Men Benefit More than Women from Networks in Science

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Abstract

We study how networks in the scientific community contribute to the persistent gender gap in science. To do so, we exploit sudden and plausibly exogenous variation in the academic networks of scientists. We study a group of individuals who are finalists for selection to temporarily serve at a national scientific funding agency, the National Natural Science Foundation of China (NSFC). We show how those who are selected for service benefit from networks formed during this period, documenting that this service differentially affects later grant outcomes and the career development of male and female scientists. After their service concludes, male scientists are much more likely than females to acquire NSFC grants, especially high-stakes grants, both for themselves and their colleagues, and are more likely to be promoted to administrative positions. We also find that the temporary work experience at NSFC does not affect subsequent scientific productivity. Analysis of administrative network data and text data collected from online discussions suggest that men are more likely than women to develop connections with powerful NSFC grant panelists who decide final funding outcomes and are mostly male. Overall, our findings suggest that this type of academic network benefits men more than women, contributing to the persistent gender gap in scientists' career development.

Keywords: research; science; gender gap; networks; scientific funding; China

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1 Introduction

There is a large and persistent gender gap in the career development of scientists (Ceci and Williams, 2011; Huang et al., 2020; Larivière et al., 2013; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; Wennerås and Wold, 1997). Among many candidate influences – such as discrimination, unequal distribution of home labor, and institutional male preference – the role of personal networks in career advancement has received recent attention as a possible and important contributor to this gap (Cheng and Weinberg, 2021; Ductor et al., 2022; Vásárhelyi et al., 2021). This work has been limited in scope by the difficulty of isolating variation in a person's academic network.

In this paper, we exploit sudden shocks to scientists' academic networks to characterize how these networks shape career advancement, and how this differs by gender. We study the common practice of funding agencies using temporary "rotators" who serve in the agency for a set period of time to assist with agency operations, and with grantmaking in particular. Our empirical analysis focuses on rotators at the National Natural Science Foundation of China (NSFC), the world's largest basic research funding in terms of applications. Rotators at the NSFC work for two years and then return to their home institution. We show how networks formed during the rotating period differentially affect post-rotation grant outcomes and the career development of male and female scientists. We find that male rotators develop stronger connections with the powerful NSFC grant panelists who decide final funding outcomes and are themselves mostly male. We also find that male rotators are much more likely than females to exploit networks to acquire NSFC grants (especially high-stakes ones), both for themselves and their colleagues. They are also more likely to be promoted to administrative positions after leaving the NSFC.

We study this phenomenon in China because of several traits which allow us to study how networks formed in the workplace differentially affect career development of male and female scientists. First, despite large improvements in recent years, a large gender gap still exists in career development among Chinese scientists (Ma et al., 2018). For instance, although females account for 41.87% of PhD students and 51.22% of college faculty in China in 2020, only 31.65% of full professors and only 6% of fellows

of Chinese Academy of Sciences are women.[1] Second, China has a long tradition of cherishing networking (in Chinese, *guanxi*) that plays an important role in Chinese academia (Fisman et al., 2018; Shi and Rao, 2010), with people in power able to use their influence to allocate scientific research resources to those in their network. Third, the NSFC is the world's largest agency in terms of scientific funding applications, and a third of its officers are rotating directors. Furthermore, it publicizes the name list of these rotators – as well as finalists who were not ultimately selected to be rotators[2] – as well as data on scientific networks related to different grants, enabling us to identify rotators and study how they develop networks during their temporary work period.

We find that male rotators are much more likely than females to acquire NSFC grants, especially high-stakes ones, after their period of service. For instance, we find that rotator experience increases the chance of acquiring high-stakes NSFC grants by about one half for male rotators, but no such effect exists for female rotators. Colleagues of male rotators at the rotator's home institution are also more likely to receive grants both during and after the rotation period. In addition, we find that male rotators are more likely to be promoted to administrative positions after leaving the NSFC. We find no evidence of effects for female rotators in any of these outcomes.

Our interpretation of these results is that male rotators exploit networks formed during their tenure at the NSFC to help obtain scientific grants and thus advance their career development or benefit colleagues at their home institutions. Using administrative data on networks of NSFC scientists, we find that male rotators are more likely than females to develop connections with the NSFC grant panelists who decide final funding outcomes. The results are also consistent with qualitative evidence we provide on the networking activities taking place at conferences and, separately, from analysis of text scraped from online discussion forums popular among scientists.

We can reasonably exclude the likelihood of two possible alternative explanations: information gathering/learning and, separately, increased academic performance as a

[1] Data sources: http://www.moe.gov.cn/jyb_sjzl/moe_560/2020/quanguo/; http://casad.cas.cn/ysxx2017/xgtj/ysxbbl/201803/t20180306_4637292.html.

[2] The NSFC has 122 rotating directors, accounting for one third (=122/371) of all of its directors in 2020. https://www.nsfc.gov.cn/publish/portal0/ndbg/2020/06/info81482.htm. By contrast, in the US National Science Foundation, rotators only account for about 12% of the total workforce (Mervis, 2016).

result of rotator service. First, information gathering/learning is unlikely to be the main mechanism because male and female scientists are likely to acquire roughly the same amount of knowledge regarding the grant selection process from their work as rotators, given that they do a fixed set of jobs while at the NSFC. Second, for both males and females we find no evidence of effects of rotator experience on the person's number and quality of publications post-rotation.

Our paper makes the following contributions. First, our paper adds to understanding of the causes of the persistent gender gap in the ranks of senior scientists. We advance this literature by providing causal estimates of the role of networking in driving the gender gap. Gender discrimination (Bol et al., 2022; Card et al., 2020; Hengel, 2022), gender differences in child-rearing responsibilities (Kim and Moser, 2021; Shen, 2013), and gender differences in noncognitive skills such as confidence or competitiveness (De Paola et al., 2017; Niederle and Vesterlund, 2007) are all likely to contribute to this gap, but the role of personal networks in perpetuating this gap has only recently begun to be explored empirically. Cheng and Weinberg (2021) and Vásárhelyi et al. (2021) show that men's collaboration networks are more likely than women's to be associated with higher online visibility of their publications or with adoption of new scientific ideas. Ductor et al. (2022) show that the gender gap in economics journal publications is associated with differences in the co-authorship networks of men and women. Building on these studies, which primarily examine the gendered correlation between networks and publications, our paper provides causal estimates of the effect of networking on the gender gap in science. Furthermore, we study novel outcomes highly important to the career development of scientists in essentially all STEM fields: the procurement of large and prestigious scientific funding awards, and career promotion.

Second, our paper contributes to an emerging literature on the effects of social networks in science (Fisman et al., 2018; Wennerås and Wold, 1997; Zinovyeva and Bagues, 2015). We study how insider networks help applicants to obtain scientific grants. Hoenen and Kolympiris (2020) study how NSF rotators help early-career colleagues obtain scientific grants via mentoring. We build on this work, focusing instead on the gendered influence of networks on scientific grantmaking. We also use a dataset with a larger sample size and time frame than prior work. Our data cover

roughly 80% of all NSFC rotators over a 20-year period.[3]

The rest of our paper proceeds as follows. Section 2 provides the background on NSFC funding and rotators. Section 3 introduces the main datasets used in our analyses, followed by empirical strategies in Section 4. Section 5 studies how rotator experience differentially affects male and female scientists' chances of getting NSFC grants and career development. Section 6 explores how male and female rotators differentially form networks and exclude other possible mechanisms. The final section concludes.

2 Institutional Background

In this section, we provide background information on the NSFC and give a brief overview of the NSFC rotator program, describing rotators' main job responsibilities.

2.1 NSFC funding

The National Natural Science Foundation of China was established in 1986. Its aim is to support basic research and to foster talented scientists, and it provides support based on a rigorous merit-review system. Its funding budget has increased from about 10 million US dollars in 1986 to 4.88 billion in 2020.[4] Like the US National Science Foundation, the NSFC is China's largest funder of basic science research.[5] In recent years, the NSFC has become the world's largest agency in terms of scientific fund applications (Cyranoski, 2019; Yang, 2017)[6]; in 2019, the NSFC received about 230,000 applications, more than three times that of NSF or NIH.

The NSFC has eight scientific departments that sponsor funding in different fields and one interdisciplinary science department established at the end of 2020.[7] Each

[3] Hoenen and Kolympiris (2020) use the information on 80 out of a total of 240 individuals serving as NSF rotators over the period 2009-2011.

[4] The amount of NSFC funding was 33.63 billion RMB (4.88 billion U.S. dollars) in 2020. https://www.nsfc.gov.cn/publish/portal0/ndbg/2020/01/info81328.htm.

[5] In 2017, 11.63% of all scientific papers published globally were sponsored by the NSFC (Yang, 2017).

[6] http://www.scio.gov.cn/xwfbh/xwbfbh/wqfbh/35861/37047/.

[7] These departments are Department of Mathematical and Physical Sciences, Department of Chemical Sciences, Department of Life Sciences, Department of Earth Sciences, Department of Engineering and Material Sciences, Department of Information Sciences, Department of Management Sciences,

department is responsible for selecting grant proposals and managing approved grants in its field. The NSFC also has supportive offices that help coordinate activities across scientific departments or provide services for the scientific departments. These offices include the office of planning and policy, the office of international cooperation, the office of finance, and the office of human resources.[8]

The NSFC has a two-round grant review procedure for most NSFC grant applications, which are required to be submitted in March of each year (Yao and Xiong, 2017). After an initial screening of submitted applications by department directors (including both permanent employees and rotating directors), the NSFC invites experts to perform the first round of review for applications meeting basic qualification standards. This first round takes place in April and May. The NSFC holds second-round meetings in July or August to decide on which of the grant proposals that passed the first-round will be approved.

The NSFC has more than ten types of grants, which can be divided into two broad categories. The first category is ordinary grants, including a general grant open to all scientists, a youth grant with an age limit, and a grant for less developed regions. The second category is higher-stakes special grants, including the excellent young scientist grant, the NSFC award for distinguished young scholars, the international (regional) joint research grant, and other large grants such as the key grant and major grant.[9] While ordinary grants account for the majority of the total number of approved NSFC grants, they have a much smaller amount of funding and are less competitive than special grants, which play an important role in scientists' career development.[10]

Department of Health Sciences, and Department of Interdisciplinary Sciences.

[8] For detailed information on the NSFC's organizational structure, see https://www.nsfc.gov.cn/publish/portal0/jgsz/04/.

[9] For detailed information on NSFC grants, see: http://www.nsfc.gov.cn/english/site_1/pdf/NationalNaturalScienceFundGuidetoPrograms2020.pdf

[10] Ordinary grants account for 87.49% of all approved NSFC grants over the period from 2000-2021. The average amount of funding provided by an ordinary grant is 0.408 million RMB. The average amount provided by a special grant is more than three times that level (1.294 million RMB). Certain special grants, such as the NSFC award for distinguished young scholars. are so important for a person's career development that the NSFC issued an open letter to remind institutions that these special grants should not be regarded as equivalent to PI honors and discouraging institutions from making compensation or career advancement dependent upon their receipt

2.2 NSFC rotators

The NSFC rotator program was established in 2002 to improve the efficiency of grant funding and management and to alleviate the workload of permanent employees, who faced an ever-growing number of grant applications. Like in the U.S. National Science Foundation (NSF) and the Japan Science and Technology Agency (JST), NSFC rotators are mostly drawn from universities or other research institutions, and work for a fixed period (normally two years) before returning to their home institutions (Zhang et al., 2019). During a rotator's stay at the NSFC, their home institution still pays their salary, and the NSFC provides only those subsidies that are strictly necessary for their support during the period of service.

Each year the NSFC posts job advertisements online to recruit rotator candidates. It selects rotator candidates based on evaluation of written applications, followed by face-to-face interviews of finalists. These interviews focus on assessing candidates' academic background and organizational or management skills. Over the period 2002-2021, the NSFC employed a total of 587 rotators.[11] In 2020, rotators accounted for one third of the NSFC's total workforce.

Like in the US NSF, the main responsibilities of NSFC rotators are screening initial grant applications in their fields, organizing the evaluation of grant applications, and supervising the execution of approved grants. Rotators are also responsible for organizing experts to write each year's guidebook for submitting an NSFC grant application, and to establish priority fields for funding.

Time at the NSFC not only helps rotators gain first-hand information on grant applications, but also provides rotators unique opportunities to develop connections with the top experts in their fields who serve as panelists for the second-round grant review meetings.[12] Although rotators are prohibited from applying for NSFC grants

(https://www.nsfc.gov.cn/publish/portal0/tab442/info73839.htm).

