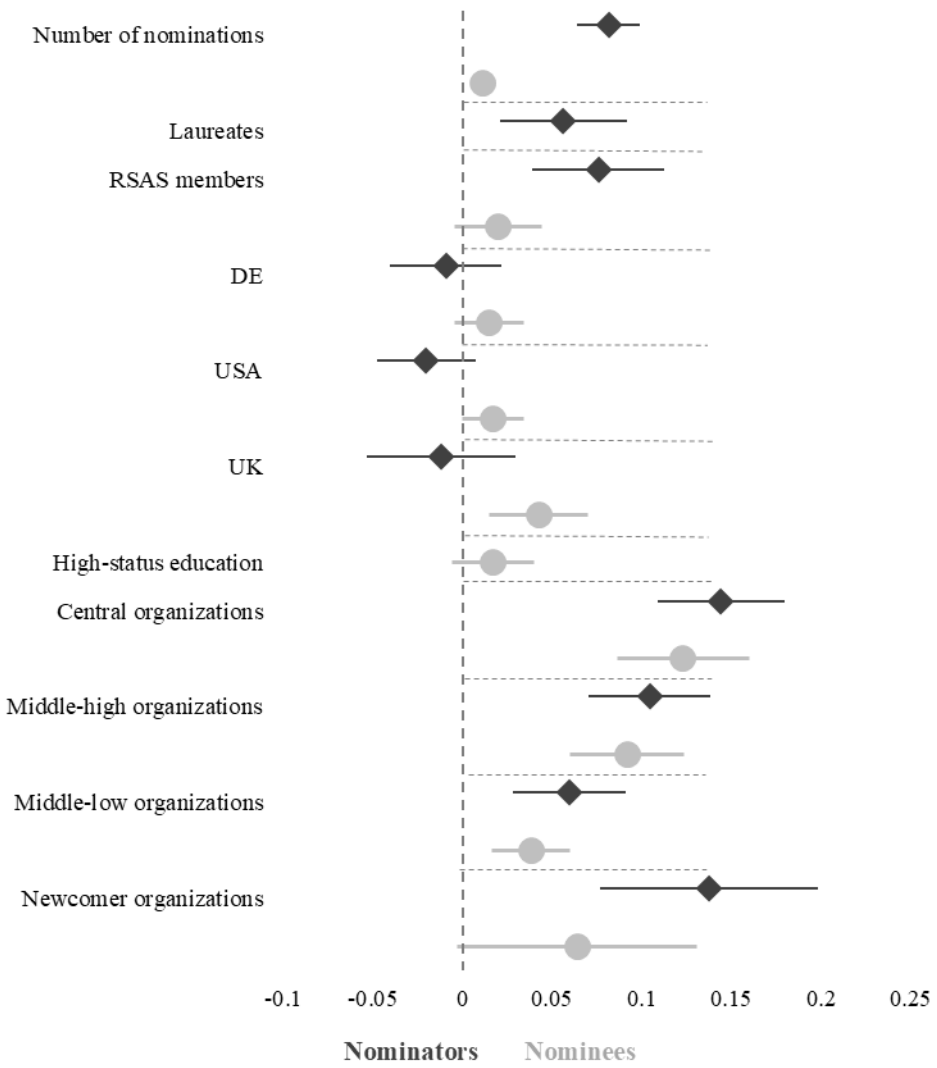
However, newcomer organizations, which have relatively wide whiskers in the forest plots, also show consistently positive effects on nominators' placement power, even surpassing the effect of central organizations in the annual model.

Figure 27: AMEs with 95% confidence intervals for annual regression models



This forest plot shows the average marginal effects (AME) for nominators (dark gray) and nominees (light gray) within the annual model. The AME is represented by dots/squares with 95% confidence intervals as whiskers. Effects are significant if they are either below or above 0 (vertical line) and can be interpreted as the change in probability of success.

Figure 28: AMEs with 95% confidence intervals for 3-years-period regression models

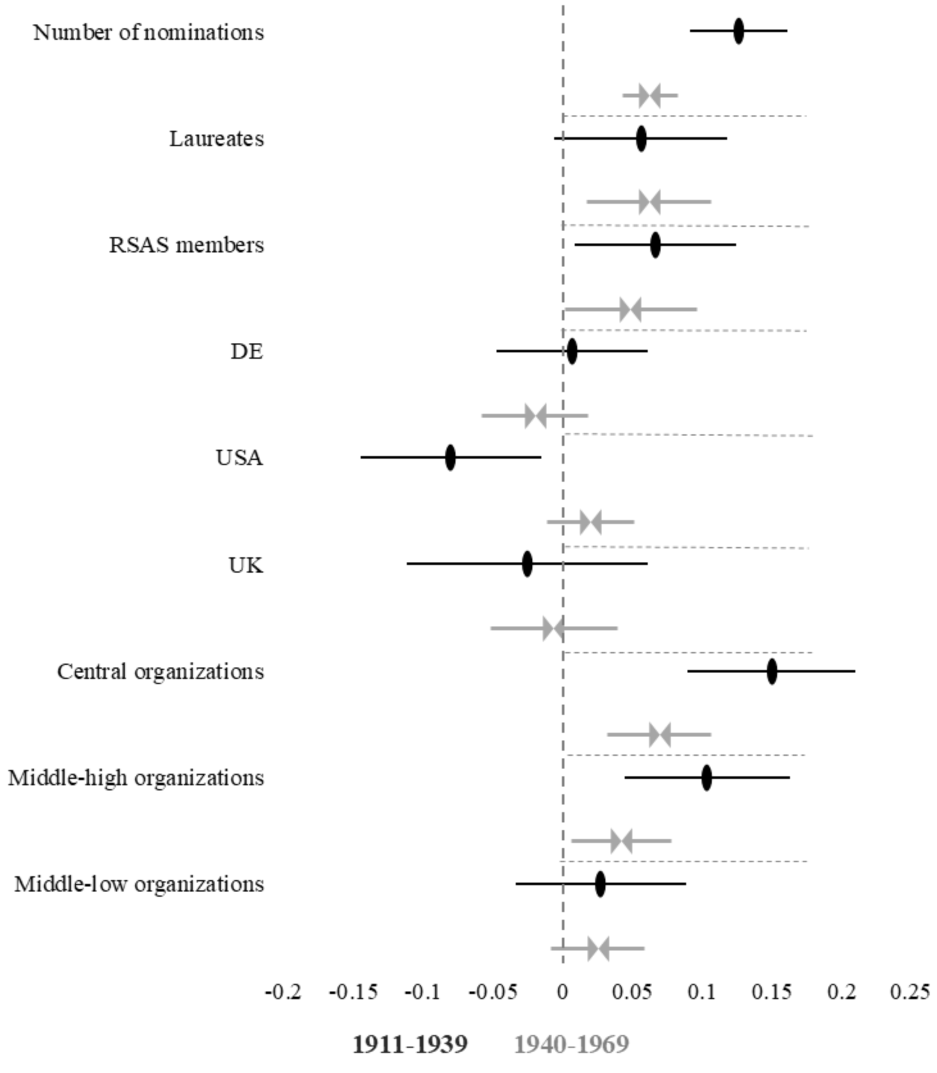


This forest plot shows the average marginal effects (AME) for nominators (dark gray) and nominees (light gray) within the 3-year period model. The AME is represented by dots/squares with 95% confidence intervals as whiskers. Effects are significant if they are either below or above 0 (vertical line) and can be interpreted as the change in probability of success.

One question that might arise is whether the effects shrink or grow over the period covered by this analysis. Since the observation period of the regression analysis covers almost 60 years, data is split it into two observation periods in order to compare which factors might become more important over time as the nomination system consolidates and leads up to the educational expansion that begins in the 1960s. The first period covers data from 1911 to 1939, and the second period covers data from 1940 to 1969. Moving the cut between periods after 1945 (the end of World War II) does not significantly alter the results. Splitting the data after 1933, as performed in previous chapters, would result in small sample sizes for the first period. Therefore, I transferred the cut point. However, due to the reduced sets on nominees' and nominators' claims, results should be interpreted with caution. The variable for newcomer organizations is omitted from further comparison due to its relatively small coverage within the first time period when split.

Figure 29 shows a forest plot for AMEs of nominators’ placement power for time periods. The data for nominator claims is aggregated into 3-year periods, although the results remain robust to annual presentation.

Figure 29: AMEs with 95% confidence intervals for 3-year-period regression models on placement power

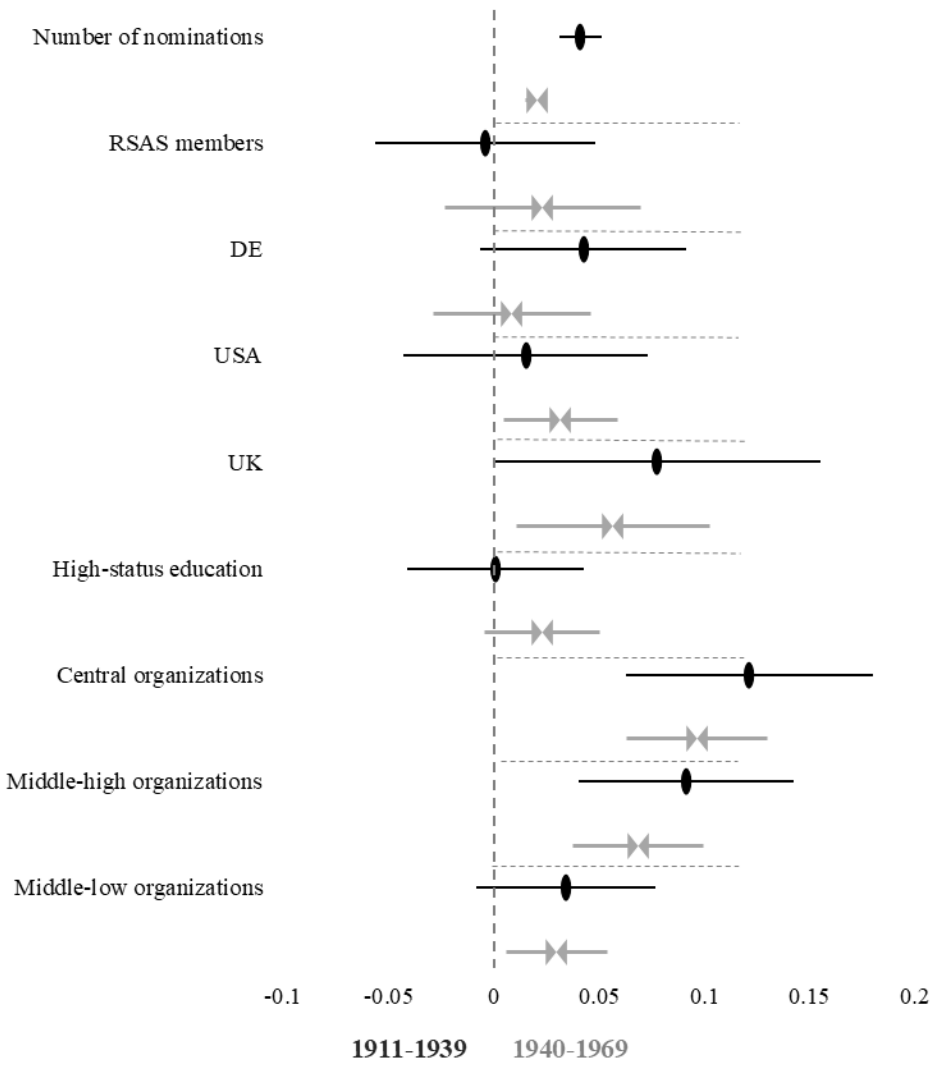


This forest plot shows the average marginal effects (AME) for the time periods 1911-1939 (dark gray) and 1940-1969 (light gray) within the 3-year period model on nominators’ placement power. The AME is represented by dots/ squares with 95% confidence intervals as whiskers. Effects are significant if they are either below or above 0 (vertical line) and can be interpreted as the change in probability of success.

In general, the results confirm previous interpretations: individual factors remain rather constant, while effects at the national level are small and inconsistent, but show that AMEs for Germany and the United States change from positive to negative and vice versa, corresponding to the change in global scientific leadership.

Especially, organizational status appears to become less important over time, further diluting the small evidence of reputational advantages for central organizational hubs.

Figure 30: AMEs with 95% confidence intervals for 3-year-period regression models on candidates' success



This forest plot shows the average marginal effects (AME) for the time periods 1911-1939 (dark gray) and 1940-1969 (light gray) within the 3-year period model on nominees' candidacy success. The AME is represented by arrows/ bars with 95% confidence intervals as whiskers. Effects are significant if they are either below or above 0 (vertical line) and can be interpreted as the change in probability of success.

Figure 30 shows a similar forest plot for nominees' claims, measuring which factors influence success for the two time periods. Similar to placement power, organizational status with respect to authorities tends to lose influence over time, implying that the nomination system becomes more permissive as it consolidates over time. This is indicated by lower AMEs and narrower confidence intervals in the second period 1940-1969.

As noted above, the effects remain rather small and show only very weak signs of stratification by prestige.

In this chapter, I have approached the complex question of identifying factors that influence decision-making in the awarding of Nobel Prizes. A first regression model was implemented on all nominations to identify factors that might influence the process. The models were categorized by the three main theoretical themes, ranging from particularistic selection criteria checked in model 1, to global scientific environments in model 2, and organizational stratification in model 3. The models encompassed three levels of analysis; individual variables based on characteristics of scientists acting as nominators and nominees, organizational information about scientists' training and workplace, and national affiliation.

In general, individual factors tended to have the greatest influence on successful nominations, particularly the number of previous nominations a nominee had received (positive influence) and the number of previous nominations a nominator had submitted (negative influence). Extending the results of chapter 7.2 on self-nominations, I demonstrate on the basis of the general nomination network that self-nominations have a consistently negative influence on the success of nominations, from the individual to the national level.

Furthermore, I aggregated data structure to suit the more precise concepts of placement power and candidates' success, referring specifically to the sides of nominators and nominees.

In terms of placement power, I collected data based on individual nominators, excluding any duplicate entries per year. Next, I aggregated the data into 3-year periods. The same approach was applied to nominees by aggregating all of their received nominations into one annual or periodical claim. For both models, the frequency of nominations within the year/period was included in the model to provide additional information.

The success measurement for placement power was customized to indicate whether a nominator submitted a nomination within the given timeframe that resulted in an award, demonstrating the nominator's ability to place at least one candidate. For nominees, awarding years were used, following the same approach as the nomination-based model.

Regarding the hypotheses stated in chapter 5, it is interesting to note that the influence of RSAS members, especially as nominators, holds on, although their nomination power significantly diminishes over time. Nominating RSAS members exhibit a slight advantage in nomination power that is consistent for analysis on grounds of nominations as well as nominators' claims.

On the country level, models rather present small and inconsistent effects with low explanatory power. Due to the long time period covered which could have led temporal effects of countries to offset each other, I included an interaction term with the nomination year and checked for time-variance within the models as a robustness check. I expected to find temporal effects especially for Germany and the United States due to their shift in scientific leadership within the observation period. I have demonstrated that success rates for German nominators have slightly decreased over time, while US nominators have had increasing success rates with each passing year. This finding consolidates the shift in hegemony found within nomination power. However, as stated in hypothesis H2b, I expected Germany and the United States to emerge as leading countries within the first and second time period, exhibiting placement power by having advantages in placing successful nominations. This did not occur, which is why there is not enough support for H2b to be confirmed, although there is evidence for a change in leadership (especially regarding scientific authorities).

Concerning hypothesis H3d, at the organizational level, there is no clear reputation hierarchy that advantages success for high-prestige organizations (for neither hubs nor authorities). Although it has been observed for placement power that central organizational status provides the greatest advantage compared to peripheral organizations, these effects are not properly stratified throughout the models, and middle-low and central organizations have rather comparable effects. Therefore, there is not enough evidence to confirm H3d. Consistent with this finding, newcomer organizations are more likely to successfully place candidates than established organizations, despite lacking reputational benefits and facing inertia. This supports the rejection of H3e.

Regarding the questions raised at the beginning of this chapter, identifying factors that lead to successful nominations is a complex analysis. The results presented here are a first approach to detecting some mechanisms that are at play. Further studies are needed to validate and enhance these findings. In general, my analysis indicates that the awarding is influenced by various factors at different levels, ranging from individual to national factors. Both nominators and nominees contribute to the success of a nomination.

8. Conclusion

The Nobel Prize is the most well-known and celebrated science prize in the international community. Awardees become ambassadors of science on a greater societal level and are distinguished from other top-tier scientists due to the excessive media interest surrounding the prize. Although the Nobel Prize is widely regarded as the gold standard for scientific achievements, its selection process has evolved over time to manage growth and maintain legitimacy. As the prize has gained in popularity and prestige, it has become necessary to standardize and formalize the procedures used to determine who should receive the award and who should not.

In the literature, two basic approaches have been identified to characterize the selection process and deal with the large number of scientists who achieved innovative results but did not receive awards and therefore did not become renowned as laureates, but rather as overlooked, unlucky geniuses. The first approach, expressed by Harriet Zuckerman, emphasizes merit-based factors for selecting the best from a large number of highly talented and innovative scientists. Based on this analysis, the Nobel Prize's objective is to select the most qualified candidates, which it generally achieves, according to Zuckerman. Overlooked scientists are a rare occurrence due to the limited number of prizes. The metaphor 'candidates of the 41st chair' is used to illustrate that there sometimes is a conflict between keeping honors scarce and meaningful, while also providing enough recognition for those who deserve it. However, this conflict does not alter the fact that within this view the Nobel Prize is an indicator of the scientific elite.

In contrast to this view, other authors, such as Elizabeth Crawford and Robert Friedman, place greater value on the conflicts of selection, which often lead to controversial decisions that are not based on merit, but rather reflect the internal politics of the Nobel institutions, personal biases, and the self-serving agendas of powerful actors within the committees. The common view is that there is no distinction between scientists of a certain caliber, whether they are laureates or not, because the Nobel Prize elevates some individuals to a higher status simply because of its own label, not in terms of scientific achievement.

Both these approaches are still debated in current literature, indicating that the question of whether the scientific prize landscape is driven by ascription or meritocracy remains an interesting topic that is exemplified by the Nobel Prize.

In my dissertation, I aim to contribute to this discussion by providing a quantitative perspective on the selection process. To achieve this, I compiled a unique dataset that is historically valid and contains detailed information on nominators and nominees for the categories of Chemistry and Physics, including a previously unimplemented level of organizational affiliation. The basis for this dataset were the records available in the Nobel Foundation's online Nomination Archive for the years 1901-1969, supplemented by other sources.

The dynamics within the nomination process were examined through the lens of three theoretical themes. The presence of quantifiable ascriptive elements within the nomination process was investigated, particularly focusing on the roles of women and members of the Royal Swedish Academy as nominators. The concepts of universalism and particularism (Merton, 1973 [1942]; Parsons, 1964 [1951]) were drawn upon for this purpose. Secondly, I examined the shift in global scientific leadership from Germany to the United States (Ben-David, 1971; Hollingsworth, 2006), extending findings that give insight into hegemonic patterns found within the selection of laureates (Heinze et al., 2019; Heinze et al., 2020). Third, principles of prestige, social closure and stratification within the nomination process are addressed, considering whether there is a skewed distribution and hierarchical structure similar to other academic networks (Burris, 2004) and whether it impacts the distribution of nomination and placement power. These theoretical frameworks have helped contextualize the empirical findings and contribute to a deeper understanding of the complex mechanisms at play in the Nobel Prize nomination system.

The key findings of my analysis regarding the hypotheses set up in chapter 5 are summarized in Table 17.

Table 17: Overview over research hypothesis and key findings

Label	Description	Key findings	
H1a	Women are disadvantaged in the nomination network, resulting in fewer female nominators and nominees.	Confirmed: women's share as nominators is smaller than as nominees, even undercutting female proportion within academia.	✓
H1b	RSAS members are privileged in the nomination process, and thus dominate the nomination network.	Confirmed only for early nomination decades. Nomination power is decreasing immensely as are self-nomination rates. Small placement advantages maintain.	✓
H2a	The global center of nomination power shifted from Germany to the United States in the first half of the 20th century.	Confirmed: Germany and the United States lead the distribution of nominators' national affiliations in consecutive periods. The shift occurs in the early 1930s.	✓
H2b	The global center of placement power shifted from Germany to the United States in the first half of the 20th century.	Rejected: Over time, the placement power of Germany decreases, while that of the United States increases. However, neither country is really predominant as placement hegemon.	✗
H3a	The distribution of nominations is skewed among countries, resulting in a concentration of nominators from a small number of countries.	Confirmed: the distribution is highly skewed, as shown by even increasing Gini coefficients. The top three countries submit 50 percent of nominators.	✓
H3b	The distribution of nominations is skewed among organizations, resulting in a concentration of nominators from a small number of organizations.	Confirmed: high and rising Gini coefficients, strong concentration of nominating power in metropolises, organizational elite of top universities.	✓
H3c	The distribution of self-nominations is skewed among organizations, resulting in a concentration of self-nominations in a small number of organizations.	Confirmed: Self-nominations correlate with measures of scientific achievement and organizational status, showing that self-nominations are more likely to occur in innovative, prestigious organizations.	✓
H3d	The distribution of placement power is skewed among organizations, resulting in a concentration of successfully placed nominations from a small number of organizations.	Rejected: Although peripheral organizations have the lowest chances of placing nominations, the differences are genuinely small and rather do not reflect a stratified hierarchy.	✗
H3e	Nominators from newcomer organizations place fewer successful nominations than established organizations.	Rejected: Conversely, newcomer organizations have a higher chance of submitting successful nominations than established organizations.	✗

Results highlight nominators as an understudied group that is critical to the entire selection process. I have distinguished between two concepts, nomination power and placement power. The first refers to the composition of nominators, showing mainly on a descriptive basis who has the right to nominate, while the second refers to the actual power to successfully place nominations, measured by logistic regressions.

Two phenomena have been identified that affect the nomination power of certain groups based on descriptive aspects within the nomination network rather than their general ability. The low representation of women among nominators is a persistent problem, with slow progress toward gender parity, and even lower participation of women among nominators than in academia as a whole. Members of the Royal Swedish Academy of Sciences (RSAS) have historically held a privileged position in early nomination decades. However, this particularism has decreased over time as the network has grown and counteracted this trend. Though, small placement advantages for RSAS members persist over time.

The transition of the global center of nomination power from Germany to the United States in the first half of the 20th century is confirmed, adding further substance to the literature on power dynamics between scientific centers. In consecutive periods, Germany and the United States lead the distribution of national affiliations among nominators, with the shift occurring in the early 1930s. Self-nominations mirror this shift, showing that these two scientific hegemons perpetuate their nomination power and, on top, reveal greater success in nominees' candidacies during their respective leading period. However, in terms of placement power, their dominance within their respective hegemonic phases is not as apparent with respect to low explanatory power and inconsistent effects, although controlling for time-variation.

The distribution of nomination power shows significant disparities among countries, resulting in a concentration of nominators from a select few nations. This distribution is highly skewed, as evidenced by the increasing Gini coefficients, with just three countries accounting for half of all nominators.

Similarly, the allocation of nomination power among organizations displays substantial imbalances, resulting in a concentration of nominators from a limited number of organizations. Gini coefficients reveal a significant concentration of hubs in major European and US metropolises, as well as an organizational elite of leading universities.

Self-nominations follow a similar pattern of concentration within organizations, with a few universities accounting for the majority of such nominations. Self-nominations are associated with measures of scholarly achievement and institutional standing, suggesting a higher likelihood of occurrence within innovative and prestigious organizations. Thus, I have added a new perspective that considers organizational status to reconsider implications that this behavior can be characterized as non-meritocratic voting.

In terms of placement power, organizational status does not result in substantial placement advantages, leading to a concentration of successfully placed nominations from a limited number of organizations. Although peripheral universities within the nomination network have the lowest chance of successful nominations, the differences to other status groups are small and do not reflect a stratified hierarchy in most models.

In contrast, findings suggest that nominators from newcomer organizations have a higher likelihood of placing successful nominations than their established counterparts, adding to the renewal of the nomination process.

Overall, these results provide important insights into the functioning and structure of the Nobel Prize nomination network and contribute to discussions on gender inequality, institutional power, and international scientific dynamics.

In general, my findings regarding the uneven distribution of nomination power suggest a discussion about broadening nomination rights to underrepresented groups. A substantial portion of the nomination system operates in a self-replicating manner, wherein the choices of nominators wield considerable influence over both the nominees and eventual recipients of the Nobel Prize. While there have been attempts to diversify the pool of nominators, they have not kept up with the overall growth of the nomination network prior to 1969. However, it is crucial to cover new actors in the process, especially for organizational renewal that is shown to positively influence candidates' chances.

Results indicate complex dynamics at individual, organizational, and national levels that reveal both factors contributing to merit-based aspects as well as those that reveal reputational advantages. The logistic regression models presented in this analysis have rather low explanatory power, suggesting that exploring further sets of variables would be fruitful. Enhancements may consider factors such as nominees' productivity, collaboration networks, and mobility patterns. Additionally, information already provided could be further applied to examine the international support of candidates, measured by nominations from different organizations and countries, the direct influence of top performing organizations and individuals.

Models may incorporate the importance of multiple claims, as well as an indicator of how the number of nominations received relates to the number of different nominators for nominees. For nominators, an indicator of previous successful nominations could be included. With regard to the organizational aspects highlighted in this study, they mainly relate to reputational factors within the nomination network itself. It would be interesting to compare the findings of a structural hierarchy among organizations based on other measures. For example, additional measures could build on the number of Nobel Prizes awarded to staff scientists in the past, or the ratio of an organization's research output and quality through publication records, which would be relatively comparable to common university rankings. Organizations could also be classified according to their focus on education, research, administration, and manufacturing in order to assess whether the great number of nominators from universities is also more successful in placing candidates. Similarly, it could be explored whether nominees from universities have an advantage over other organizational forms.

According to the Nobel committees, nominators from the same organizations often vote for the same candidate to strengthen their claim. However, my analysis shows that this nomination pattern would be detrimental to a candidate's claim, resulting in a high number of self-nominations on an organizational level. This demonstrates that there are numerous nomination patterns that are worth analyzing. The organizational component, presented in this analysis for the first time, offers various perspectives for further analysis. For instance, it allows for the exploration of the network for illustrative case studies that go beyond the individual level.