[11] We calculate the total number of rotators over the period from 2002-2016 using Zhang et al. (2019). For the 2017-2021 period, we use announcements published on the NSFC's official website (https://www.nsfc.gov.cn/publish/portal0/tab476/).

[12] The NSFC published an open letter in *Science & Technology Daily*, the official newspaper of Ministry of Science and Technology of China, to urge NSFC rotators to keep their promises of being fair, honest and self-disciplined, and not to engage in networking activities during their period of rotation (https://nsfc.gov.cn/publish/portal0/tab440/info75026.htm). Table A1 of the Appendix contains anecdotal evidence on rotators' likely roles in allocating grant resources and networking activities.

during their tenure, they may use the networks formed during this period to help them acquire scientific grants after leaving the NSFC, and are able to help their home institutions obtain more NSFC grants throughout the period.[13]

3 Data

In this section we describe our three main data sources: the roster of NSFC rotators and finalists matched to demographic and background information on each person, administrative data on approved NSFC grants over the period 2000-2021, and data on each person's scientific publications from the website Scopus.com.

3.1 NSFC rotators

To obtain the roster of NSFC rotators and finalists who were not selected – which, together, we will call our list of "rotator candidates" – we pulled data from the following sources: (1) For the most recent cohorts (2020 and 2021), we collected a list of names of all rotator candidates and the related NSFC department information from the NSFC's official website. (2) For rotator candidates who attended the NSFC's face-to-face interviews before 2020, we collected the rotator information from the Internet Archive (http://web.archive.org/), from author information published in the *Bulletin of National Natural Science Foundation of China*, the official journal associated with NSFC, and from Google or Baidu searches with the keywords "NSFC rotators" (in Chinese, *liudong xiangmu zhuren*). This produced a list of 464 rotators, accounting for 79.05% (=464/587) of all rotators during the 2002-2021 period. From these sources we also collected the names of the 348 people who were finalists and attended a face-to-face interview but were not selected to serve as rotators. We call these individuals our "finalist" sample, and we have the full list of finalists over the period from 2017-2021.[14]

[13] Academic institutions place great value on having their faculty serve as rotators, particularly given their role in the grant review process. One expression of this value is the custom of most home institutions to provide both financial and career incentives to faculty and staff who serve as rotators. For example, Shanghai Dianji University offers a financial incentive which almost doubles the salary of an individual during the period they serve as an NSFC rotator (https://zwgk.sdju.edu.cn/2019/1015/c3851a71675/page.htm).

[14] We are only able to collect the list of names of NSFC rotator finalists who were not ultimately selected over the period from 2017-2021; before 2017, this information is not publicly available.

Based on these data and related NSFC department information, we link rotator candidates to information posted on their CV or web page. These data include gender, home institution, year of birth, educational history, academic job title at the time of attending the face-to-face interview, and their job history, which includes mobility to and from other institutions and their promotion to administrative positions. This yields data for 763 rotator candidates with information on their NSFC department and home institution.[15]

In Table 1 we present summary statistics for these NSFC rotator candidates. Female scientists account for less than one quarter of the total. About two-thirds of rotator candidates obtained their bachelor degrees from top-tier Chinese universities, and the majority (89%) of them obtained their PhDs from top-tier Chinese universities, overseas universities, or Chinese Academy of Sciences. While most NSFC rotator candidates are currently affiliated with this set of high-ranked institutions, about one third of them come from lower-ranked universities.

We find little difference between successful rotators and failed rotator candidates in terms of observable characteristics, as shown in the final column of Table 1. In a regression exercise using a dummy variable for being successful rotator as the outcome variable and controls for both NSFC department fixed effects and interview year fixed effects, we find that the two groups (rotators and finalists) are balanced on almost all observable characteristics (see Table A2). While we cannot know with certainty the ultimate reason for selection of a candidate, our analyses suggest that rotators and finalists are similar on observable characteristics.[16]

[15] About 80% (=611/763) of rotators work for NSFC scientific departments, with the remainder working for NSFC supportive offices. Although rotators working for supportive offices may not be directly involved in the grant review process, they may still have the ability to use influence to help themselves or others at their home institutions obtain NSFC grants. In our empirical analyses, we assume that rotators working for supportive offices mainly affect grant outcomes in the scientific department to which their own academic fields belongs.

[16] We also compare characteristics of male and female rotators. As Figure A1 suggests, we find little difference among rotators by gender, with the exception that female rotators are more likely than male rotators to come from the Chinese Academy of Sciences, China's largest leading research organization.

3.2 Administrative NSFC grants

Each year the NSFC publishes basic information on approved grants. This information includes grant type, approval year, and the NSFC department that a grant belongs to, along with the awardee's name and institution. We webscraped these administrative data from the NSFC's official website (http://kd.nsfc.gov.cn/).

Table 1 Summary statistics of NSFC rotator candidates

	Rotators (1)	Failed rotator candidates (2)	(1) - (2)
Female	0.233	0.230	0.004
Age at the interview	38.194	38.687	-0.493
Full professor at the interview	0.489	0.430	0.059
Bachelor from a top-tier university	0.657	0.639	0.017
Institution of PhD graduation			
Top-tier Chinese university	0.624	0.647	-0.023
Other Chinese university	0.098	0.074	0.024
Overseas university	0.157	0.114	0.043
Chinese Academy of Sciences	0.106	0.132	-0.027
Other research institution	0.015	0.033	-0.018
Affiliated home institution			
Top-tier Chinese university	0.564	0.528	0.036
Other Chinese university	0.304	0.340	-0.036
Chinese Academy of Sciences	0.079	0.081	-0.002
Other research institution	0.053	0.052	0.001
Working for a NSFC scientific department	0.817	0.777	0.040
Observations	454	309	

Note: A top-tier university is one of 116 elite Chinese universities, which include 39 "985-project" universities and 77 "211-project" universities, with the former being ranked higher than the latter. Chinese Academy of Sciences is the world's largest research organization, with about 60,000 researchers working in more than 100 research institutions.

We focus on grants awarded to NSFC rotator candidates and to their home institutions. Our grant data include the two sets of grants described above: ordinary grants and the more competitive, higher-stakes special grants that award much higher levels of funding. Our NSFC grant data comprise information on 315,148 grants, accounting for 57.35% of all NSFC grants approved during the 2000-2021 period.

3.3 Scientific publications from Scopus.com

We use the online database Scopus.com to collect NSFC rotator candidates' scientific publications. We choose Scopus over other bibliographic databases such as Web of

Science (WOS) for three reasons: (1) Scopus is the world's largest abstract and citation database of scientific publications; (2) Scopus covers much more Chinese-language journals than Web of Science, which is very important because many Chinese university professors publish both English- and Chinese-language papers;[17] and (3) we can use Scopus to identify authors by their full names, with each author being assigned a unique id by Scopus staff.[18] By contrast, Web of Science identifies authors only by first initial and last names, and author ids are established by authors themselves.

We use the Scopus API to extract the publication information for our list of rotator candidates. We obtained information on publications from Scopus for 83.09% of our sample. We use these data to create several variables: the annual number of academic papers published, which we use to measure the quantity of rotator candidates' publications; the annual average number of citations per paper, which we use to measure the quality of their publications. We also measure rotator candidates' performance based on the annual number of first-authored papers, which may be more appropriate for measuring "true" productivity.

4 Empirical Strategy

To explore how rotator experience differentially affects male and female scientists' grant outcomes and career development over time, we use the following event study specification:

$$Y_{it} = \alpha_0 + \sum_{T=-5}^{5} \alpha_{1\#T} Rotator_{it} + \rho_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Y_{it} is the outcome variable for rotator candidate i in year t. The outcome variables we use include number of grants, number of publications, and promotion to a senior

[17] We do not use publication records from CKNI, the Chinese version of JSTOR that publishes academic papers in Chinese. We make this choice in light of two facts: one, that most Chinese scientists publish in English-language journals; and two, that Chinese-language journals not indexed by Scopus are, on average, less selective and less well-regarded (Fisman et al., 2018).

[18] Scopus uses an algorithm based on authors' names, affiliations, and email addresses to determine whether a paper is added to that author's profile. In cases when multiple profiles match with a given author in our list of rotator candidates (i.e., with the same author name, the same affiliations, and the same field), we manually check the profiles against the author's CV to assign on the match.

administrative position. ρ_i and λ_t represent rotator candidate fixed effects and year fixed effects, respectively. We are interested in estimating coefficients $\alpha_{1\#T}$, which represent possible dynamic benefits associated with being a rotator. Because the three quarters of rotator candidates in our analysis sample attended their NSFC interview after 2017 and our grant information is between 2000 and 2021, we limit our analysis to a 5-year window on either side of their interview date. Standard errors are clustered at the rotator candidate level.

We also use a differences-in-differences (DD) design to estimate the overall effect of serving as a rotator. We compare the outcomes of rotators with those of finalists (i.e., failed rotator candidates) before and after the interview date; we also estimate this effect by gender. Our specification is:

$$Y_{it} = \alpha_0 + \alpha_1 Rotator_i * AfterInterview_t + \rho_i + \lambda_t + \varepsilon_{it} \quad (2)$$

Y_{it} is again the outcome of rotator candidate i in year t. $Rotator_i$ is a dummy variable indicating whether one is a rotator or a failed candidate. $AfterInterview_t$ is a dummy variable that takes value 1 if year t is at or after the NSFC interview date. ρ_i and λ_t represent rotator candidate fixed effects and year fixed effects, respectively. We are interested in estimating the coefficient α_1 on the interaction term between $Rotator_i$ and $AfterInterview_t$. Standard errors are again clustered at the rotator candidate level.

5 Empirical Results

In this section we explore how being a rotator affects male and female scientists' chances of subsequent scientific funding and career development. We first examine how rotator experience affects male and female rotators' likelihood of winning scientific grants from the NSFC after their time as rotators. We study this effect for both low-stakes ordinary grants and high-stakes special grants. We then estimate whether the rotator effect spills over to scientific funding awarded to other scientists at a rotator's home institution. Finally, we explore whether the rotator experience contributes to the gender gap in later chances of being promoted to administrative positions.

5.1 Being a rotator and scientific funding by gender

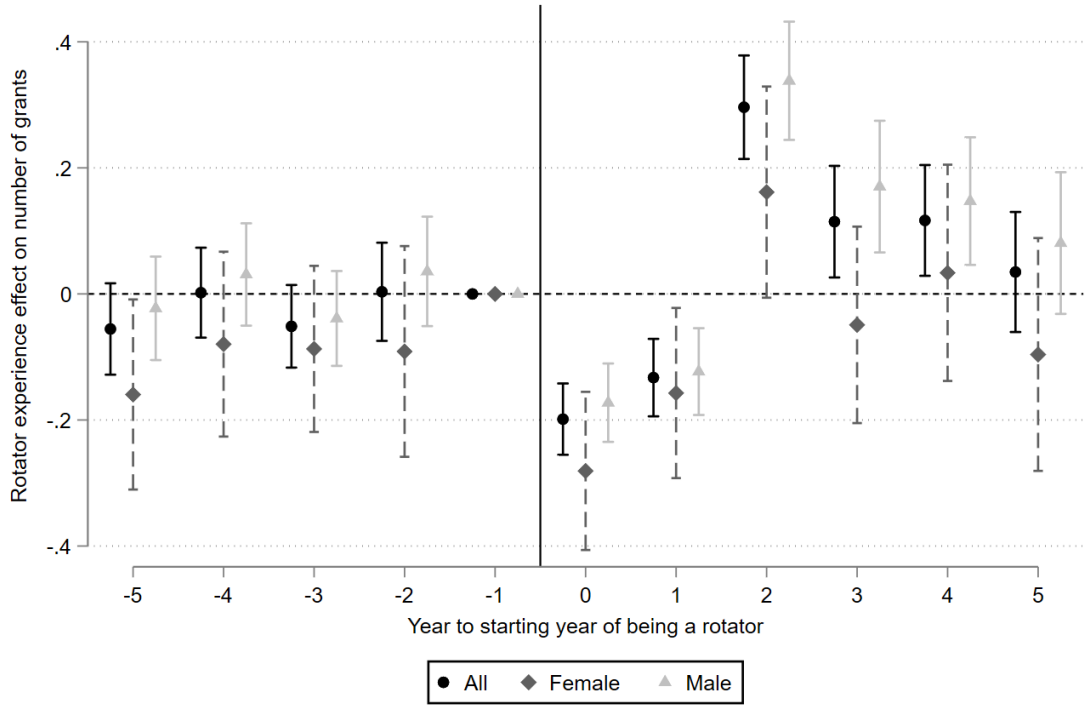
We first examine how rotator experience differentially affects male and female

scientists' chances of obtaining scientific grants.

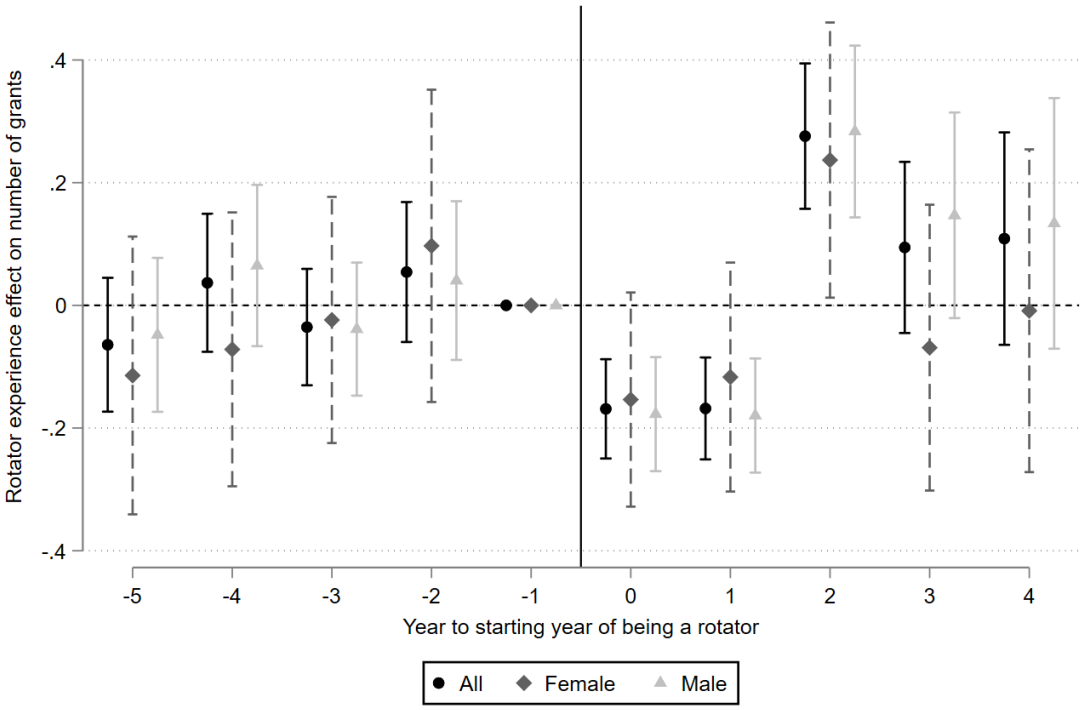
5.1.1 Event study estimates

Figure 1(a) shows that there are almost no differences in number of scientific grants received between successful and failed rotator candidates in the years prior to attending their NSFC rotator interview, suggesting that the two groups (rotators and finalists) may have similar ability of obtaining scientific grants when they both did not have rotator experience. In the two years following the interview, we see a negative effect of being a rotator for both males and females, consistent with the NSFC's regulation that rotators are not permitted to apply for NSFC grants during their period of tenure (usually two years). In contrast, we find a large positive effect of being a rotator on number of received NSFC grants in the first year after rotators return from the NSFC, but the effect for male rotators is nearly double that for females. In the years that follow, the effect persists for male rotators, but not for females.

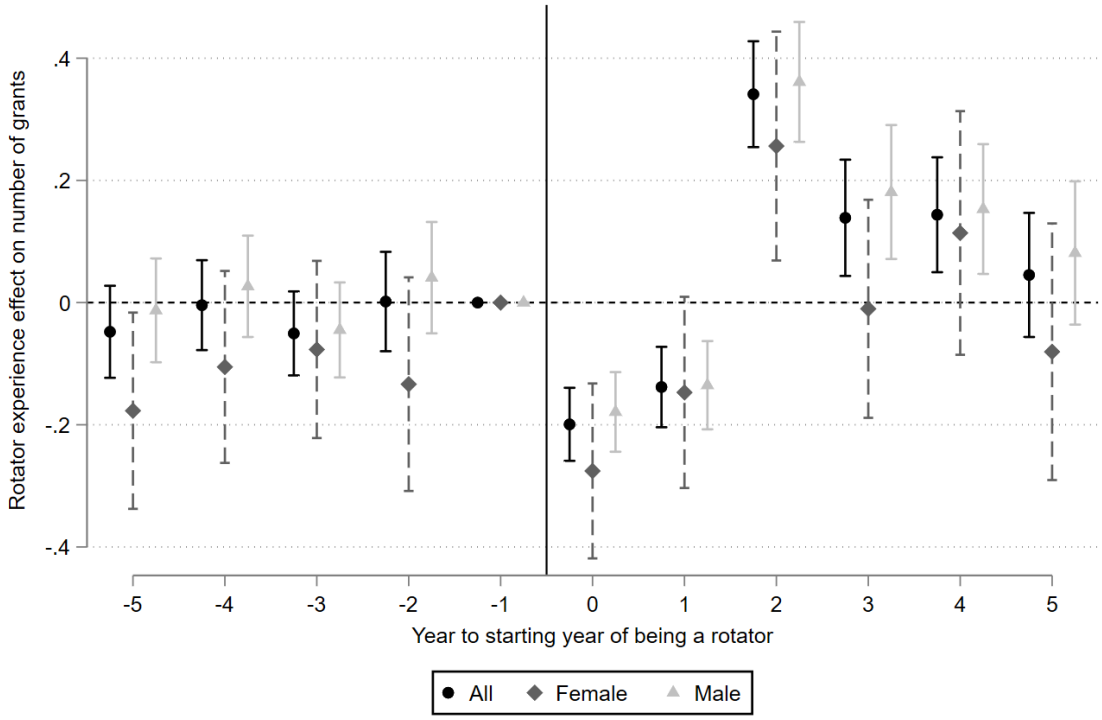
We perform several robustness checks to evaluate the sensitivity of our main results. First, we limit the analysis to rotator candidates who attended the NSFC face-to-face interview after 2017 (75.49% of the total) because the failed rotator candidate sample is only available after 2017. Second, we repeat the main analysis by dropping rotator candidates who later become permanent NSFC employees and thus are not permitted to apply for NSFC grants afterwards. As Figures 1(b) and 1(c) show, the estimation results are similar to our main results, suggesting that estimates in Figure 1(a) are robust to these concerns.



(a) Number of NSFC grants: main results



(b) Number of NSFC grants: rotator candidates after 2017



(c) Number of NSFC grants: excluding later permanent NSFC employees

Figure 1 Rotator experience and number of scientific grants

Note: in this figure we estimate how rotator experience affects the number of NSFC grants received by a rotator overall, and by gender. Panel (a) shows point estimates and 95% confidence intervals for the coefficients $\alpha_{1\#T}$ in Equation (1); Panel (b) provides a robustness check for these results, limiting the analysis to rotator candidates from after 2017; Panel (c) shows an additional robustness check, dropping rotator candidates who later became permanent NSFC employees. All coefficients are plotted relative to the first year of being a rotator (this is set to the year of attending the interview for failed rotator candidates). Standard errors are clustered at the rotator candidate level.

We next explore heterogeneity in the rotator effect on number of received scientific grants by grant type and NSFC department type. First, high-stakes special grants (including talent grants) have a much larger amount of funding and are much more important than ordinary grants.[19] We therefore might expect to see a larger rotator effect on the number of high-stakes special grants received than on the number of ordinary grants, given their greater reward and importance.

[19] Special grants include i) the excellent young scientist grant, ii) the distinguished young scientist grant, iii) the key grant, iv) the major research grant, v) the joint grant, vi) the international cooperation grant, and vii) the special-purpose grant. These all confer a much larger amount of funding than ordinary grants (e.g., the general, youth, and regional grants). The excellent young scientist and distinguished young scientist grants are further recognized as "talent" grants; we study them as a separate area of interest later in this paper.

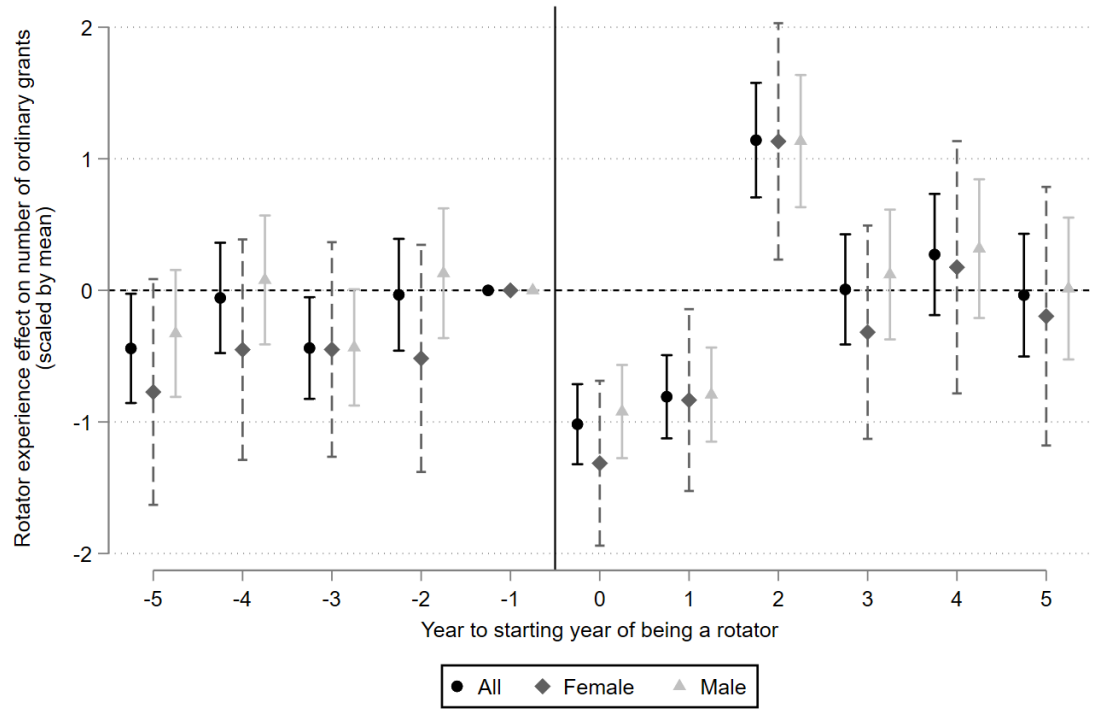
As Figure 2(a) shows, while the rotator effect on number of ordinary grants is similar for both male and female rotators, rotator experience has a large positive effect on the number of these higher-stakes grants – both special grants and talent grants – received by male rotators, but we see no evidence of an effect for female rotators. The results provide suggestive evidence that male rotators may be more likely than females to use networks to help advance their career development, as these high-stakes special grants require far more networking activities to win (Shi and Rao, 2010).