There are numerous examples of Nobel Prize winners in Medicine at the individual level. To provide a quantitative comparison to the data for Physics and Chemistry, it would be interesting to systematically record these examples and support findings with quantitative data. Moreover, further studies could specialize on elaborating differences within the three scientific disciplines of the Nobel Prize. As I have briefly outlined, differences and specialties of individual disciplines become evident, for instance, on the organizational level with research-oriented universities that excel within a specific subfield or industrial institutes that make it into the selection process of the Nobel Prize such as Bell Labs or BASF. Furthermore, a subject-related look at the scientific fields could lead to further insights.

It will be even more exciting to explore these questions once new nomination data becomes available post-1969. The Nobel Prize Foundation has a significant responsibility to increase transparency in data for a more transparent prize awarding process.

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10. Tables

11. Figures

12. Abbreviations

Abbreviation	Full title
AH	Austria-Hungary
AME	Average marginal effect
AR	Argentina
AT	Austria
AU	Australia
e.g.	Exempli gratia (for example)
Che	Chemistry
Caltech	California Institute of Technology
CH	Switzerland
CZ	Czechoslovakia (later Czech Republic)
DE	Germany
DK	Denmark
ETH Zurich	Swiss Federal Institute of Technology
FI	Finland
FR	France
FU Berlin	Free University of Berlin
HD	Highest degree
HU Berlin	Humboldt University of Berlin
i.e.	Id est (that is to say)
IL	Israel
IT	Italy
LMU Munich	Ludwig Maximilian University of Munich
Med	Medicine
MIT	Massachusetts Institute of Technology
MPI	Max Planck Institute
NL	The Netherlands
NO	Norway
NP	Nobel Prize
RSAS	Royal Swedish Academy of Sciences
RU	Russia(n empire)
SE	Sweden
StE	Standard error
SP	Spain
TU	Technical University
TUR	Turkey
Phy	Physics
PL	Poland
U	University
UK	United Kingdom
US(A)	United States of America
WW I	World War I
WW II	World War II

13. Appendix

Figure 31: Annual course of the Nobel nomination process

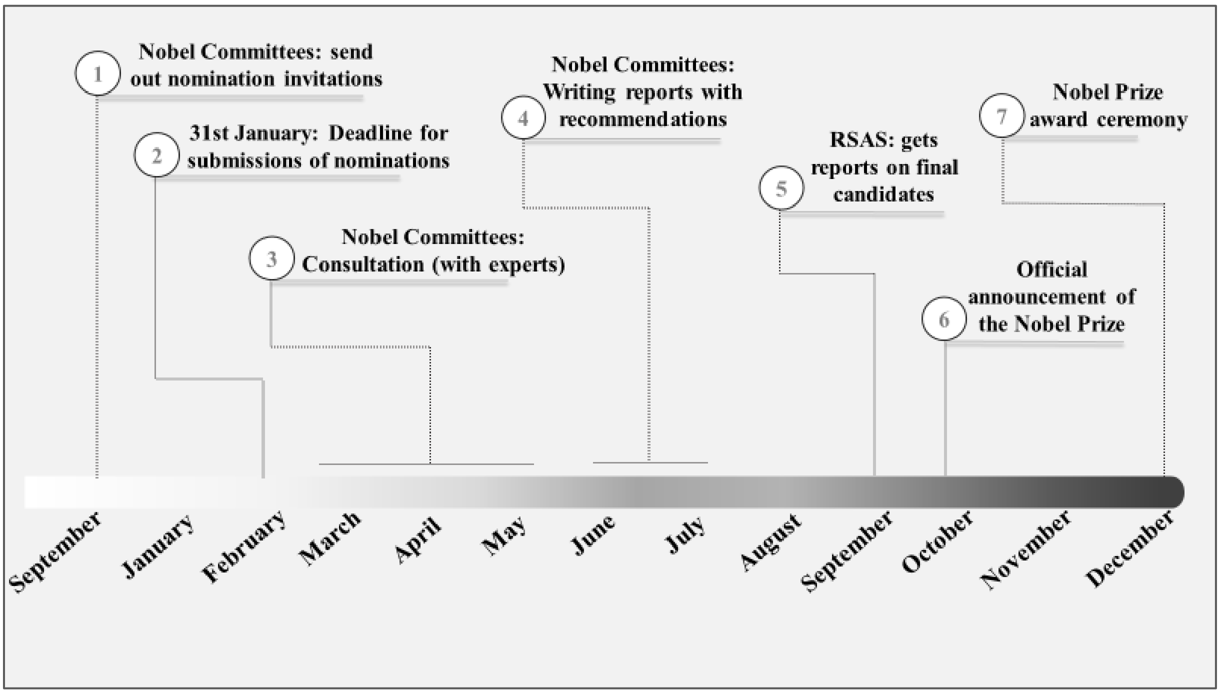


Table 18: Illustration of data structure (sample)

General information		**Biographical entries of the nominees**					**Biographical entries of the nominators**				
Year	**Discipline**	**Name**	**Birth year**	**Organizational affiliation**	**National affiliation**	**Successful nomination**	**Name**	**Birth year**	**Organizational affiliation**	**National affiliation**	**Laureate**
1901	Phy	Svante Arrhenius	1859	Stockholm University	SE	No	Adolf von Baeyer	1835	LMU Munich	DE	No
1901	Phy	Svante Arrhenius	1859	Stockholm University	SE	No	August Sundell	1843	University of Helsinki	FI (RU)	No
1901	Phy	Wilhelm Röntgen	1845	LMU Munich	DE	Yes	Knut Ångström	1857	Uppsala University	SE	No
1901	Phy	Wilhelm Röntgen	1845	LMU Munich	DE	Yes	Svante Arrhenius	1859	Stockholm University	SE	No
1901	Phy	Philipp von Lenard	1862	University of Kiel	DE	No	Knut Ångström	1857	Uppsala University	SE	No
1901	Phy	Philipp von Lenard	1862	University of Kiel	DE	No	Svante Arrhenius	1859	Stockholm University	SE	No

Table 19: List of all sources used for validating/ enhancing biographical information

Name	**URL**
AAE ENSCM Chimie Montpellier	https://www.aae-enscm.fr/
Academic Tree	https://academictree.org/
Accademia delle Scienze di Torino	https://www.accademiadellescienze.it/home
ACS Publications	https://pubs.acs.org/
Acta Crystallographica Section A: Foundations and Advances	https://journals.iucr.org/a/
AIM 25 - Archives in London and the M25 area	https://aim25.com/index.stm
American Astronomical Society	https://journals.aas.org/
American Chemistry Society	https://www.acs.org/content/acs/en.html
American Institute of Physics, especially its magazine "Physics Today"	https://www.aip.org/
Ann Arbor District Library	https://aadl.org/
Annual Reviews	https://www.annualreviews.org/
Archiv der Max-Planck-Gesellschaft	https://www.archiv-berlin.mpg.de/
Archiv für Agrargeschichte	https://www.histoirerurale.ch/afa/index.php/de/
Archives de la Faculté des Sciences de Nancy	http://cussenot-fst-nancy.ahp-numerique.fr/cussenot2/index.php
Archives Hub	https://archiveshub.jisc.ac.uk/
Archives Quickaccess	https://archives-quickaccess.ch/
Archivio Storico Università di Bologna	https://archiviostorico.unibo.it/it
Archivportal-D	https://www.archivportal-d.de/
Arevipharma	https://arevipharma.com/
Astro Databank	https://www.astro.com/astro-databank/Main_Page
Astrophysics Data System	https://ui.adsabs.harvard.edu/
Atomic Heritage Foundation	https://www.atomicheritage.org/
Australian Dictionary of Biography	https://adb.anu.edu.au/
Bayerische Akademie der Wissenschaften	https://badw.de/die-akademie.html
Bestor	https://www.bestor.be/wiki/index.php/Bestor_---
Bibliografie dějin Českých zemí	https://biblio.hiu.cas.cz/#!/
Biblioteka Wirtualna Nauki	http://przyrbwn.icm.edu.pl/
Bibliothèque de l'Académie des Sciences et Lettres de Montpellier	https://www.ac-sciences-lettres-montpellier.fr/
Bibliothèque nationale de France	https://data.bnf.fr/
Biografický slovník	http://biography.hiu.cas.cz/Personal/index.php/Hlavn%C3%AD_strana
Bright Sparcs by University of Melbourne eScholarship Research Center	https://www.asap.unimelb.edu.au/bsparcs/bsparcshome.htm
Bundesarchiv	https://www.bundesarchiv.de/DE/Navigation/Home/home.html
Caltech	https://www.caltech.edu/

Cambridge University Press	https://www.cambridge.org/universitypress
Catalogus Professorum Halensis	https://www.catalogus-professorum-halensis.de/
Catalogus Professorum TU Berlin	https://cp.tu-berlin.de/
Catalogus Professorum Universiteit Utrecht	https://profs.library.uu.nl/
Chemical & Engineering News	https://cen.acs.org/
Chemical Papers	https://www.chemicalpapers.com/
Chemistry Europe	https://chemistry-europe.onlinelibrary.wiley.com/
Chemistry World	https://www.chemistryworld.com/
Chicago Tribune	https://www.chicagotribune.com/
Comité des travaux historiques et scientifiques	https://cths.fr/hi/index.php
Deepdyve	https://www.deepdyve.com/
Den Store Danske	https://denstoredanske.lex.dk/
Deutsche Biographie	https://www.deutsche-biographie.de/home
Deutsche Digitale Bibliothek	https://www.deutsche-digitale-bibliothek.de/
Dignity Memorial	https://www.dignitymemorial.com/
EAD-Inventare im Schweizerischen Literaturarchiv	https://ead.nb.admin.ch/
ECHO - Cultural Heritage Online	https://echo.mpiwg-berlin.mpg.de/home
eCommons Cornell University Library	https://ecommons.cornell.edu/
EDP Sciences	https://www.edpsciences.org/en/
Encyclopædia Britannica	https://www.britannica.com/
Encyclopedia.com	https://www.encyclopedia.com/
E-Periodica	https://www.e-periodica.ch/
Faculty History Project University of Michigan	http://faculty-history.dc.umich.edu/
Fédération Québécoise des Sociétes de Généalogie	https://federationgenealogie.qc.ca/
Freiburger historische Bestände	https://www.ub.uni-freiburg.de/go/dipro
Freie Universität Berlin	https://www.fu-berlin.de/
Friedrich-Schiller-Universität Jena	https://www.uni-jena.de/
Geni	https://www.geni.com/family-tree/html/start
Gesellschaft Deutscher Chemiker	https://www.gdch.de/
Google Books	https://books.google.de/?hl=de
Historia Mathematica Heidelbergensis	http://histmath-heidelberg.de/
Historisches Lexikon der Schweiz	https://hls-dhs-dss.ch/de/
Huygens Instituut	https://www.huygens.knaw.nl/en/
In Memoriam Prof. Hans Ziegler	https://hansziegler.com/
Indiana University Bloomington Archives	https://blogs.libraries.indiana.edu/topic/iubarchives/
Institute for Advanced Study	https://www.ias.edu/
International Aerosol Research Assembly	https://iara.org/
Inventing Aviation	http://econterms.net/aero/Inventing_Aviation_main_page
Iowa College of Engineering	https://engineering.uiowa.edu/cbe
Italia Documenti	https://fdocumenti.com/
JSTOR	https://www.jstor.org/

Karlsruher Insitut für Technologie	https://www.kit.edu/
Kazerne Dossin	https://kazernedossin.memorial/
Kieler Gelehrtenverzeichnis der CAU	https://cau.gelehrtenverzeichnis.de/
Koninklijke Nederlandse Chemische Vereniging	https://chg.kncv.nl/
Larousse	https://www.larousse.fr/encyclopedie
Legacy.com	https://www.legacy.com/obituaries/search
Lexikon Theme Römpp	https://roempp.thieme.de/lexicon/keywordoftheweek
MacTutor: School of Mathematics and Statistics, University of St Andrews, Scotland	https://mathshistory.st-andrews.ac.uk/
MIT Libraries Institute Archives	https://libraries.mit.edu/distinctive-collections/collections/institute-archives/
Munzinger	https://www.munzinger.de/search/start.jsp
Nagoya University	https://en.nagoya-u.ac.jp/
National Academy of Engineering	https://www.nae.edu/
National Academy of Sciences	http://nasonline.org/
Nature	https://www.nature.com/
NCPedia	https://www.ncpedia.org/
Newspapers.com™	https://www.newspapers.com/
Organic Syntheses	http://www.orgsyn.org/
Österreichisches Biographisches Lexikon	https://biographien.ac.at/oebl
Otto Lummer - Leben und Wirken	http://www.otto-lummer.de/index.html
Pisa University Press	https://www.pisauniversitypress.it/
Prabook	https://prabook.com/web/home.html
Princeton University (Physics)	https://phy.princeton.edu/
Professorenkatalog der Universität Leipzig	https://research.uni-leipzig.de/catalogus-professorum-lipsiensium/
pro-physik	https://pro-physik.de/
Radboud Universiteit	https://www.ru.nl/
Real Academia de la Historia	https://www.rah.es/
Reflets de la physique	https://www.refletsdelaphysique.fr/
ResearchGate	https://www.researchgate.net/
Routledge	https://www.routledge.com/
Royal College of Physicians	https://history.rcplondon.ac.uk/
Royal Society of Chemistry	https://www.rsc.org/
Science History Institute	https://www.sciencehistory.org/
ScienceDirect	https://www.sciencedirect.com/
Smithsonian Online Virtual Archives	https://sova.si.edu/
Springer Link	https://link.springer.com/
St Petersburg University	https://english.spbu.ru/
Stanford University	https://www.stanford.edu/
Suomen kemian historia	https://kemianhistoria.luma.fi/
Technical University of Denmark	https://www.dtu.dk/
The Caltech Archives	https://collections.archives.caltech.edu/
The Canadian Encyvlopedia	https://www.thecanadianencyclopedia.ca/en