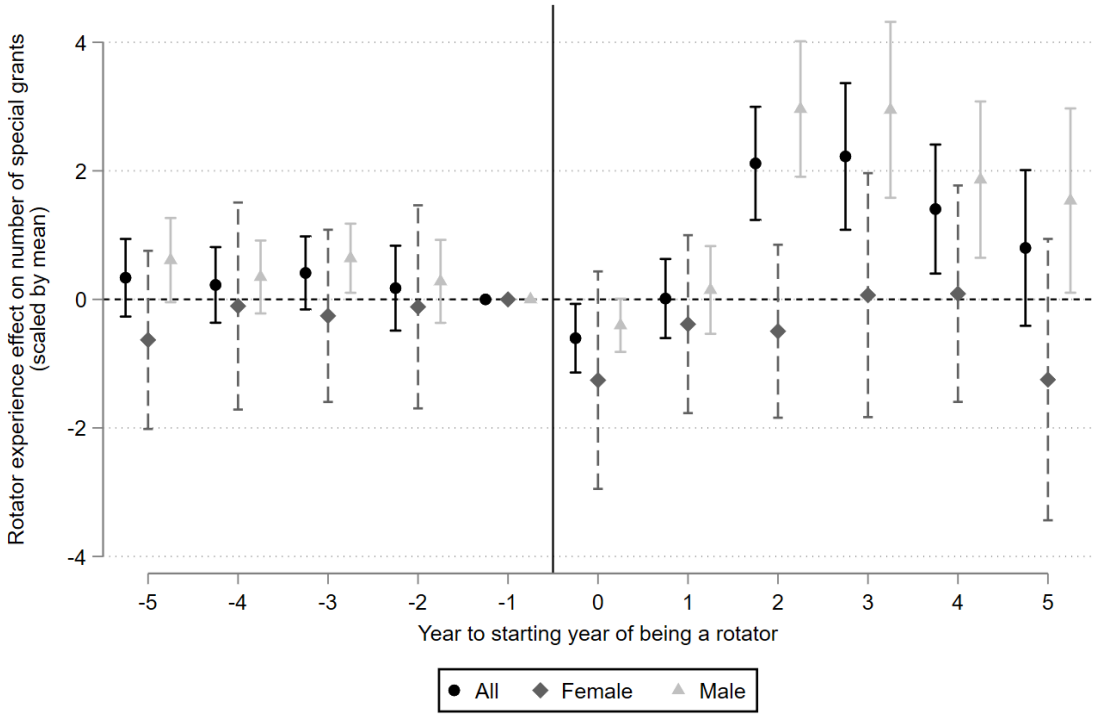
Second, we examine heterogeneity by NSFC department type. NSFC departments are divided into two types of departments: scientific departments and supportive offices.[20] Rotators working for scientific departments are more involved in the procedure of evaluating grant applications and thus have more opportunities to connect with NSFC panelists who decide on final grant outcomes. We therefore expect to see a larger rotator effect for rotators from scientific departments than from supportive offices. If male rotators benefit more from networking activities, gender differences in the effect would be smaller for service in supportive offices than for service in scientific departments.

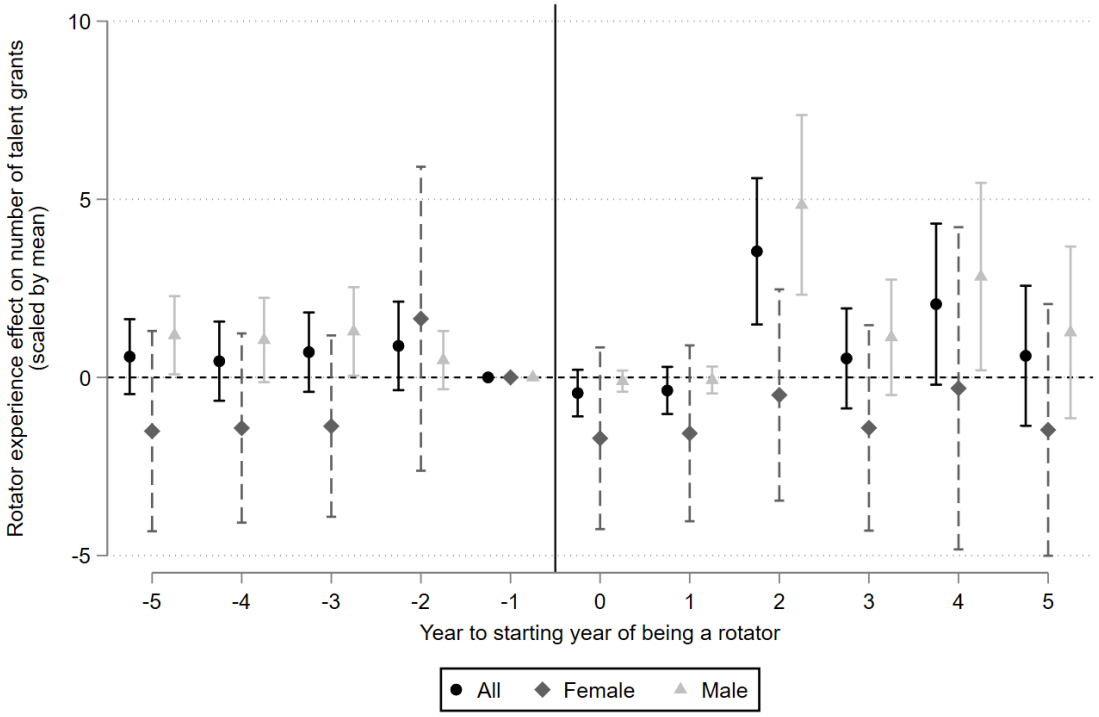
Our results, shown in Figure 2(b), are consistent with our predictions: we find a much smaller effect for rotators working for supportive offices than for those working for scientific departments. Furthermore, while we find a large gender gap in the rotator effect for rotators working for scientific departments, we observe almost no gender differences for rotators working for supportive offices.

Overall, our heterogeneity estimation results show that the gender difference in grant outcomes is more prominent in situations where males are more likely than females to exploit networks to help them acquire grants, suggesting that gender gap in networking may contribute to gender gap in grant outcomes.

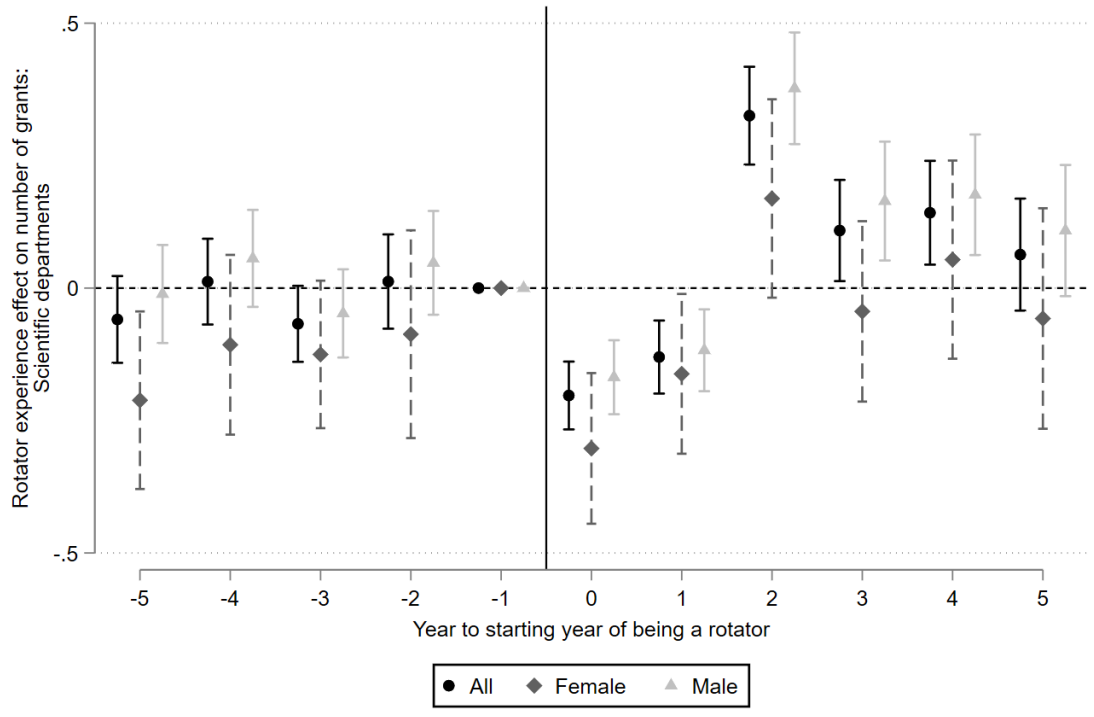
[20] Because the Department of Interdisciplinary Sciences only began to accept applications for certain special grants (the excellent young scientist grant, the distinguished young scientist grant, the creative research group grant, and the basic science center grant) in 2021, and because the NSFC does not publicize the information on these special grants, we exclude rotator candidates from this department in our analysis of heterogeneity by scientific departments.

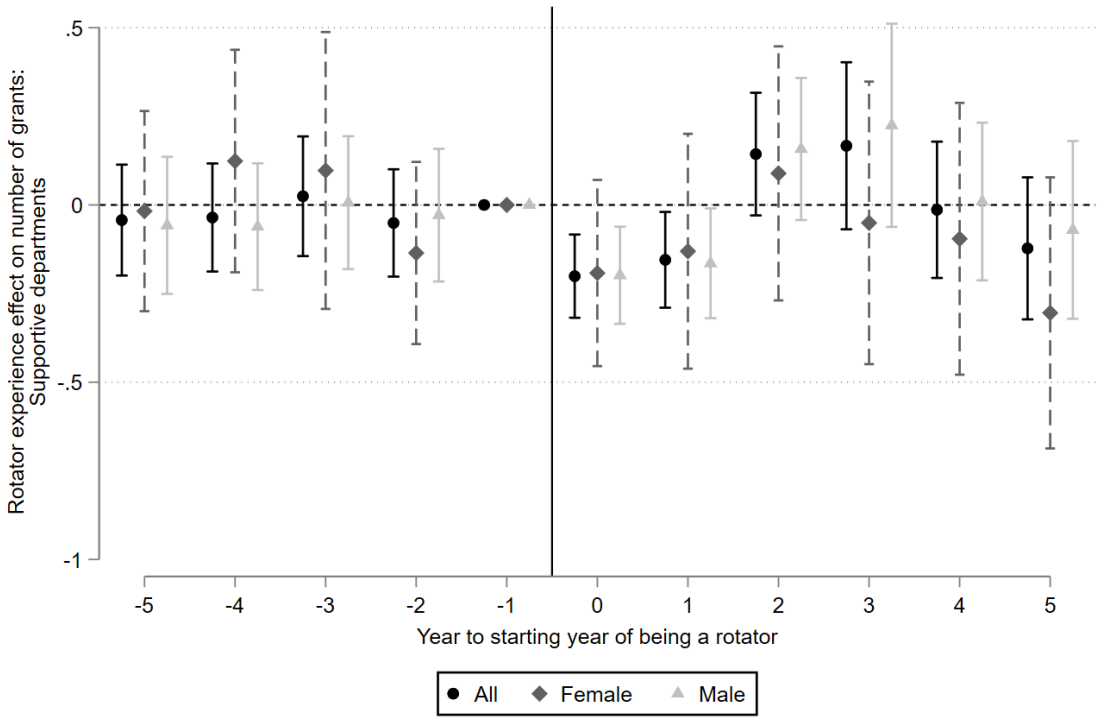

Rotator experience effect on number of ordinary grants (scaled by mean)
2
1
0
-1
-2
-5
-4
-3
-2
-1
0
1
2
3
4
5
Year to starting year of being a rotator
All
Female
Male


Rotator experience effect on number of special grants (scaled by mean)
4
2
0
-2
-4
-5
-4
-3
-2
-1
0
1
2
3
4
5
Year to starting year of being a rotator
All
Female
Male



(a) By NSFC grant type





(b) By NSFC department type

Figure 2 Rotator experience and number of scientific grants: heterogeneity

Note: This figure shows point estimates and 95% confidence intervals for the coefficients $\alpha_{I\#T}$ in Equation (1), with each panel showing investigation of heterogeneity, on the dimension listed in the panel title, in our estimates of how rotator experience affects number of NSFC grants received. We present the results for all candidates, and then for females and males separately. Panel (a) shows heterogeneity by grant type: ordinary grants (including general, youth, and regional grants) special grants (including excellent young scientist grant, distinguished young scientist grant, key grant, major research grant, joint grant, international cooperation grant, and special-purpose grant), and talent grants (including excellent young scientist grant and distinguished young scientist grant). Panel (b) shows the heterogeneity in terms of NSFC department, including scientific departments and supportive offices. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Standard errors are clustered at the rotator candidate level.

5.1.2 Difference-in-Difference estimates

Our event study estimates show that the rotator experience effect is negative during the two years in which rotators are at the NSFC, and then become positive after departure from the NSFC. In this section, we estimate the overall net effect of working for the NSFC using the difference-in-difference strategy described in Section 4.

As panel A of Table 2 shows, the net overall effect of the rotator experience is negative: compared with a failed rotator candidate, a rotator's chance of being awarded a NSFC grant decreases by 20% (= 0.043/0.216).[21] The negative rotator experience

[21] The rotator experience effect may be underestimated because our analysis is limited to a 5-year

effect is concentrated in relatively low-stakes grants ("ordinary grants"). The chance of being awarded a high-stakes special grant increases by 26% (= 0.013/0.051), though this estimate is not statistically significant.

The results in Panels B and C show divergent results for males and females. Both male and female rotators acquire fewer low-stakes grants ("ordinary grants") after working for the NSFC. By contrast, rotator experience brings more high-stakes grants ("special grants" and "talent grants") for male rotators, increasing their chance of being awarded a special grant by 46% (= 0.026/0.056) and their chance of being awarded a talent grant by 58% (= 0.007/0.012). For female rotators, the effect is negative.

In sum, working as a rotator has an overall negative effect on the number of scientific grants received by female rotators, concentrated on their likelihood of receiving low-stakes grants. By contrast, while rotator experience negatively affects male rotators' chance of winning low-stakes grants, it substantially increases their chances of winning high-stakes grants.

Table 2 Rotator experience and number of grants: DD estimates

	(1)	(2)	(3)	(4)
	All grants	**Ordinary grants**	**Special grants**	**Talent grants**
Panel A: All observations				
Being a rotator × After	-0.043**	-0.056***	0.013	0.001
	(0.019)	(0.017)	(0.010)	(0.004)
Mean(outcome)	0.216	0.165	0.051	0.011
Observations	4,635	4,635	4,635	4,635
R-squared	0.118	0.081	0.194	0.110
Panel B: Female				
Being a rotator × After	-0.087**	-0.056	-0.032	-0.018
	(0.042)	(0.035)	(0.024)	(0.012)
Mean(outcome)	0.208	0.170	0.038	0.009

window around the NSFC interview year, and so we are unable to capture any benefits in years outside of our window, particularly those which compound over time.

Observations	1,174	1,174	1,174	1,174
R-squared	0.124	0.090	0.237	0.122
Panel C: Male				
Being a rotator × After	-0.030	-0.057***	0.026**	0.007*
	(0.022)	(0.019)	(0.011)	(0.004)
Mean(outcome)	0.219	0.164	0.056	0.012
Observations	3,461	3,461	3,461	3,461
R-squared	0.123	0.083	0.195	0.115

Note: this table presents estimates of α_l from Equation 2. The outcome variable is the number of NSFC grants of different types the person has won, as listed in the column heading, at the individual-year level. We control for both individual and year fixed effects in all regressions. Standard errors are clustered at the rotator candidate level. *** < 0.01, ** < 0.05, * < 0.1.

5.2 Being a rotator and NSFC grants received by colleagues at home institutions: male vs. female rotators

In this subsection we further explore how rotator experience affects NSFC grants received by colleagues at home institutions. We compare the rotator experience effect of male rotators with that of female rotators to understand possible spillover effects to rotators' colleagues at home institutions.

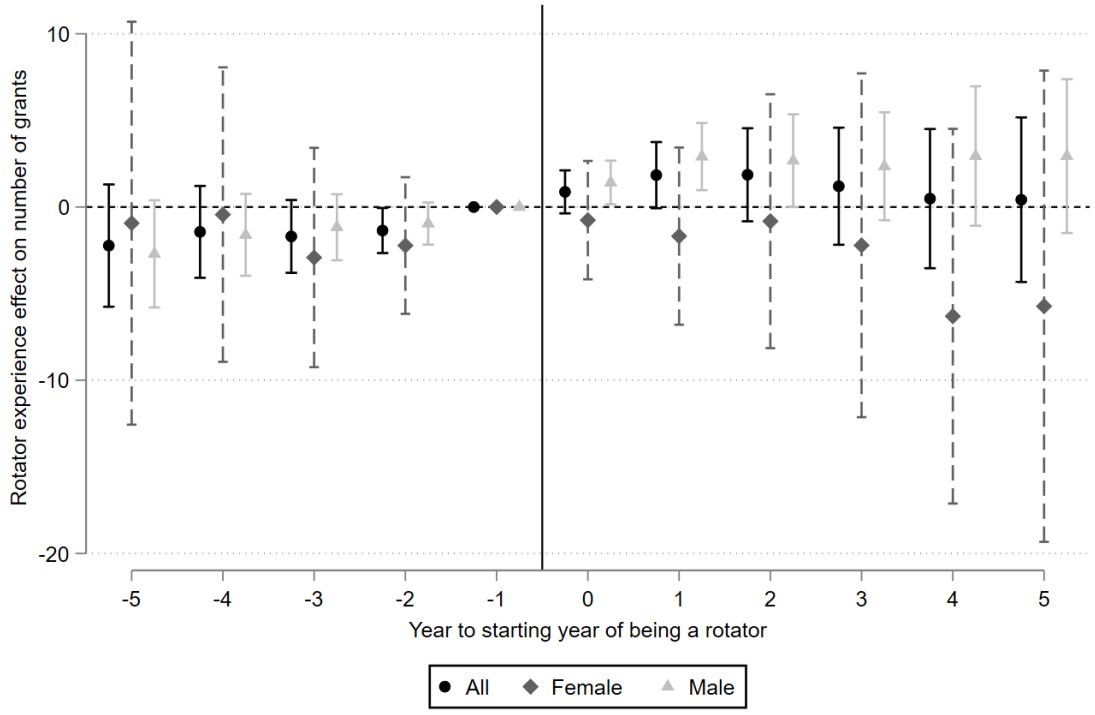
As Figure 3(a) shows, we find a modest rotator effect on the number of grants awarded to colleagues at home institutions. The estimated rotator effect is larger during rotators' temporary work experience period and in the first year after leaving the NSFC, but decreases afterwards. As expected, while we find a statistically significant male rotator effect on number of grants awarded to colleagues, the rotator effect is almost zero for females, suggesting that male rotators are more likely than females to use networks to help colleagues at home institutions get scientific grants.

For these results, we perform the following robustness checks: (1) limiting the analysis to rotator candidates who attended the NSFC face-to-face interview after 2017 to make them more comparable, and (2) dropping rotator candidates who later moved to other institutions (including those who become permanent NSFC employees) and thus are ineligible for promotion at their (previous) home institution.[22] As Figures 3(b)

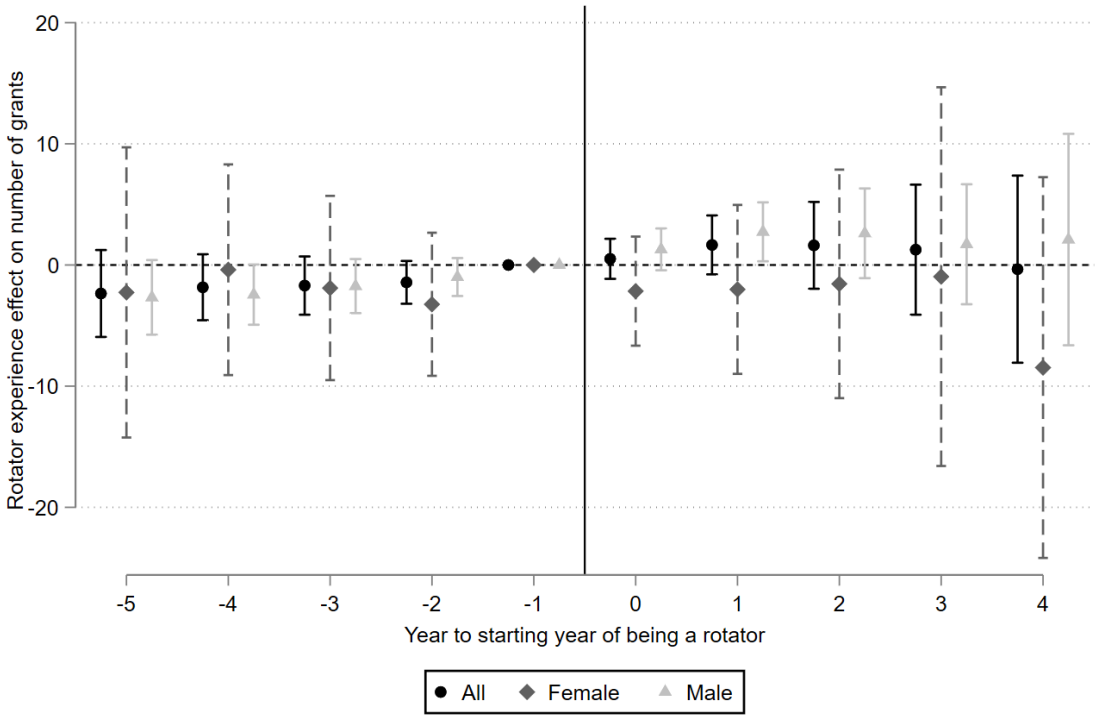
[22] In our analysis sample, 10.56% of rotators moved to other institutions after their temporary jobs at the NSFC ended.

and 3(c) show, the estimation results are similar to our main results.

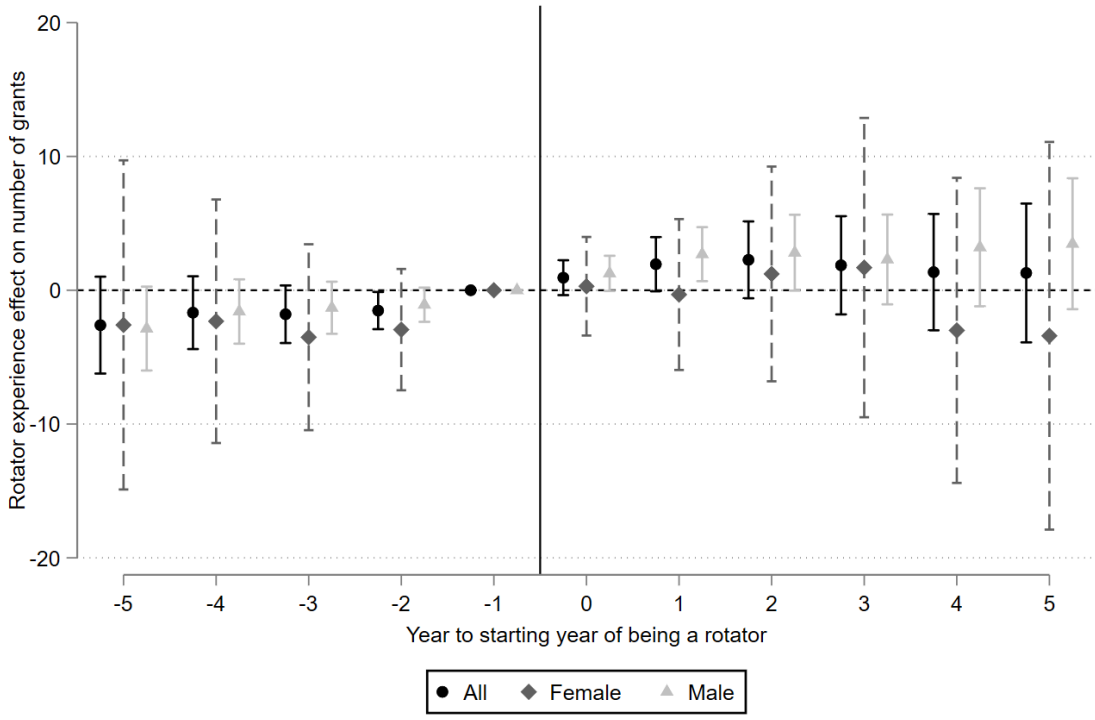
We also perform heterogeneity analysis by grant type and NSFC department type. As shown in Figure A2, we find that being a rotator increases the number of both low-stakes ordinary grants and high-stakes special grants awarded to colleagues at home institutions. The results in Figure A3 show that the gendered rotator effect is concentrated on rotators working for NSFC scientific departments, suggesting that networking may play an important role in NSFC scientific funding.



(a) Number of NSFC grants received by colleagues: main results



(b) Number of NSFC grants received by colleagues: rotator candidates after 2017



(c) Number of NSFC grants received by colleagues: excluding those who moved to other institutions afterwards

Figure 3 Having a rotator and scientific grants received by colleagues at home institutions

Note: in this figure we present estimates of $\alpha_{1\#T}$ from Equation 1, first for all rotator candidates, and then for females and males separately, for outcome variables listed in the panel title. We control for both individual and year fixed effects in all regressions. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Panel (a) shows the event study point estimates and 95% confidence intervals of the coefficients $\alpha_{1\#T}$ in Equation (1), which

represent how rotator experience affects likelihood of being promoted. Panel (b) shows a robustness check, re-estimating these parameters after limiting the analysis to rotator candidates after 2017. Panel (c) shows a separate robustness check, re-estimating these parameters after dropping rotator candidates who later moved to other institutions (including those who became permanent NSFC employees) from the sample. Standard errors are clustered at the rotator candidate level.

We also estimate the overall net effect of rotator experience on NSFC grants awarded to colleagues at the rotator's home institution. As Table 3 shows, the net overall effect is positive and concentrated among male rotators. Rotator experience increases the number of NSFC grants awarded to colleagues of male rotators by 6% (= 2.686/45.852), but we find no evidence of any effect for female rotators.