The Collected Papers of Albert Einstein	https://einsteinpapers.press.princeton.edu/
The Electrochemical Society	https://www.electrochem.org/
The Irish Times	https://www.irishtimes.com/
The National Archives	https://www.nationalarchives.gov.uk/
The New York Times	https://www.nytimes.com/
The Royal Society	https://royalsociety.org/
The University of Chicago Photographic Archive	https://photoarchive.lib.uchicago.edu/
Treccani	https://www.treccani.it/
TU Delft research repository	https://repository.tudelft.nl/islandora/search/?type=dismax&collection=research
U.S. Department of Energy	https://www.osti.gov/
UC Press E-Books Collection	https://publishing.cdlib.org/ucpressebooks/
Universität Bamberg	https://www.uni-bamberg.de/
Universität Basel	https://www.unibas.ch/de
Universität Hamburg	https://www.uni-hamburg.de/
Universität Zürich Archiv	https://www.archiv.uzh.ch/de.html
Universitätsarchiv Wien	https://bibliothek.univie.ac.at/archiv/
Universitätsbibliothek Bern	https://www.ub.unibe.ch/ub/index_ger.html
Universiteit Leiden	https://www.universiteitleiden.nl/en
University of California Digital Library	https://cdlib.org/
University of Glasgow	https://www.gla.ac.uk/
University of Illinois Archives	https://archives.library.illinois.edu/
University of Lodz	https://www.uni.lodz.pl/
University of Minnesota Libraries	https://www.lib.umn.edu/
University of Pennsylvania	https://www.upenn.edu/
University of Toronto	https://www.utoronto.ca/
Uniwersytet Warszawski	https://www.wuw.pl/
Professorinnen und Professoren der Universität Mainz	https://www.gutenberg-biographics.ub.uni-mainz.de/home.html
Wikidata	https://www.wikidata.org/wiki/Wikidata:Main_Page
Wikipedia	https://www.wikipedia.org/

Sources in bold were accessed by default, constituting a substantive base for biographical data, while non-bold sources were used only if no entry was found in the standard references.

Table 20: List of all NP laureates for whom the official year of awarding does not correspond to the year of announcement

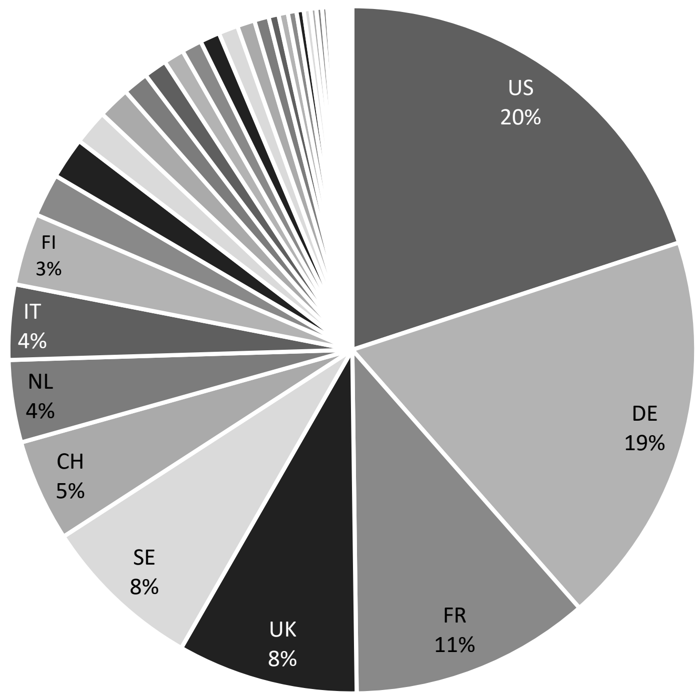
Nobel Laureate	Category	Official Award Year	Announcement Year
Max von Laue	Phy	1914	1915
Theodore Richards	Che	1914	1915
Charles Glover Barkla	Phy	1917	1918
Max Planck	Phy	1918	1919
Fritz Haber	Che	1918	1919
Walther Nernst	Che	1920	1921
Albert Einstein	Phy	1921	1922
Frederick Soddy	Che	1921	1922
Manne Siegbahn	Phy	1924	1925
James Franck	Phy	1925	1926
Gustav Hertz	Phy	1925	1926
Richard Zsigmondy	Che	1925	1926
Heinrich Wieland	Che	1927	1928
Sir Owen Richardson	Phy	1928	1929
Werner Heisenberg	Phy	1932	1933
Richard Kuhn	Che	1938	1939
Otto Stern	Phy	1943	1944
George de Hevesy	Che	1943	1944
Otto Hahn	Che	1944	1945

Table 21: Relevant changes to country borders included in the dataset

Affected countries	Affected cities	Historical Background
Norway, Sweden	Bergen, Oslo, Trondheim	In 1905, Norway withdrew from the union with Sweden and became independent.
Austro-Hungarian Empire, Austria, Czechoslovakia, Hungary, Poland, Yugoslavia	Belgrade, Budapest, Brno (Brünn), Graz, Innsbruck, Kraków (Krakau), Prague, Vienna, Zagreb	In 1918, the Austro-Hungarian Empire collapsed and disintegrated into several smaller countries.
Estonia, Finland, Latvia, Russia (Soviet Union/ Russian Empire), Poland	Helsinki, Lviv, Tartu, Turku, Oulu, Riga, Warsaw	The Grand Duchy of Finland declared its independence from the Russian Empire in 1917. Estonia and Latvia achieved independence in 1918, Poland in 1919 due to the ongoing civil war. In 1944, Russia occupied Estonia and Latvia, eventually incorporating them into the Soviet Union. Lviv, which was previously part of Poland, became a constituent republic of the Ukrainian Soviet Republic in 1939.
Danzig, France, Germany, Poland	Strasbourg, Danzig	Germany, having lost the First World War, surrendered territories to neighboring France and Poland. The city of Danzig, a free city after WWI, was integrated into the Polish Republic as Gdansk after WW II.
UK, Ireland	Dublin	In 1919, Ireland gained its independence from the UK.
Germany, Germany (DDR), Poland, Russia (Soviet Union)	Berlin, Dresden, Greifswald, Halle, Jena, Kaliningrad (Königsberg), Leipzig, Magdeburg, Potsdam, Rostock, Wroclaw (Breslau)	Germany lost WW II and ceded additional territories to Poland and Russia. In 1949, Germany was divided into the former American, British, and French occupation zones (BRD) and the Soviet occupation zone (DDR). Berlin was also split, placing Humboldt University on the side of the DDR while the Technical University of Berlin continued to exist in the BRD. As a counterpart to the Sovietized Humboldt University, the Free University of Berlin was established.

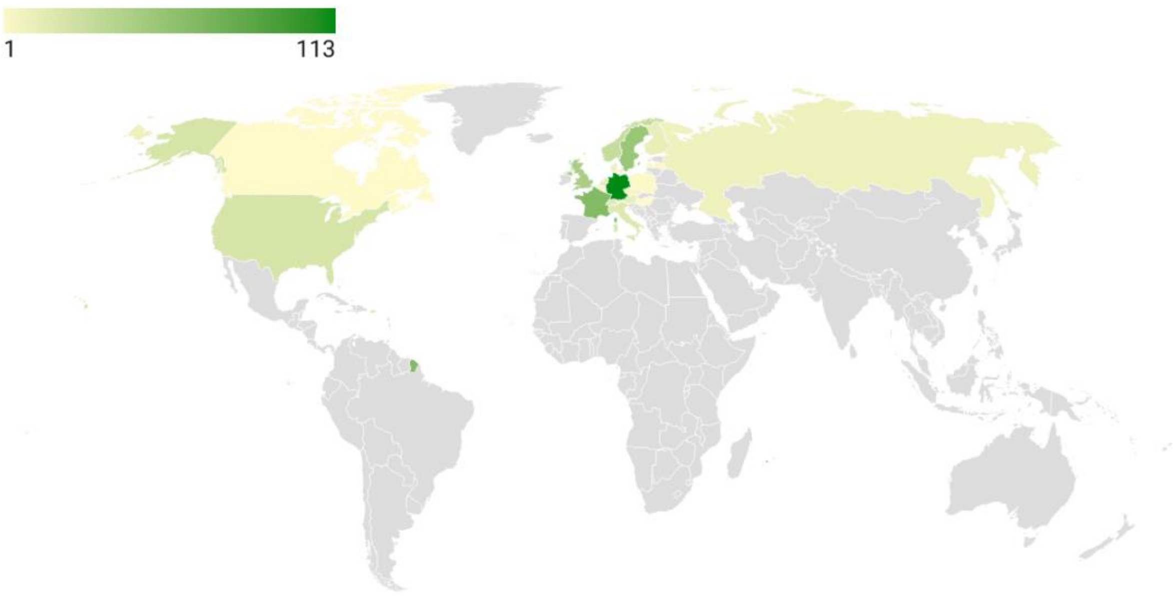
This table shows relevant changes to country borders in the time frame 1901-1969. The presentation of changes is not historically profound, but is limited to the shifts that occur in my dataset. Sources for historical information: Bartlett (2018); Bosworth and Maiolo (2015); McNeill and Pomeranz (2015); Mowat (2008 [1968]).

Figure 32: Proportion of countries in terms of submitting nominators 1901-1969



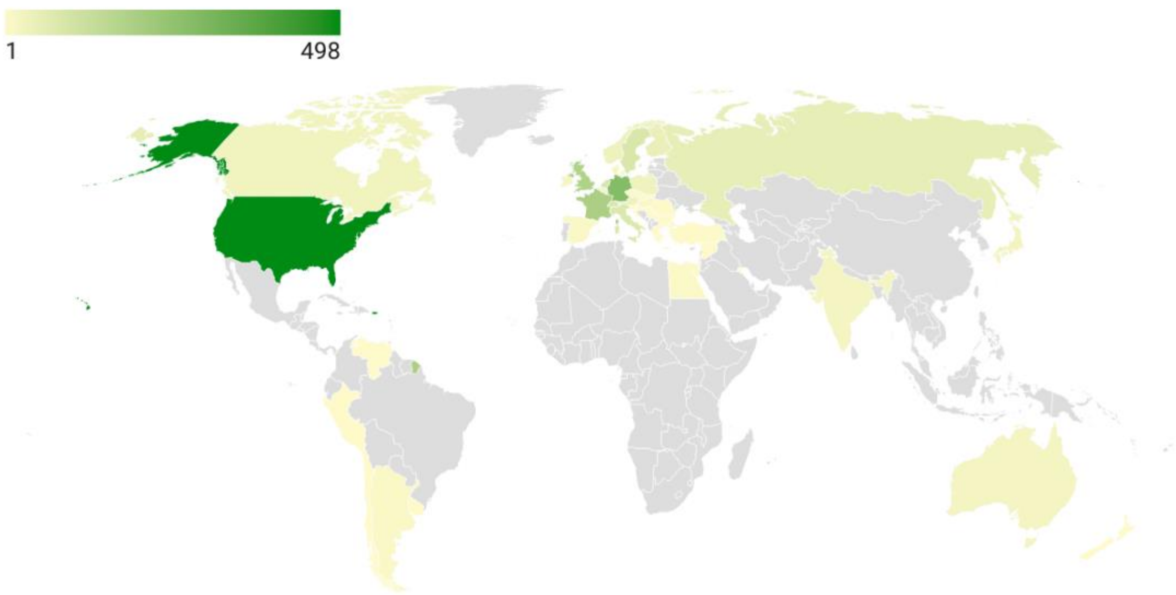
This figure shows the proportion of countries in the submission of nominators, 1901-1969. Countries comprising less than 3 percent of nominators are not depicted in this figure. Country indicators are included in the list in section 12 Abbreviations.