Table 3 Rotator experience and number of NSFC grants awarded to colleagues: DD estimates

	(1) All rotator candidates	(2) Female	(3) Male
Being a rotator × After	2.218**	0.417	2.686***
	(1.006)	(3.074)	(0.908)
Mean(outcome)	53.760	79.251	45.852
Observations	6,411	1,518	4,893
R-squared	0.964	0.963	0.967

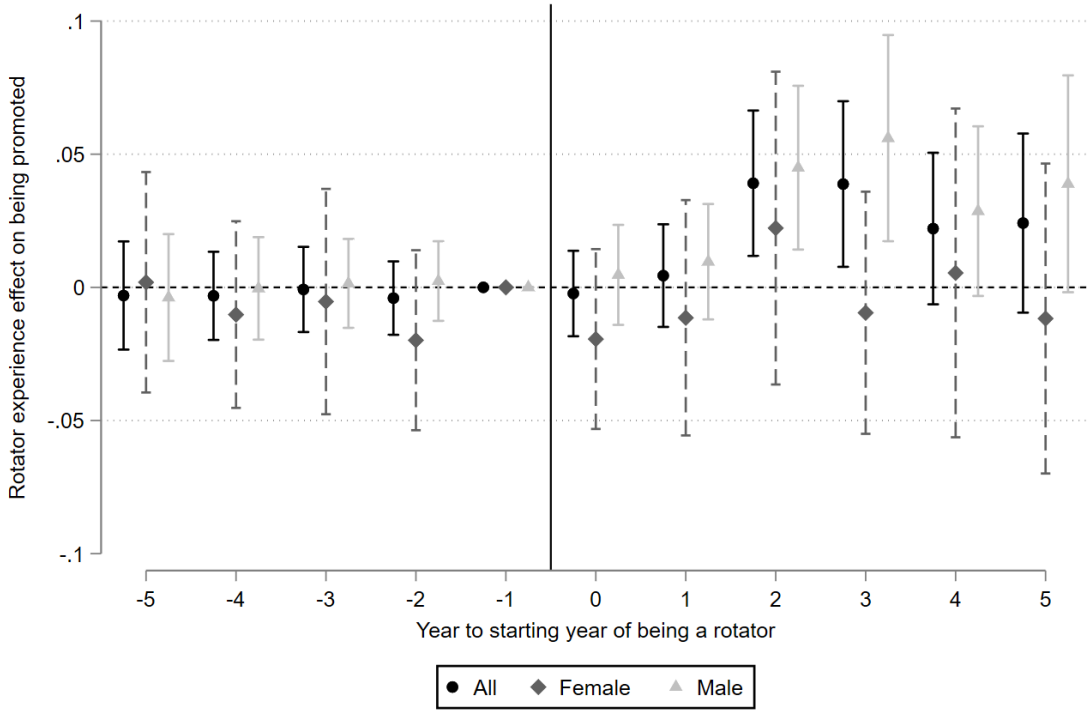
Note: this table presents estimates of α_l from Equation 2. The outcome variable is the number of NSFC grants scholars at the candidate's home institution have won after the rotation period begins, measured at the individual-year level. We control for both individual and year fixed effects in all regressions. Standard errors are clustered at the rotator candidate level. *** < 0.01, ** < 0.05, * < 0.1.

5.3 Being a rotator and chances of promotion by gender

In this subsection we explore how rotator experience affects the career development of male and female rotators. We focus on the chance of being promoted to an administrative position as our main outcome. The estimation results in previous subsections show that rotator experience benefits male rotators in terms of both NSFC grants (especially high-stakes grants) awarded to themselves and grants awarded to their home institutions. By contrast, female rotators are overall negatively affected by the temporary work experience and bring almost no benefits to their home institutions in term of grants. We, therefore, expect that rotator experience may also increase males' chance of being promoted, but not females'.

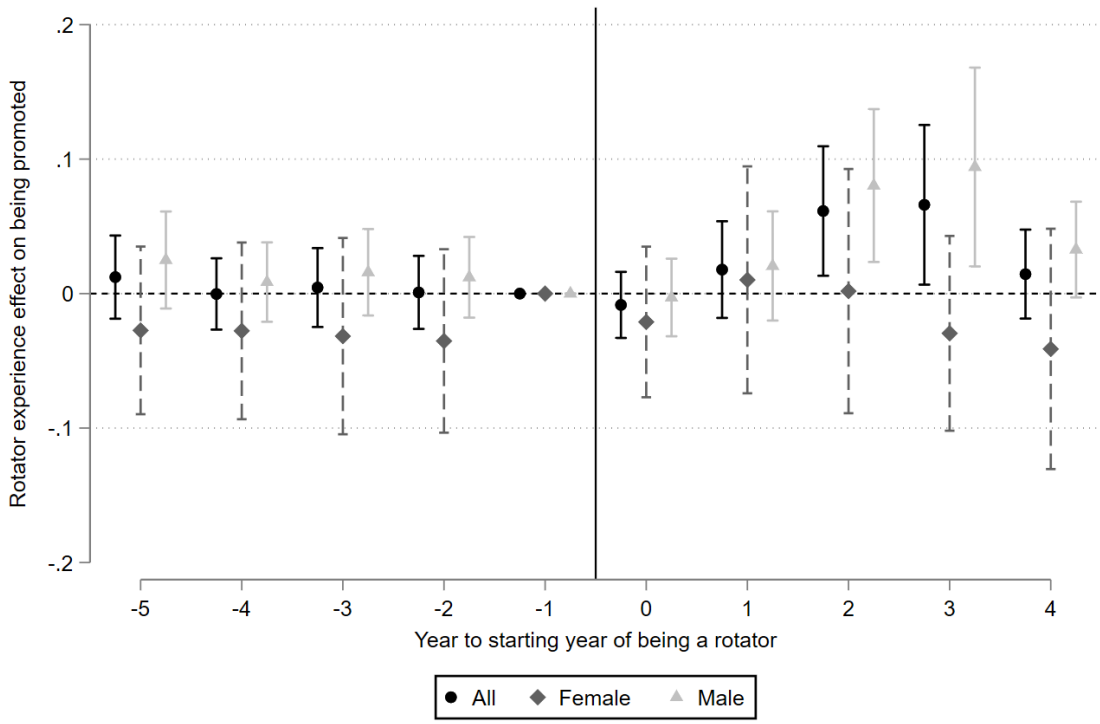
As Figure 4(a) shows, there are almost no differences in probability of being promoted between successful and failed rotator candidates in the years prior to attending the interview. After rotators return from the NSFC, however, we find a large effect on the probability of being promoted. The effect persists in the following years, suggesting that rotator experience has a significant impact on a person's career development. As expected, while we find a large rotator effect on likelihood of being promoted for males after leaving the NSFC, the rotator effect is almost zero for females, suggesting that male rotators are more likely than females to use networks to advance career development.

We also perform robustness checks similar to those in the previous subsection: (1) limiting the analysis to rotator candidates who attended the NSFC face-to-face interview after 2017 to make the two groups (rotators and finalists) more comparable, and (2) dropping rotator candidates who later moved to other institutions (including those who become permanent NSFC employees) and thus are ineligible for promotion at their previous home institution.[23] As Figures 4(b) and 4(c) show, the estimation results are similar to our main results.

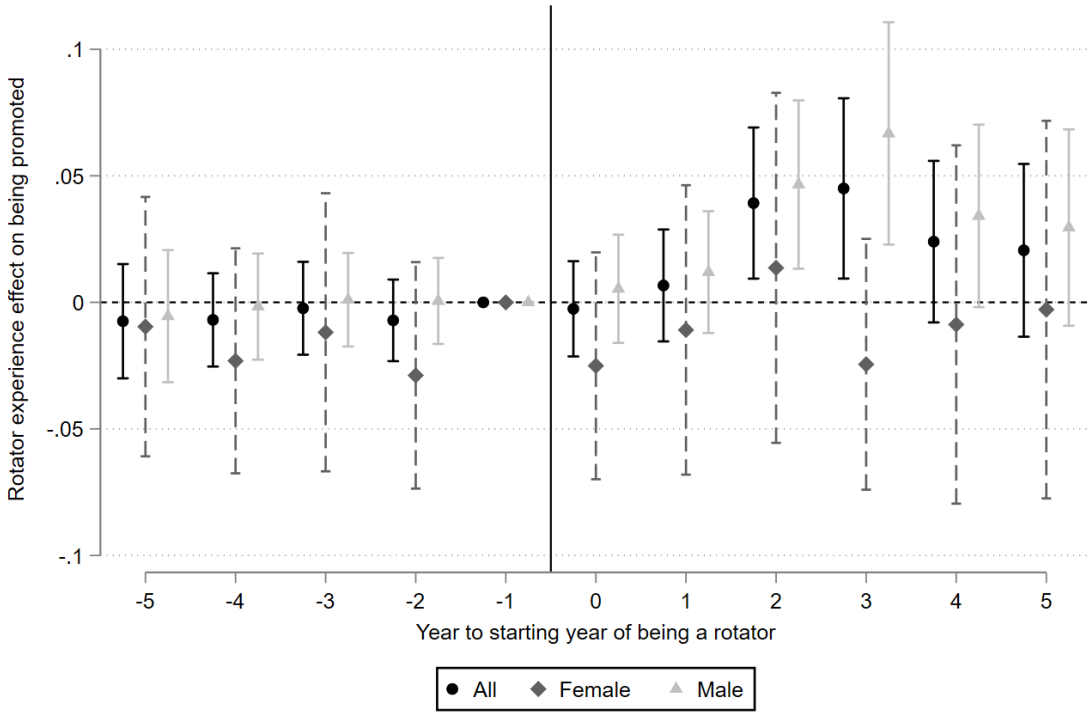


(a) Probability of being promoted: main results

[23] In our analysis sample, 10.56% of rotators have migrated to other institutions after their temporary jobs at the NSFC ended.



(b) Probability of being promoted: rotator candidates after 2017



(c) Probability of being promoted: excluding those who moved to other institutions afterwards

Figure 4 Rotator experience and probability of being promoted

Note: in this figure we present estimates of $\alpha_{1\#T}$ from Equation 1, first for all rotator candidates, and then for females and males separately, for a person's likelihood of professional promotion. We control for both individual and year fixed effects in all regressions. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Panel (a) shows

effects on the likelihood of being promoted; Panel (b) provides a robustness check, re-estimating the parameters after limiting the analysis to rotator candidates from 2017 or later. Panel (c) provides an additional robustness check, re-estimating the parameters after dropping those rotator candidates who later moved to other institutions, including those who became permanent NSFC employees. Standard errors are clustered at the rotator candidate level.

We also estimate the overall net effect of rotator experience on likelihood of being promoted to an administrative position.[24] As Table 4 shows, the net overall effect of the rotator experience is positive and concentrated among male rotators. Rotator experience increases male rotators' chance of being promoted by 81% (= 0.017/0.021), but we do not find such an effect among female rotators. The results are consistent with gender gap in acquiring NSFC grants to themselves and to colleagues at home institutions in in previous subsections, suggesting that male rotators benefit much more than females from networks formed during their temporary work period.

Table 4 Rotator experience and likelihood of being promoted: DD estimates

	(1)	(2)	(3)
	All rotator candidates	**Female**	**Male**
Being a rotator × After	0.013**	0.001	0.017**
	(0.006)	(0.012)	(0.008)
Mean(outcome)	0.019	0.012	0.021
Observations	4,635	1,174	3,461
R-squared	0.098	0.102	0.103

Note: this table presents estimates of α_l from Equation 2. Our outcome variable of interest is the person's chance of being promoted to an administrative position. The outcome variables are likelihood of being promoted at the individual-year level. We control for both individual and year fixed effects in all regressions. Standard errors are clustered at the rotator candidate level. *** < 0.01, ** < 0.05, * < 0.1.

[24] We also explore the heterogeneity in rotator experience effect on probability of being promoted in terms of type of departments rotators have temporarily worked for. As Figure A4 of the Appendix shows, we find male rotators are much more likely than females to be promoted for those working for NSFC scientific departments. But we find no such a gendered effect among rotators working for supportive offices. The estimates are consistent with heterogeneity results in terms of NSFC department type in previous subsections.

6 Probing Underlying Mechanisms

The empirical results presented so far show that male rotators are more likely than females to acquire scientific grants (especially high-stakes grants) and to be promoted to an administrative position after leaving the NSFC. We have provided suggestive evidence that networking may play an important role in driving the gender gap among rotators. In this section we will provide detailed evidence on the networking mechanism and argue against other possible mechanisms.