Figure 33: Visualization of countries by numbers of submitted nominators in the 1910s



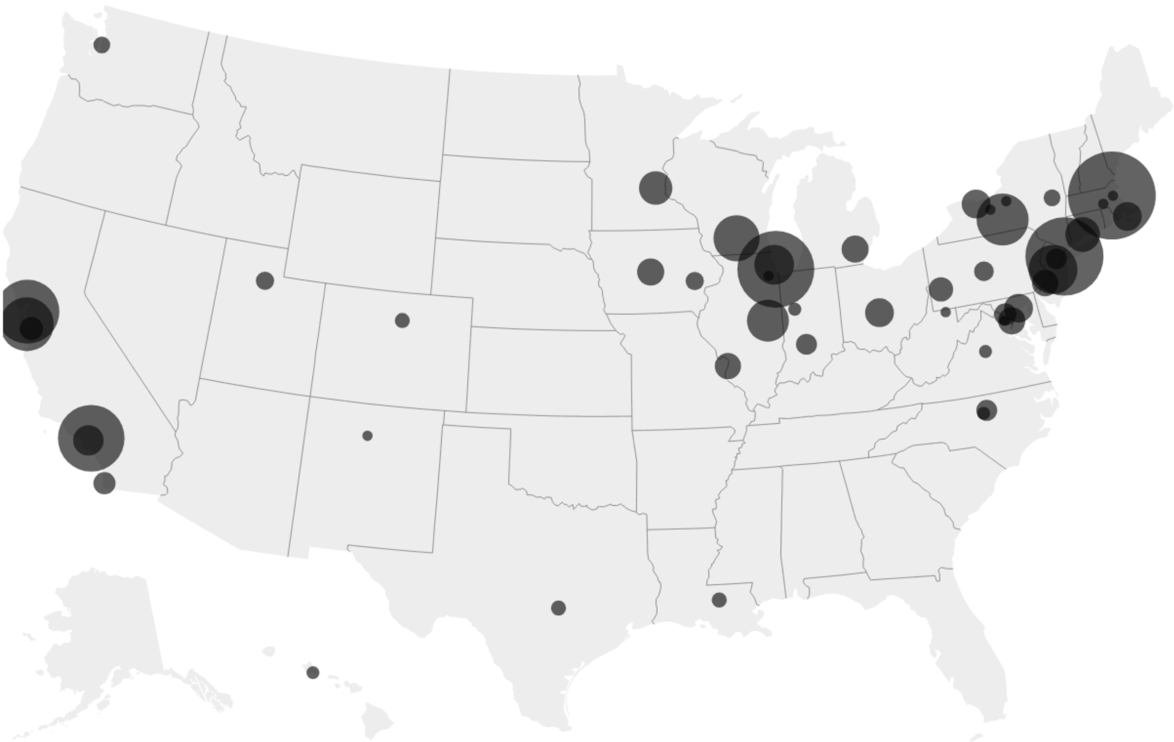
This figure (created with Datawrapper) visualizes countries that submit nominators within the second nomination decade (1910-1919). A country's color is selected after nomination counts. The scale moves from pastel yellow (one nomination) to bright green (with a maximum of 113 nominations). Grey countries submit no nominators.

Figure 34: Visualization of countries by numbers of submitted nominators in the 1960s



This figure (created with Datawrapper) visualizes countries that submit nominators within the last nomination decade (1960-1969). A country's color is selected after nomination counts. The scale moves from pastel yellow (one nomination) to bright green (with a maximum of 498 nominations). Grey countries submit no nominators.

Figure 35: Visualization of cities submitting nominators within the United States 1901-1969



This figure (created with Datawrapper) visualizes US American cities that submit nominators within the observation period (1901-1969) as grey dots on a US map depicting their geographic location. Dots are sized after nomination counts.

Figure 36: Visualization of cities submitting nominators within Europe 1901-1969

This figure (created with Datawrapper) visualizes European cities that submit nominators within the observation period (1901-1969) as grey dots on a map depicting their geographic location. Dots are sized after nomination counts.

Table 22: Global Top 5 organizations in submission of nominators categorized after decades and disciplines

Decade	Physics	Chemistry
1901-1909	University of Paris	University of Oslo
	HU Berlin	HU Berlin
	Stockholm University	LMU Munich
	LMU Munich	Stockholm University
	Collège de France	University of Paris
1910-1919	HU Berlin	HU Berlin
	University of Paris	Stockholm University
	Stockholm University	Heidelberg University
	Technical University of Denmark	LMU Munich
	LMU Munich	University of Paris
1920-1929	HU Berlin	HU Berlin
	University of Paris	University of Paris
	LMU Munich	LMU Munich
	University of Vienna	Leipzig University
	Technical University of Denmark	University of Oslo
1930-1939	Harvard University	LMU Munich
	University of London	HU Berlin
	HU Berlin	University of Helsinki
	University of Paris	University of Lyon
	University of Vienna	University of Jena
1940-1949	University of Chicago	University of Helsinki
	Caltech	Stockholm University
	Harvard University	ETH Zurich
	University of London	Caltech
	University of Paris	Uppsala University
1950-1959	University of Paris	University of Helsinki
	University of California, Berkeley	University of Chicago
	University of Chicago	Rockefeller University
	Collège de France	University of California, Berkeley
	ETH Zurich	University of Paris
1960-1969	University of Paris	ETH Zurich
	KTH Royal Institute of Technology	University of California, Berkeley
	University of Cambridge	Rockefeller University
	MIT	University of London
	Caltech	Stanford University

Table 23: Top 50 organizations for laureate affiliation (1901-1969)

Organization	Score	Rank
University of Cambridge	32	1
Humboldt University of Berlin	23	2
University of California, Berkeley	22	3
LMU Munich	15	4
University of Göttingen	14	5
Columbia University	14	6
Harvard University	14	7
Russian Academy of Sciences	14	8
California Institute of Technology (Caltech)	13	9
University of Chicago	12	10
University of Paris	11	11
Princeton University	11	12
University of Zurich	10	13
University of London	10	14
Uppsala University	9	15
Leiden University	8	16
University of Leipzig	7	17
University of Oxford	7	18
University Pierre And Marie Curie, Paris	7	19
Cornell University	7	20
Bell Laboratories	6	21
University of Heidelberg	6	22
University of Kiel	5	23
École normale supérieure (ENS)	5	24
University of Manchester	5	25
Stanford University	5	26
Institut Curie, Paris	4	27
University of Freiburg	4	28
Stockholm University	4	29
University of Amsterdam	4	30
University of Copenhagen	4	31
Massachusetts Institute Of Technology (MIT)	4	32
Technical University Of Munich	4	33
Rockefeller University	4	34
MRC Laboratory of Molecular Biology	3	35
The Royal Institution, London	3	36
University of Tokyo	3	37
Yale University	3	38
University of Marburg	3	39
University of Graz	3	40
University of Birmingham	3	41
University of Liverpool	3	42
Polytechnic University of Milan	3	43
University of Strasbourg	3	44

Sapienza University of Rome	3	45
University of Groningen	3	46
University of Helsinki	3	47
Swiss Federal Institute of Technology, Zurich	3	48
University of Oslo	3	49
University of Illinois, Urbana-Champaign	3	50
University of Cambridge	3	51

This table shows top organizations ranked after laureate affiliation based on three career stages (highest degree, prize-winning research, and awarding). Data were provided by (Heinze & Fuchs, 2022). Analogous to their paper, I replicated the calculation of the top organizations based on summarized counts for the career stages within my time frame (1901-1969) for my categories of physics and chemistry.

Table 24: Organizations with corresponding numbers for network plots

Organization	number	Organization	number
Cancer Research Institute of Villejuif	1	Faculté des sciences de Dijon	2
National Institute of Hygiene	3	Nikolaus-Kopernikus-University	4
University of Jyväskylä	5	AB	6
Aberystwyth University	7	Åbo Akademi University	8
Accademia dei Lincei	9	Aéroplanes Voisin	10
AGH University of Science and Technology	11	Agricultural University of Berlin	12
Air Liquide	13	Aix-Marseille University	14
Alexandru Ioan Cuza University	15	Allmänna Lifförsakringsbolaget	16
American Crystallographic Association	17	American Telegraphone Company	18
American University in Cairo	19	Ames Laboratory	20
Arevipharma	21	Argonne National Laboratory	22
ASEA (Allmänna Svenska Elektriska Aktiebolaget)	23	Associated Universities, Inc.	24
Atomic Energy Research Establishment (AERE)	25	Australian National University	26
Barnes Engineering Company	27	BASF	28
Bauman Moscow State Technical University	29	Bayerische Stickstoffwerke AG	30
Beckman Instruments	31	Bell Labs	32
Blohm + Voss	33	Bornö Marine Research Station	34
Brewing Industry Research Foundation	35	Brookhaven National Laboratory	36
Brown University	37	Budapest University of Technology	38
Bureau of Chemistry, U.S. Department of Agriculture	39	California Institute of Technology (Caltech)	40
Cancer Research Institute at Mount Vernon Hospital	41	Cardiff University	42
Carlsberg Laboratory	43	Carnegie Institute of Technology	44
Carnegie Institution of Science	45	Carnegie Mellon University	46
Cary Instruments	47	Case School of Applied Science	48
Case Western Reserve University	49	Catholic University of America	50
Catholic University of Leuven	51	Catholic University of Paris	52
Catholic University of Toulouse	53	Central Radio Laboratory	54
Central University of Venezuela	55	Centre national de la recherche scientifique (CNRS)	56
CERN	57	Chalk River Laboratories	58
Chalmers University of Technology	59	Charles University	60
Ciba AG	61	Clarkson University	62
Collège de France	63	Columbia School of Mines	64
Columbia University	65	Comenius University	66
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	67	Complutense University of Madrid	68
Consejo Superior de Investigaciones Científicas (CSIC)	69	Cornell University	70
Czech Technical University of Prague	71	Czech[oslovak] Academy of Sciences	72
DECHEMA	73	Delft University of Technology	74
Director of a sugar refinery	75	Dmitri Mendeleev Chemical-Technical University	76
Dow Corning	77	Dublin Institute for Advanced Studies	78
Duke University	79	DuPont	80
E. B. Eddy Company	81	École Centrale de Lille	82
École Centrale Paris (ECP)	83	École des Mines et de la Métallurgie	84
École municipale de chimie industrielle	85	École nationale supérieure de chimie de Paris (ENSCP)	86
École normale supérieure (ENS)	87	École Polytechnique	88

École pratique des hautes études	89	École supérieure d'électricité	90
Eötvös Loránd University	91	ESPCI Paris	92
Federal University of Rio de Janeiro	93	Finsbury Technical College	94
Ford Motor Company	95	Fordham University	96
FOX	97	Franklin Institute	98
Free Church Training College	99	Free Polish University	100
Free University of Amsterdam	101	Free University of Berlin	102
Free University of Brussels	103	French Army's Engineering Corps	104
French Navy	105	Funk Foundation for Medical Research	106
Gdańsk University of Technology	107	General Electric Company (GE)	108
George Washington University	109	Georg-Speyer-Haus	110
German Academy of Sciences at Berlin	111	German Technical University of Brno	112
German Technical University Prague	113	German University of Prague	114
Ghent University	115	Goethe University Frankfurt	116
Gray Laboratory (Oxford Institute for Radiation Oncology)	117	Graz University of Technology	118
Grenoble Alpes University	119	Gustav Werner Institute	120
Gymnasium Wolfenbüttel	121	Hadfield's Steel Foundry	122
Hale Solar Laboratory	123	Handels- und Gewerbekammer Prag (Chamber of Commerce)	124
Harvard University	125	Hebrew University of Jerusalem	126
Heidelberg University	127	Helsinki University of Technology	128
Hughes Research Laboratories	129	Humboldt University of Berlin	130
Hungarian Academy of Sciences (Institute of Technical Physics)	131	IBM	132
IG Farben	133	Imperial College London	134
Indian Academy of Sciences	135	Indian Institute of Science	136
Indiana University Bloomington	137	Institut d'optique Graduate School	138
Institut Henri Poincaré	139	Institut national des sciences appliquées de Lyon	140
Institute for Advanced Study	141	Institute for Theoretical and Experimental Physics	142
Institute for Theoretical Physics Naples	143	Institute of Experimental Medicine	144
Institute of Mathematical Sciences	145	Institute of Paper Chemistry	146
International Bureau of Weights and Measures	147	Iowa State University	148
Istituto Nazionale di Fisica Nucleare (INFN)	149	Italian National Institute of Health	150
J. R. Geigy AG	151	Jagiellonian University	152
Jernkontoret, Association of the Swedish Steel Industry	153	Jerusalem College of Technology	154
Johns Hopkins University	155	Joint Institute for Nuclear Research	156
Karlsruhe Institute of Technology	157	Karolinska Institute	158
Kazan Federal University	159	Kitasato University	160
Kloster Ironworks	161	Kobe University	162
KTH Royal Institute of Technology	163	Kuwait University	164
Kyiv University	165	Kyoto University	166
Leibniz University Hannover	167	Leiden University	168
Leipzig University	169	Lick Observatory (University of California)	170
Los Alamos Laboratory	171	Loughborough College	172
Louisiana State University	173	Ludwig Maximilian University of Munich	174
Luftschiffbau Zeppelin GmbH	175	Lund University	176
Marconi Wireless Telegraph Co Ltd	177	Marine Biological Laboratory	178
Martin Luther University of Halle-Wittenberg	179	Massachusetts Institute of Technology (MIT)	180

Max Planck Society	181	Max Planck Society (Forschungsstelle für Physik der Stratosphäre)	182
Max Planck Society (Fritz Haber Institute)	183	Max Planck Society (Institute for Biochemistry)	184
Max Planck Society (Institute for Biology)	185	Max Planck Society (Institute for Biophysical Chemistry)	186
Max Planck Society (Institute for Cellular Biology)	187	Max Planck Society (Institute for Chemistry)	188
Max Planck Society (Institute for Coal Research)	189	Max Planck Society (Institute for Developmental Biology)	190
Max Planck Society (Institute for Leather Research)	191	Max Planck Society (Institute for Medical Research)	192
Max Planck Society (Institute for Physics)	193	Max Planck Society (Institute of Immunobiology and Epigenetics)	194
Max Planck Society (Institute of Molecular Physiology)	195	Max Planck Society (Schlesisches Kohleforschungsinstitut)	196
Mayo Clinic	197	McGill University	198
McMaster University	199	Memorial Sloan Kettering Cancer Center	200
Merck & Co.	201	Metallografiska institutet (Part of Research Group Swerea)	202
Metallurgiska AB	203	Météo-France	204
Meteorological Service of the Russian Empire	205	Millstead Laboratory of Chemical Enzymology	206
Moor-Versuchsstation Bremen	207	Moscow Petroleum Institute	208
Moscow State University	209	Moscow Technical Institute of Physics	210
Mount Wilson Observatory	211	MRC Laboratory of Molecular Biology	212
Nagoya University	213	National Bureau of Standards	214
National Carbon Company	215	National Institute for Medical Research	216
National Institute of Advanced Industrial Science and Technology	217	National Institute of Standards and Technology	218
National Institutes of Health	219	National Physical Laboratory (NPL)	220
National Radio Astronomy Observatory	221	National Research Council of Canada	222
National University of Ireland	223	National University of San Marcos	224
New York State Experiment Station	225	New York University	226
Newcastle University	227	Nobel Foundation	228
Nordic Institute for Theoretical Physics (NORDITA)	229	Norsk Hydro	230
Northwestern University	231	Norwegian University of Science and Technology	232
Oak Ridge National Laboratory	233	Odessa University	234
Ohio State University	235	Osaka University	236
Osmania University	237	Osservatorio Astronomico di Brera	238
Owner of a Flying School	239	Paris Observatory	240
Pasteur Institute	241	Pennsylvania State University	242
Philips Physics Laboratory	243	Physikalisch-Technische Bundesanstalt	244
Polaroid Company	245	Polish Academy of Sciences	246
Polytechnic Institute of Brooklyn	247	Polytechnic University of Milan	248
Polytechnic University of Turin	249	Princeton University	250
Private Company	251	Private Laboratory	252
Public Health Research Institute	253	Purdue University	254
Queen's University Belfast	255	Radio Corporation of America (RCA)	256
Raman Research Institute	257	Reale Museo di Fisica e Storia Naturale	258
Research Association in Basel	259	Research Center of Ciba-Geigy	260
Rhône-Poulenc	261	Rice University	262
Riga Technical University	263	Riken	264
Rockefeller University	265	Romanian Academy (Institute of Physical Chemistry)	266
Rothamsted Research	267	Roussel Uclaf S.A.	268
Rowett Institute	269	Royal Air Force	270
Royal Institution of Great Britain	271	Royal North Shore Hospital	272

Royal Radar Establishment	273	Royal Swedish Academy of Engineering Sciences (IVA)	274
Royal Swedish Academy of Sciences	275	Royal Swedish Academy of Sciences (Academy of Agriculture)	276
Royal Veterinary and Agricultural University	277	Russian Academy of Sciences	278
Russian Academy of Sciences (Institute for Physical Chemistry)	279	Russian Academy of Sciences (Institute of Biological and Medical Chemistry)	280
Russian Academy of Sciences (Institute of natural compounds’ chemistry)	281	Russian Academy of Sciences (Ioffe Institute)	282
Russian Academy of Sciences (Kurchatov Institute)	283	Russian Academy of Sciences (Landau Institute for Theoretical Physics)	284
Russian Academy of Sciences (Lebedev Physical Institute)	285	Russian Academy of Sciences (Pulkovo Observatory)	286
Russian State Agrarian University (Moscow Timiryazev Agricultural Academy)	287	Rutgers University	288
RWTH Aachen University	289	Saarland University	290
Saint Petersburg State University	291	Sandoz Pharmaceuticals	292
Sapienza University of Rome	293	Scientific Research Institute No. 9	294
Scripps Institution of Oceanography	295	Scuola Normale Superiore di Pisa	296
Secret Nuclear Weapons Research Center, Sarov	297	Sericultural Experiment Station	298
Shizuoka University	299	Shockley Semiconductor Laboratory (Beckman Instruments)	300
Siemens & Halske	301	Slovak University of Technology in Bratislava	302
Smithsonian Institution	303	Société de la Soie Chardonnet	304
Société Française des Pétroles	305	Société Lumière	306
Spanish National Research Council	307	Staatliches Forschungsinstitut für Metallchemie	308
Stanford University	309	Statens Serum Institut	310
Stazione Zoologica Anton Dohrn	311	Sternwarte Berlin-Babelsberg (Berlin Observatory)	312
Stockholm University	313	Stora Kopparbergs bergslag	314
Sumida AG	315	Swansea University	316
Swedish Meteorological and Hydrological Institute	317	Swedish Tanning Research Institute	318
Swedish University of Agricultural Sciences	319	Swiss Federal Institute of Technology	320
Swiss Federal Institute of Technology (Lausanne)	321	Syracuse University	322
Tata Institute of Fundamental Research	323	Technical University of Berlin	324
Technical University of Braunschweig	325	Technical University of Darmstadt	326
Technical University of Denmark	327	Technical University of Dresden	328
Technical University of Iași	329	Technical University of Munich	330
Technical University of Vienna	331	Technion, Israel Institute of Technology	332
Tel Aviv University	333	Telefunken	334
Televerket	335	The Combustion Institute	336
Thomas A. Edison Incorporated	337	Tohoku University	338
UFA	339	Umea University	340
Union Carbide	341	United Institute for Nuclear Research (JINR)	342
United States Atomic Energy Comission	343	United States Geological Survey	344
Universidad De La Repúplica Uruguay	345	Université Laval	346
University at Albany	347	University College of North Wales	348
University of Aarhus	349	University of Aberdeen	350
University of Adelaide	351	University of Alaska	352
University of Algiers	353	University of Allahabad	354
University of Amsterdam	355	University of Athens	356
University of Auckland	357	University of Barcelona	358
University of Basel	359	University of Belgrade	360
University of Bergen	361	University of Bern	362
University of Birmingham	363	University of Bologna	364

University of Bonn	365	University of Bordeaux	366
University of Bristol	367	University of British Columbia	368
University of Bucharest	369	University of Buenos Aires	370
University of Cairo	371	University of Calcutta	372
University of California, Berkeley	373	University of California, Davis	374
University of California, Irvine	375	University of California, Los Angeles	376
University of California, San Diego	377	University of Cambridge	378
University of Canberra	379	University of Canterbury	380
University of Cape Town	381	University of Chemistry and Technology Prague	382
University of Chicago	383	University of Chile	384
University of Cologne	385	University of Colorado Boulder	386
University of Copenhagen	387	University of Debrecen	388
University of Delhi	389	University of Dublin	390
University of Dundee	391	University of Durham	392
University of Düsseldorf	393	University of Edinburgh	394
University of Erlangen-Nuremberg	395	University of Florence	396
University of Florida, Gainesville	397	University of Freiburg	398
University of Fribourg	399	University of Geneva	400
University of Genoa	401	University of Glasgow	402
University of Gothenburg	403	University of Göttingen	404
University of Graz	405	University of Greifswald	406
University of Groningen	407	University of Hamburg	408
University of Hawaii	409	University of Helsinki	410
University of Hull	411	University of Iceland	412
University of Illinois at Urbana-Champaign	413	University of Innsbruck	414
University of Iowa	415	University of Istanbul	416
University of Jena	417	University of Kaliningrad	418
University of Kiel	419	University of Lausanne	420
University of Leeds	421	University of Liège	422
University of Lisbon	423	University of Liverpool	424
University of London	425	University of Lorraine	426
University of Lviv	427	University of Lyon	428
University of Madras	429	University of Mainz	430
University of Manchester	431	University of Manitoba	432
University of Marburg	433	University of Maryland	434
University of Melbourne	435	University of Miami	436
University of Michigan	437	University of Milan	438
University of Minnesota, Twin Cities	439	University of Montevideo	440
University of Montpellier	441	University of Mumbai	442
University of Münster	443	University of Naples Federico II	444
University of Neuchâtel	445	University of New South Wales	446
University of North Carolina	447	University of Oslo	448
University of Otago	449	University of Ottawa	450
University of Oulu	451	University of Oxford	452
University of Padua	453	University of Palermo	454
University of Paris	455	University of Pavia	456
University of Pennsylvania	457	University of Pisa	458

University of Pittsburgh	459	University of Poitiers	460
University of Punjab	461	University of Reading	462
University of Rochester	463	University of Rostock	464
University of São Paulo	465	University of Sheffield	466
University of Sofia	467	University of Southern California	468
University of St Andrews	469	University of Strasbourg	470
University of Strathclyde	471	University of Stuttgart	472
University of Sydney	473	University of Szeged	474
University of Tartu	475	University of Tasmania	476
University of Texas at Austin	477	University of Tokyo	478
University of Toronto	479	University of Toulouse	480
University of Trondheim	481	University of Tübingen	482
University of Turin	483	University of Turku	484
University of Utah	485	University of Vienna	486
University of Virginia	487	University of Warsaw	488
University of Washington	489	University of Wisconsin-Madison	490
University of Wisconsin-Milwaukee	491	University of Wroclaw	492
University of Würzburg	493	University of Zagreb	494
University of Zurich	495	Uppsala University	496
Ural State University	497	Utrecht University	498
Veterinary University Budapest	499	Warsaw University of Technology	500
Washington University in St. Louis	501	Weizmann Institute of Science	502
Wellcome Research Laboratories	503	West Virginia University	504
Wool Industries Research Association	505	Wright Company	506
Wroclaw University of Science and Technology	507	Yale University	508
Zhukovsky Air Force Engineering Academy	509		

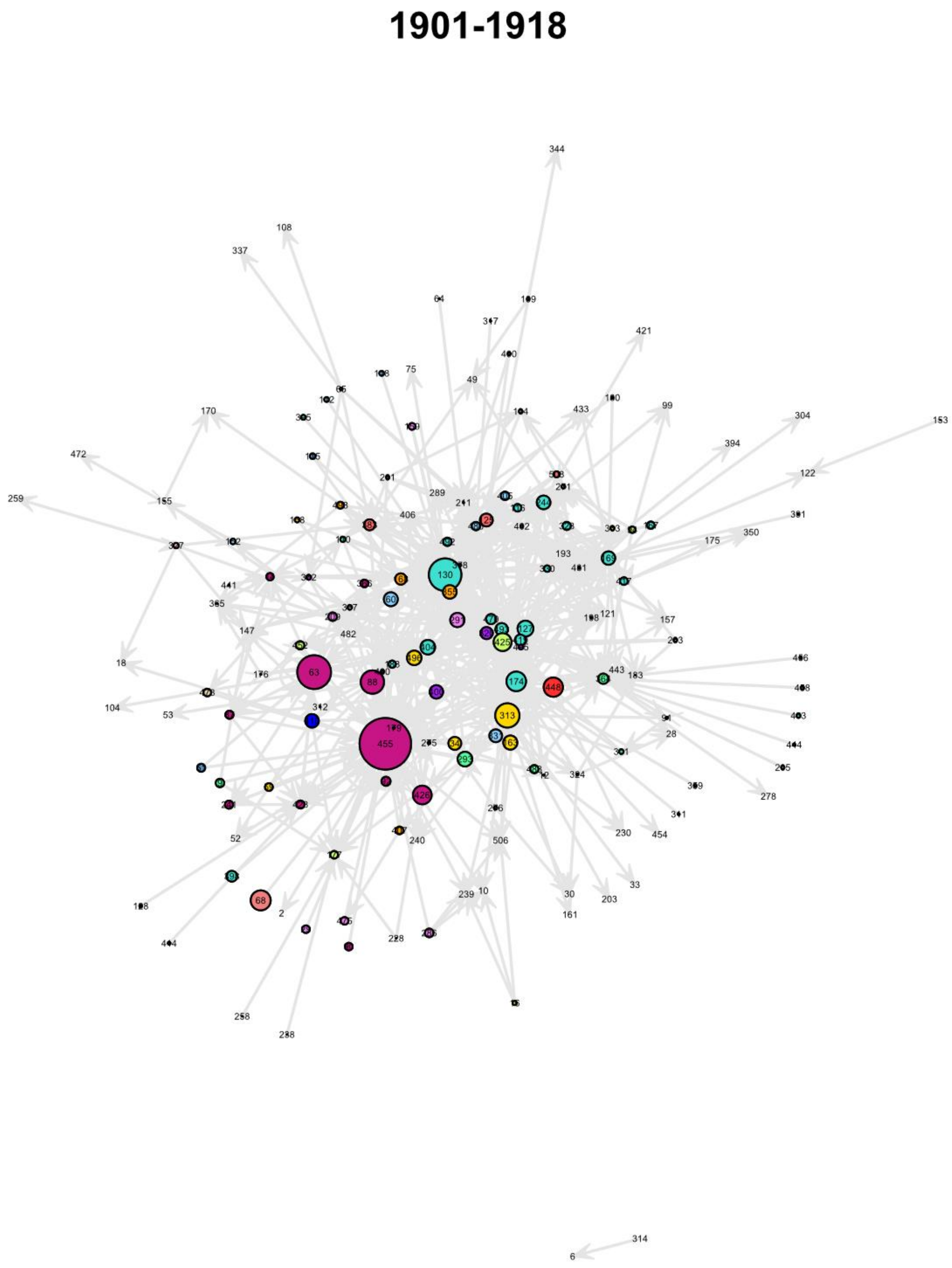
Table 25: Robustness check for models 1-3 for disciplines