6.1 Networking

This section presents analysis of data probing for evidence that might either suggest or refute the role of networking in generating the results shown in Section 5.

6.1.1 Qualitative evidence

A long series of anecdotal evidence suggests that Chinese scientists try their best to get NSFC grants by networking with senior scientists (see Shi and Rao, 2010). In this subsection we present two sets of qualitative evidence about rotators' networking activities.

Our first set of qualitative evidence comes from two large scientist discussion forums in China: Xiaomuchong (http://muchong.com/bbs/) and Shuimu community (https://www.mysmth.net/nForum). We search the two forums with the key word "NSFC rotators (liudong xiangmu zhuren, 流动项目主任 in Chinese)" and get a total of 107 discussion threads relating to recruiting NSFC rotators or what rotators do at NSFC. Among the 107 discussions, more than one half (56) mention that NSFC rotators form networks that benefit themselves or their friends or colleagues at home institutions. These threads focus on rotators exploiting networks to acquire high-stakes grants, such as the excellent young scientist grant or the distinguished young scientist grant, and to help colleagues at home institutions get NSFC grants. In Table A1, we provide several illustrative examples from these discussions.

Our second set of qualitative evidence comes from conference information on NSFC's official website (https://www.nsfc.gov.cn/).[25] We focus on conferences held to facilitate communication and interaction among NSFC grant awardees. Many NSFC

[25] The conference information is available only for 2 out of 9 NSFC scientific departments (Department of Mathematical and Physical Sciences and Department of Management Sciences).

officers and panelists attend such conferences, thus providing a great opportunity for networking. We collect the following information on each conference: relevant NSFC department, date, and host institution.

We have information on 37 conferences held outside of Beijing during the 2017-2021 period. After matching conference information with NSFC rotator information, we find that 14 out of 37 these conferences were hosted by rotators' home institutions at a time when the rotator was either temporarily working for the NSFC or within one year after they left the NSFC. This result supports the notion that rotators may try to exploit opportunities to develop or strengthen connections with NSFC officials or panelists to further their own careers.

Furthermore, there is only one female out of the 14 rotators who held these conferences, despite the fact that roughly one quarter of all rotators are female. This finding suggests that male rotators may be much more likely than females to develop connections that help promote their future career development.

6.1.2 Direct evidence from the administrative NSFC scientist network

The above qualitative evidence suggests that rotators, especially male rotators, may try to form networks during their temporary work period to help themselves or colleagues at home institutions to acquire NSFC grants. We now turn to direct evidence on gendered networking activities using administrative data on NSFC scientist networks.

These data record whether two scientists have been co-PIs (principal investigators) or participants on at least one NSFC grant approved before 2016.[26] The NSFC publicizes this information on its knowledge sharing platform, listing a network member's personal information and the number of NSFC grants a member participated in before 2016. Such network data provide us a unique opportunity to analyze how rotators develop connections with the NSFC panelists who decide final grant outcomes.

We define a rotator as connected to a panelist if they belong to the panelist's network. We use two network measures: (1) the number of connected panelists a rotator candidate has before 2016, and (2) the number of NSFC grants that connect a rotator candidate to a panelist. We also calculate the two network measures separately for panelists from home institutions and for panelists from other institutions.

We first investigate gender differences in connections with NSFC panelists before

[26] At the time of writing this paper (September 2022), the NSFC publicized the information on grants approved before 2016.

a candidate successfully becomes a rotator. We limit our analysis to rotator candidates who attended the NSFC interview after 2017. As Figure 5 shows, we find almost no gender differences in number of connected NSFC panelists and number of NSFC grants that a rotator participates in with a panelist.[27] The results suggest no gender gap among rotator candidates in connections with NSFC panelists before becoming rotators.[28]

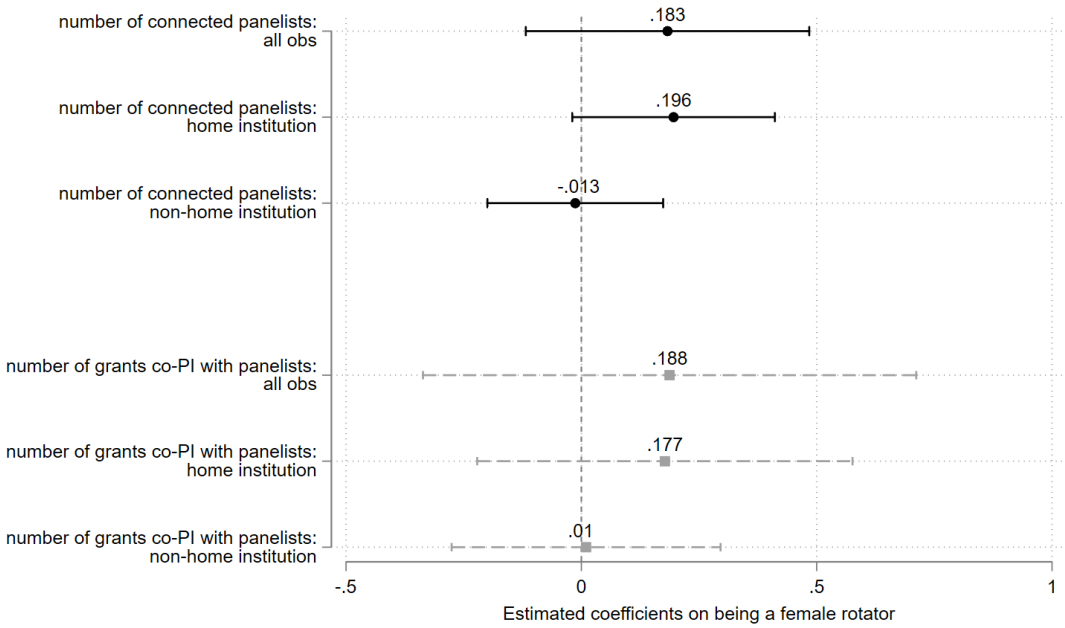


Figure 5 Gender differences among candidates in connections with NSFC panelists before becoming rotators: controlling for individual characteristics

Note: this figure shows the point estimates and 95% confidence intervals of the relationship between being a female rotator and the outcome variable listed at the left of the figure. The sample comprises only rotator candidates who attended the NSFC interview after 2017. We also report estimates separately for panelists from home institutions and for outside panelists.

We next show gender differences in connections with NSFC panelists after the person becomes a rotator. We again limit our analysis to rotators before 2016. As Figure 6 shows, male rotators have connections with more NSFC panelists and participates in more NSFC grants with panelists. Furthermore, male rotators have more connections

[27] As shown by Figure A5 of the Appendix, we find similar results after controlling for individual characteristics.

[28] As shown in Figure A6 of the Appendix, we also find no differences in connections with NSFC panelists between rotators and failed rotator candidates before attending the NSFC interview.

with NSFC panelists from other institutions, rather than from home institutions.[29] Our findings suggest that male rotators are more likely than females to develop connections with these powerful NSFC panelists who decide final grant outcomes and themselves are mostly male (Cullen and Perez-Truglia, 2022).

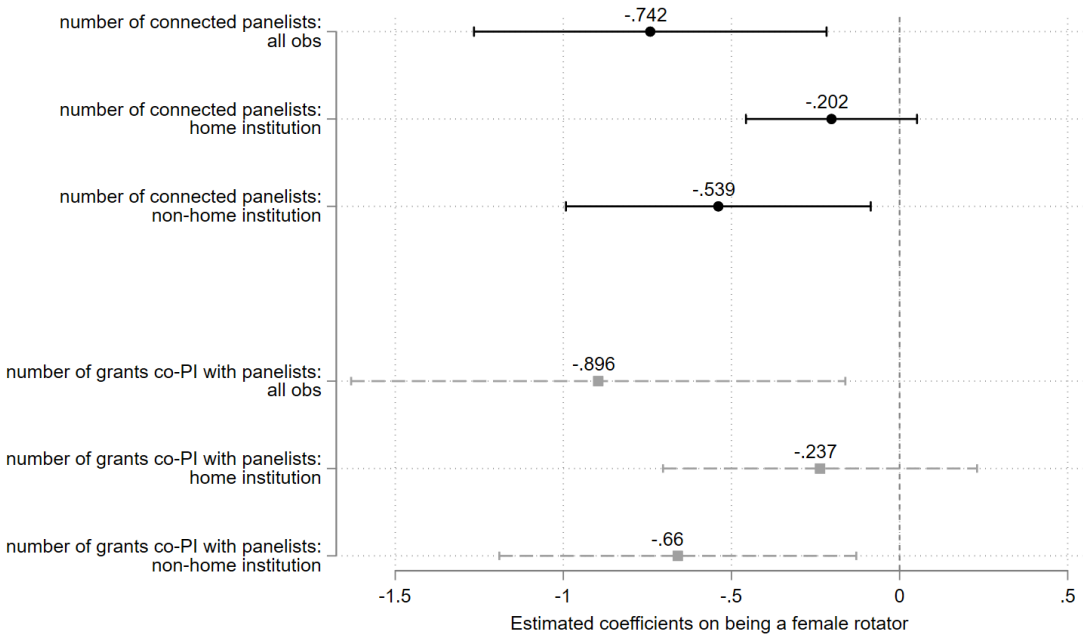


Figure 6 Gender gap among rotators in connections with NSFC panelists

Note: this figure shows point estimates and 95% confidence intervals of the relationship between being a female rotator and the outcome variable listed in the left part of the figure. The sample comprises only rotators from 2016 and before. We also report estimates separately for panelists from home institutions and for outside panelists.

6.2 Other possible mechanisms: information and learning

Until now, we have interpreted our main findings as the network mechanism: male rotators are more likely than females to form networks during their tenure at the NSFC and they use networks to help obtain high-stakes grants and thus advance their career development. But other forces may also drive our main results.[30] First, a rotator may

[29] As shown by Figure A7 of the Appendix, we find similar results after controlling for individual characteristics.

[30] Reciprocity may also explain the rotator experience effect if the NSFC wants to reward rotators with grants for their temporary work. But while this possibility may be able to explain the differences in number of awarded grants between rotators and failed candidates, it cannot explain the gender differences in the rotator effect. If this possibility holds, we will not observe gender differences in the rotator effect because both male and female rotators work for NSFC without paid salaries.

get insider information that is valuable for the success of grant applications. Such insider information may include how to choose a better research grant topic and how to write a better grant proposal. Second, a rotator may be exposed to scientific research frontiers by interacting with leading experts and processing high-quality research proposals. Rotator experience, therefore, may increase a person's scientific productivity that also increases the chance of the person being awarded a NSFC scientific grant.[31]

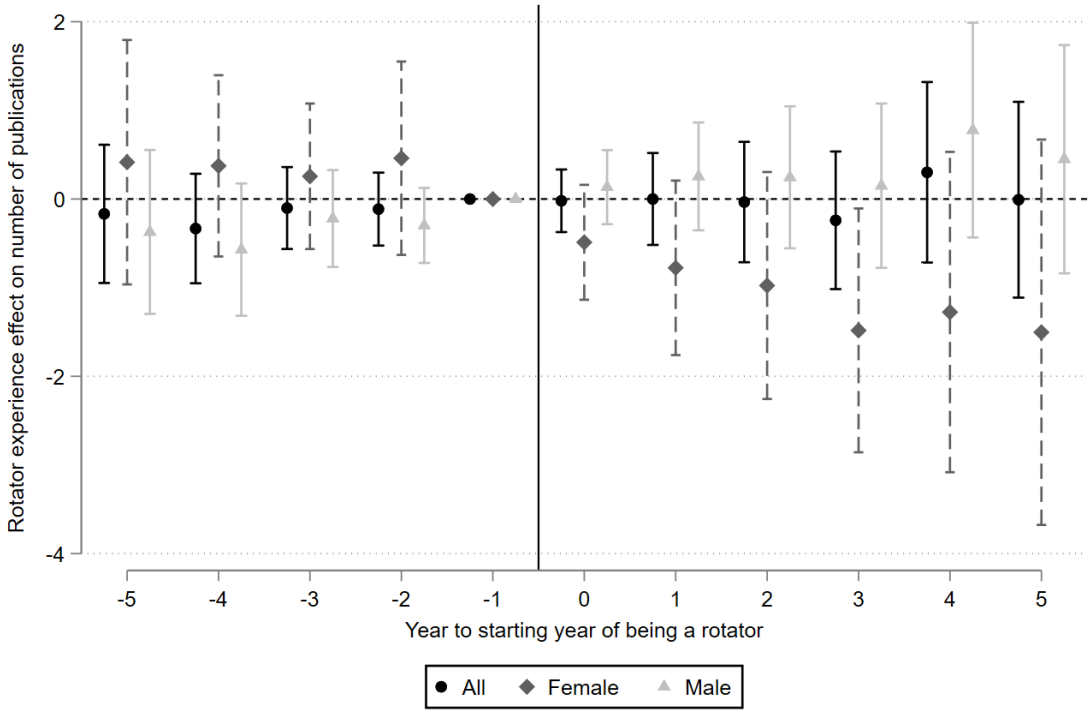
If the information channel is a major contributor to the effects we measure in Section 5, we would expect to observe no gender gap in the rotator effect on grant outcomes. This is because both male and female rotators do similar work at the NSFC and should have acquired similar information valuable for the success of future grant applications. We would also expect to find similar effects for rotators working in NSFC scientific departments and for those working in supportive departments, since they should have acquired almost the same knowledge about the insider information on how to evaluate grant applications (recall that a main difference between the two types of work is greater exposure to panelists for rotators in scientific departments). Our previous results, however, show a large gender gap between male and female rotators in acquiring scientific grants, and a larger gender gap among rotators working for NSFC scientific departments than among those working for supportive offices. Taken together, these patterns suggest that the information channel is unlikely.