	Physics			Chemistry		
	(1)	(2)	(3)	(1)	(2)	(3)
Nominees‘ variables						
Number of past nominations (numerical)	0.03***	-	-	0.04***	-	-
	(0.08)			(0.00)		
Membership in the RSAS	-0.13	-	-	0.61***	-	-
	(0.16)			(0.13)		
HD in high-status Uni	-	-	0.44***	-	-	0.17
			(0.10)			(0.12)
Organizational status Reference category: peripheral						
Middle-low	-	-	0.99***	-	-	1.19***
			(0.23)			(0.24)
Middle-high	-	-	1.40***	-	-	1.63***
			(0.23)			(0.23)
Central	-	-	2.26***	-	-	2.05***
			(0.23)			(0.23)
Newcomer organizations	-	-	1.28***	-	-	-0.62
			(0.24)			(0.46)
Country Reference category: all other countries						
Germany	-	0.64***	-	-	0.59**	-
		(0.18)			(0.19)	
USA	--	0.57***	--	--	0.48**	--
		(0.15)			(0.18)	
Northern countries		-0.55			0.09	
		(0.29)			(0.25)	
UK	-	0.76***	-	-	0.61**	-
		(0.20)			(0.20)	
France	-	0.10	-	-	-0.56	-
		(0.23)			(0.31)	
Nominators‘ variables						
Number of past nominations (numerical)	-0.04**	-	-	-0.04**	-	-
	(0.01)			(0.01)		
Membership in the RSAS	0.23	-	-	0.73***	-	-
	(0.12)			(0.14)		
Laureates	0.43***	-	-	0.36*	-	-
	(0.13)			(0.14)		
Organizational status Reference category: peripheral						
Middle-low	-	-	0.18	-	-	0.27
			(0.16)			(0.18)
Middle-high	-	-	0.12	-	-	0.47**
			(0.16)			(0.17)
Central	-	-	0.21	-	-	0.08
			(0.16)			(0.19)
Newcomer organizations	-	-	0.34	-	-	0.76***
			(0.20)			(0.20)
country Reference category: all						

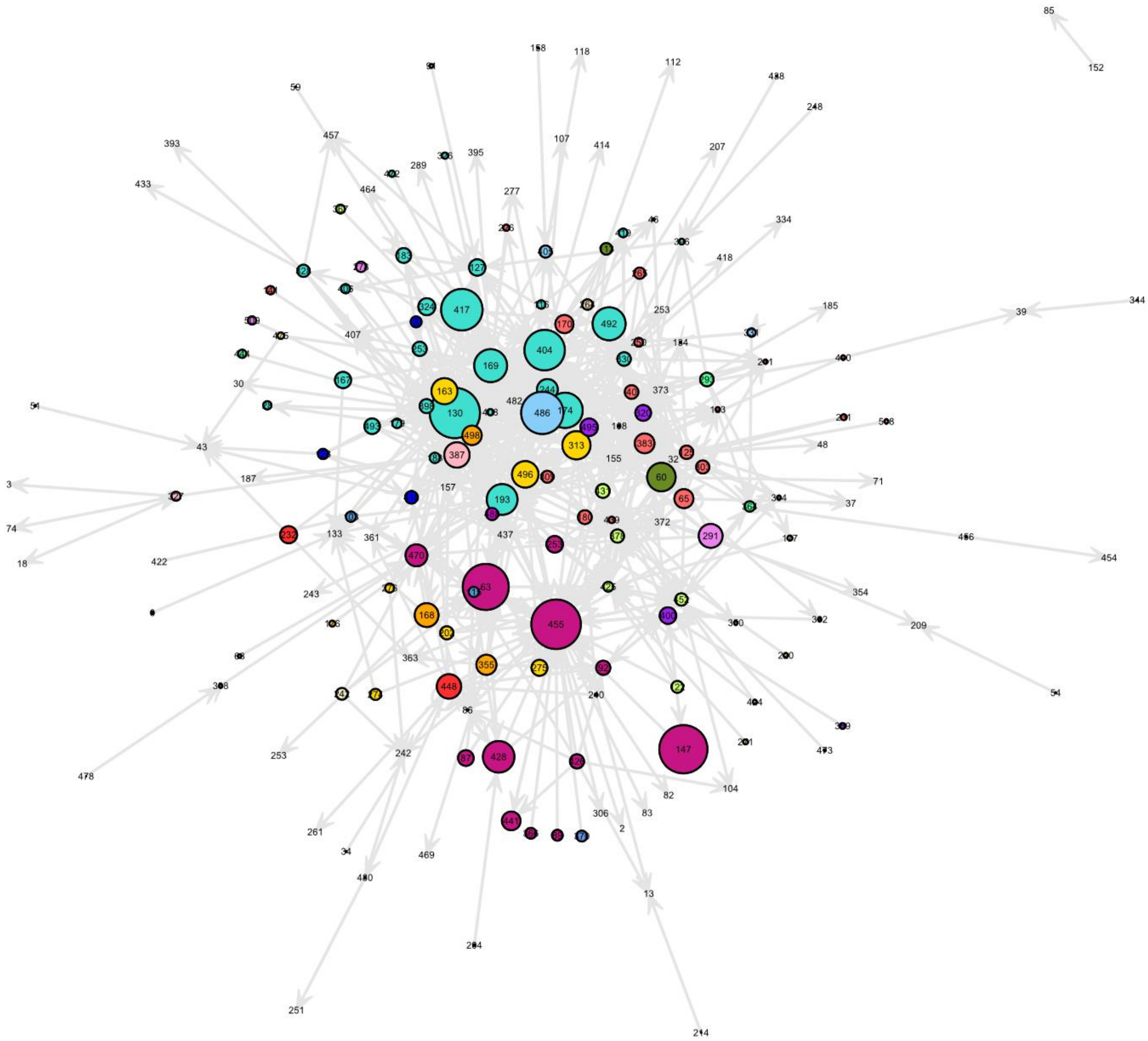
other countries						
Germany		-0.18			-0.21	
		(0.15)			(0.19)	
USA		-0.23			0.07	
		(0.14)			(0.18)	
Northern countries		0.33*			0.87***	
		(0.15)			(0.16)	
UK		-0.51*			0.25	
		(0.21)			(0.23)	
France		-0.08			0.56*	
		(0.19)			(0.22)	
Self-nominations			-0.45***			-0.53***
(national level)			(0.11)			(0.12)
Self-nominations			-0.82***			-1.25***
(organizational level)			(0.19)			(0.24)
Mentoring-relation	-0.72*			-0.67*		
	(0.31)			(0.34)		
N	4251	4251	4251	3859	3859	3859
AIC	3045	3221	3009	2367	2610	2430
BIC	3090	3291	3086	2410	2678	2505
McFadden Pseudo R^2	0.07	0.01	0.08	0.12	0.03	0.10
Nagelkerke Pseudo R^2	0.09	0.02	0.11	0.16	0.04	0.13

Standard errors in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

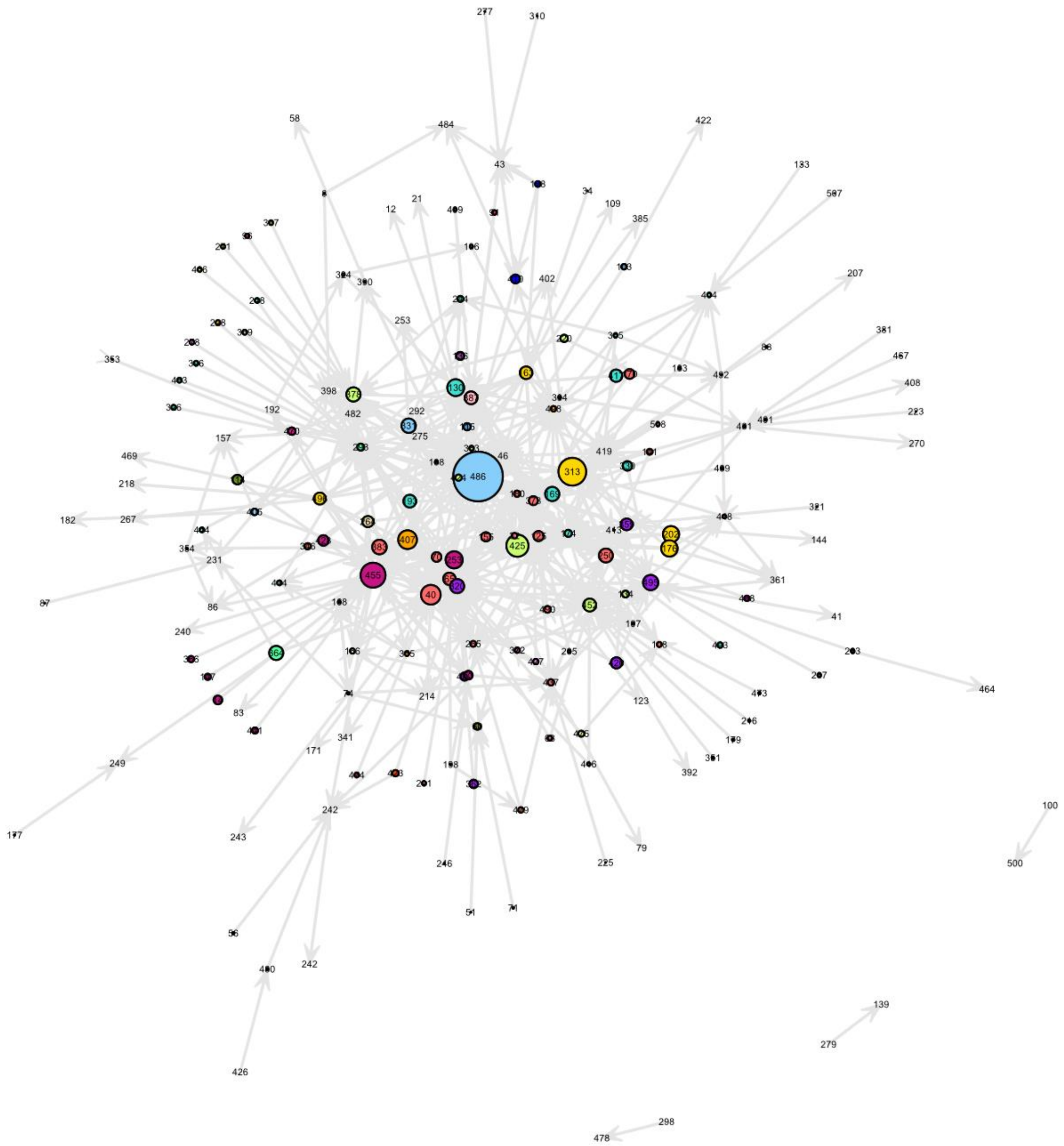
Figure 37: Organizational hubs within time periods



1919-1933

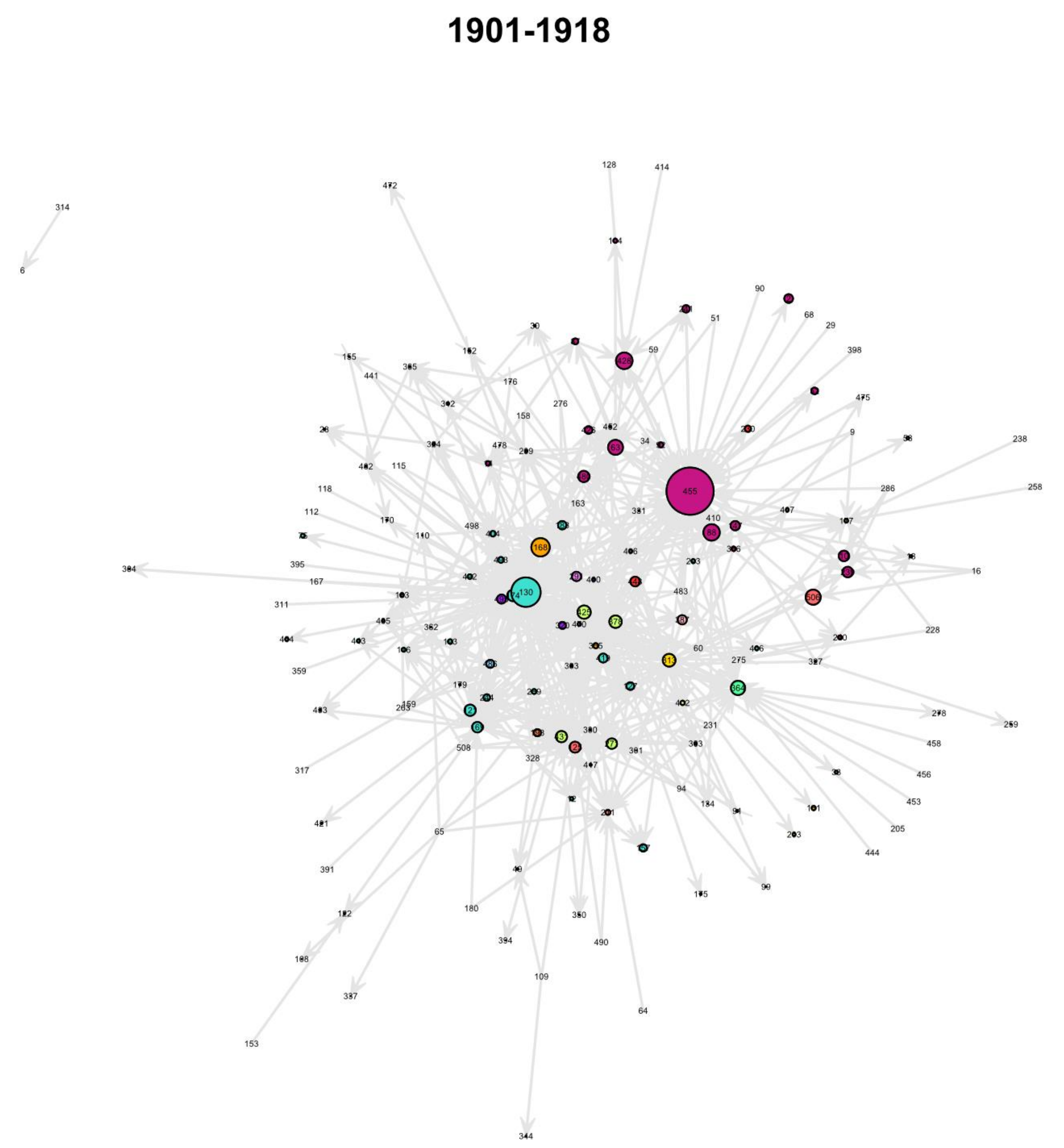


1934-1945

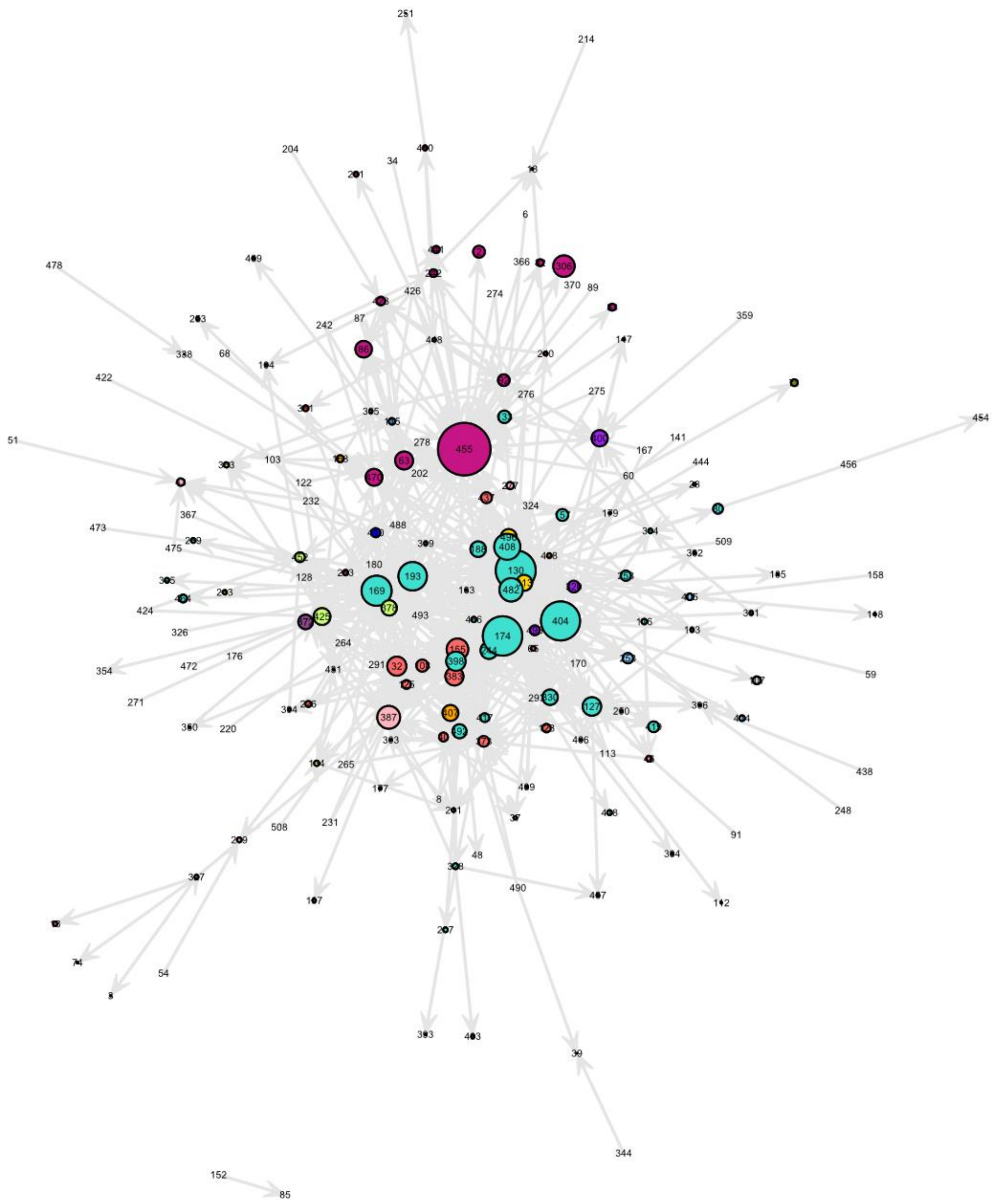


1946-1969

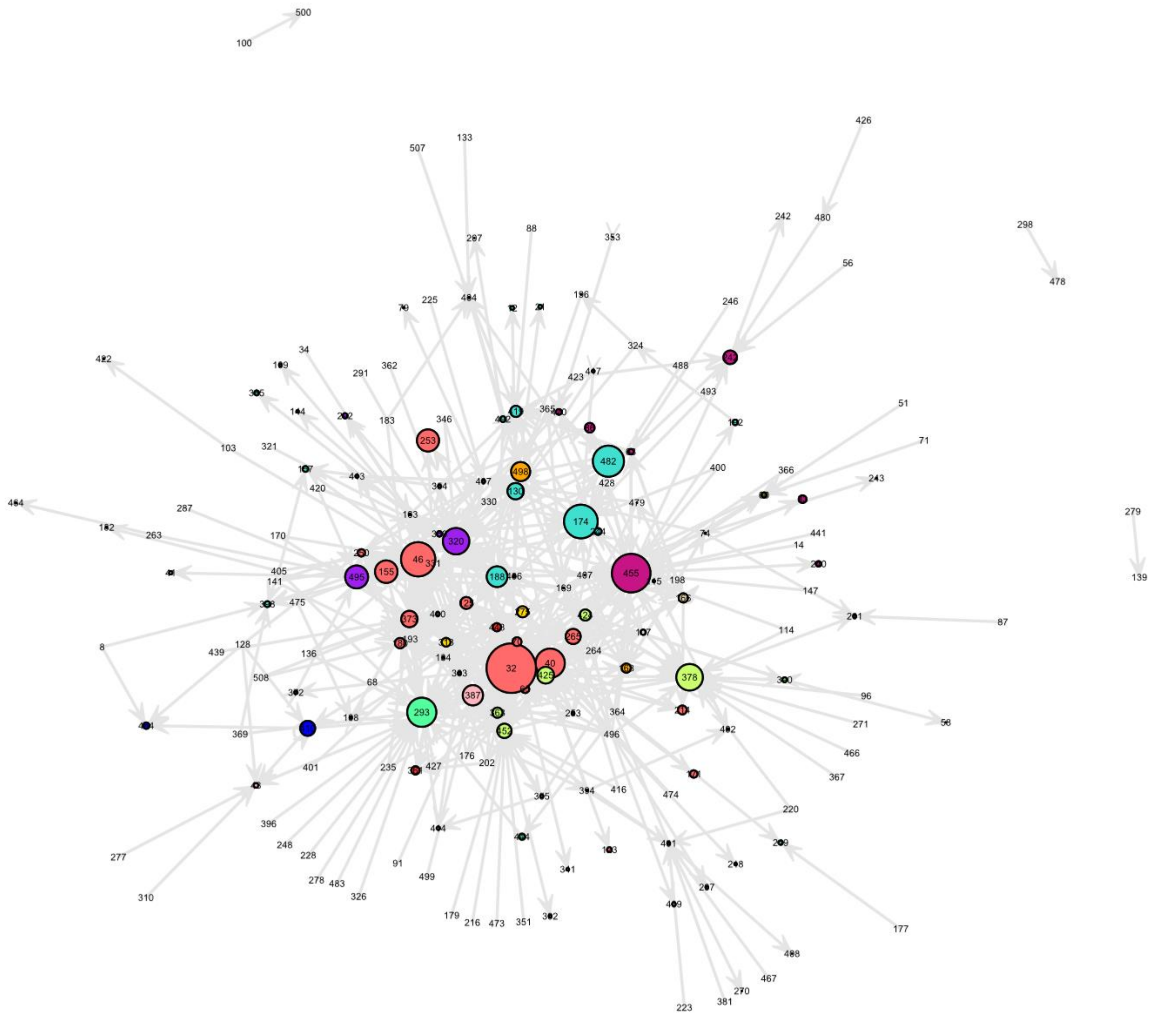
Figure 38: Organizational authorities within time periods



1919-1933



1934-1945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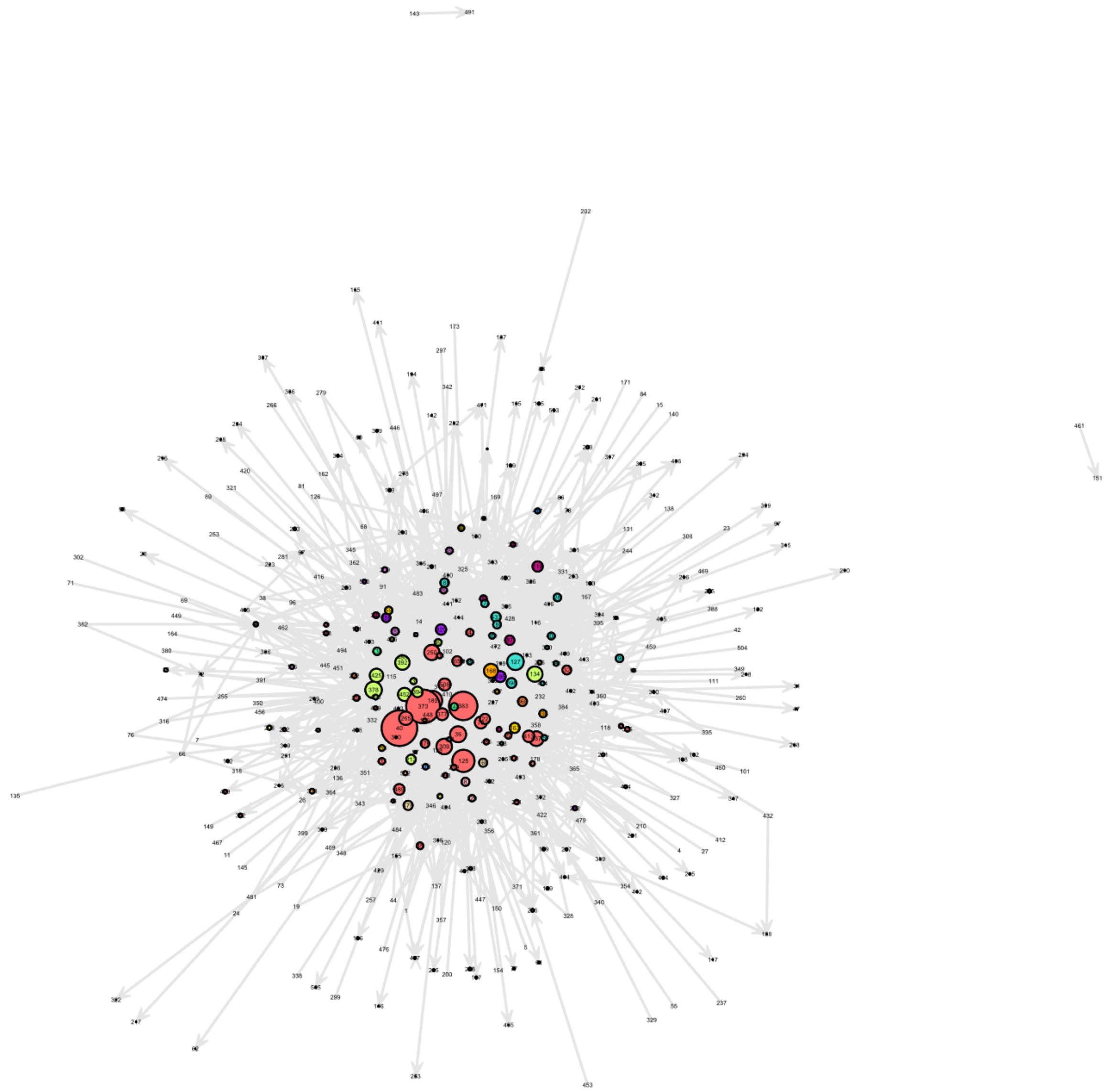
1946-1969



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