Another possibility is that male rotators may be more likely than females to increase their scientific productivity during their temporary work period at the NSFC. For instance, compared with female rotators, male rotators may learn more about the research frontier by interacting with leading experts. We explore this possibility by focusing on the following two scientific productivity indicators: a person's number of publications (including both all publications and first-authored publications) and their publication quality, as proxied by the number of citations to a person's publications.

As Figure 7 shows, we find insignificant effects of rotator experience on both the

[31] Rotator experience may also negatively affect a person's chance of being awarded an NSFC scientific grant. In addition to the fact that rotators are not allowed to apply for NSFC grants during their period of service, this time away from normal work may negatively impact their scientific productivity. Were such effects to be true, our main findings may be smaller in magnitude than the true impact of the network effects we study.

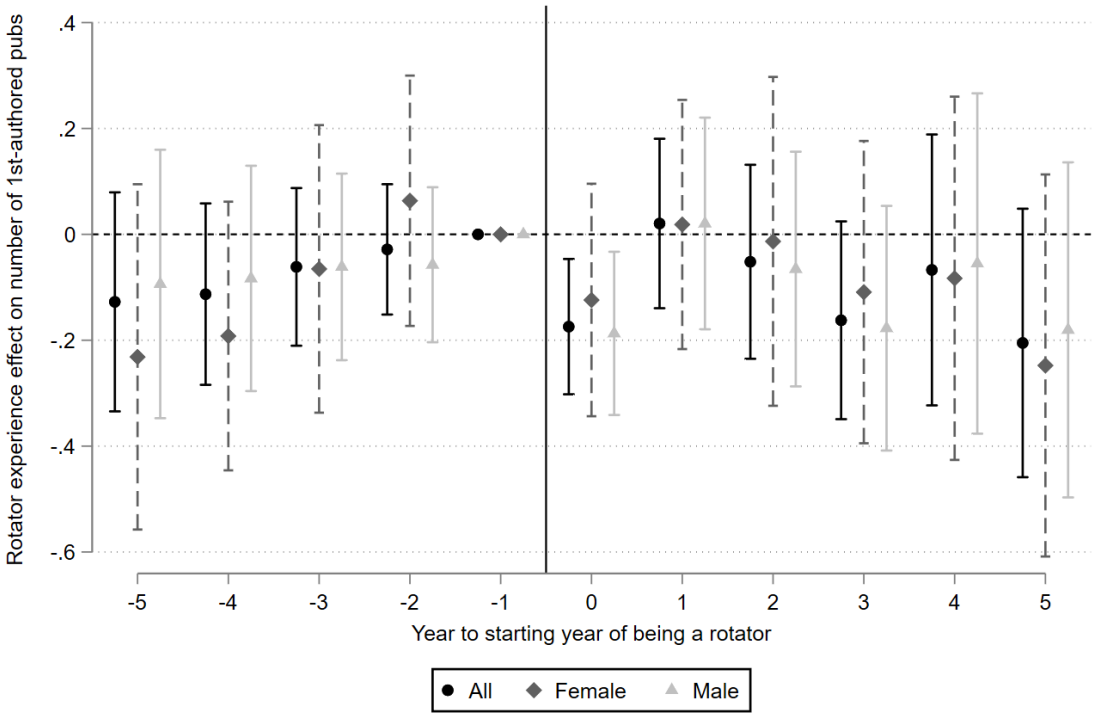
number of publications and publication quality.[32] The results suggest that being a rotator is not associated with any increase in a person's scientific productivity and we find little evidence of an effect on the gender gap in scientific productivity.[33] We can thus exclude the academic performance channel as a possible explanation for the large gendered rotator experience effect on getting NSFC grants and being promoted to an administrative position.



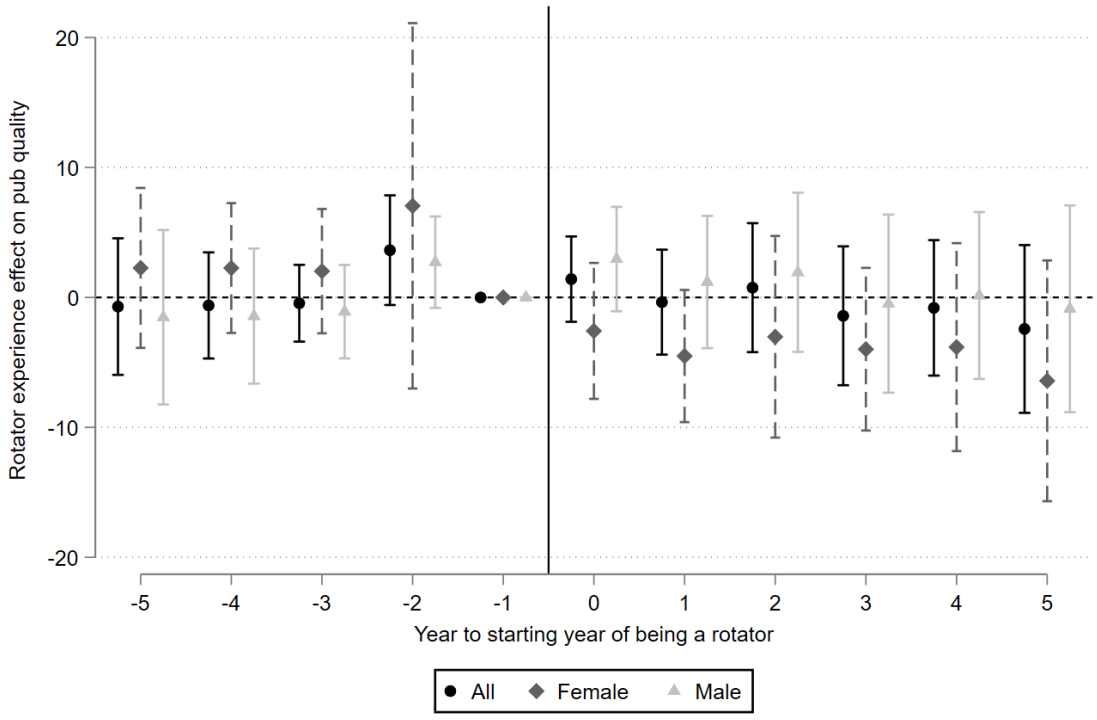
(a) Rotator experience and number of publications

[32] We also perform additional robustness checks: i) limiting publications to only journal papers, ii) limiting the analysis to only rotator candidates who attended the NSFC face-to-face interview after 2017, and iii) dropping rotator candidates who later become permanent NSFC employees and thus may not publish afterwards. As Figures A8, A9, and A10 show, these empirical results are similar to our main results in Figure 7.

[33] While we find no evidence of an effect on the total number of publications for male rotators, rotator experience slightly decreases the number of publications for female rotators. On the other hand, we do not find evidence of a gender difference in these effects for the person's number of first-authored publications and, separately, the quality of their publications as measured by citation counts. Because the NSFC requires that applicants include no more than five representative publications in their application materials, the above slight differences in the estimated effects on a person's total number of publications is unlikely to contribute to the large gender gap in benefits associated with rotator experience.



(b) Rotator experience and number of first-authored publications



(c) Rotator experience and publication quality

Figure 7 Rotator experience and scientific productivity

Note: this figure shows the event study point estimates and 95% confidence intervals of the coefficients $\alpha_{1\#T}$ in Equation (1); here the outcome variables we study relate to measures of scientific productivity as listed in the panel titles. We control for both individual and year fixed effects in all regressions. Panel (a) shows how rotator experience affects a person's total number of academic publications. Panel (b) shows how rotator experience affects a person's number of first-authored publications. Panel (c) shows how

rotator experience affects the quality of a person's scientific output, as measured by citation count. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Standard errors are clustered at the rotator candidate level.

To sum up, we provide both qualitative and direct evidence that male rotators are more likely than females to develop connections with NSFC panelists who decide final grant outcomes. We also exclude information learning or increased academic performance as possible mechanisms. We, therefore, interpret our gendered rotator experience effects as coming from rotators exploiting networks formed during their tenure at the NSFC to help obtain scientific grants and, thus, advance their career development.

7 Conclusions

This paper examines how scientists' networks contributes to gender gap in scientific funding and career development. Our study is among the first to causally study the role of networks in contributing to the gender gap in science. We exploit an exogenous shock to academic networks due to a person's temporary status as a rotator at the National Natural Science Foundation of China. We examine how the networks formed during the rotating period differentially affect grant outcomes and career development of male and female scientists.

We find that compared with females, male rotators develop stronger connections with NSFC grant panelists who decide final funding outcomes. We also find that male rotators are much more likely than females to acquire NSFC grants (especially high-stakes ones) and to be promoted to administrative positions after leaving the NSFC. We interpret the results as rotators exploiting networks formed during their tenure at the NSFC to help obtain scientific grants and thus advance their career development. We can reasonably exclude information learning or increased academic performance as possible mechanisms.

Our findings highlight the gendered role of networking in determining the allocation of research resources, and show how this may contribute to the persistent gender gap in science. Because gatekeepers of research resources (including scientific grants and journals) are mostly male, diversifying the gender composition of these positions may help reduce the gendered networking effect and thus promote career development of female scientists.

References

Asai, Y., & Koustas, D. K. (2022). Temporary Work Contracts, Parental Leave and Female Labor Market Outcomes. *Working Paper*. http://www.dmitrikoustas.com/

Bol, T., de Vaan, M., & van de Rijt, A. (2022). Gender-equal funding rates conceal unequal evaluations. *Research Policy*, *51*(1), 104399.

Booth, A. L., Francesconi, M., & Frank, J. (2002). Temporary Jobs: Stepping Stones or Dead Ends? *Economic Journal*, *112*(480), F189–F213.

Boschini, A., & Sjögren, A. (2007). Is Team Formation Gender Neutral? Evidence from Coauthorship Patterns. *Journal of Labor Economics*, *25*(2), 325–365.

Card, D., DellaVigna, S., Funk, P., & Iriberri, N. (2020). Are Referees and Editors in Economics Gender Neutral? *Quarterly Journal of Economics*, *135*(1), 269–327.

Ceci, S. J., & Williams, W. M. (2011). Understanding current causes of women's underrepresentation in science. *Proceedings of the National Academy of Sciences*, *108*(8), 3157–3162.

Cheng, W., & Weinberg, B. A. (2021). *Marginalized and Overlooked? Minoritized Groups and the Adoption of New Scientific Ideas* (Working Paper No. 29179). National Bureau of Economic Research. https://doi.org/10.3386/w29179

Cullen, Z. B., & Perez-Truglia, R. (2022). *The Old Boys' Club: Schmoozing and the Gender Gap* (Working Paper No. 26530). National Bureau of Economic Research. https://doi.org/10.3386/w26530

Cyranoski, D. (2019). Artificial intelligence is selecting grant reviewers in China. *Nature*, *569*(7756), 316–317.

Davis-Blake, A., & Uzzi, B. (1993). *Determinants of Employment Externalization: A Study of Temporary Workers and Independent Contractors*. *38*(2), 195–223.

De Paola, M., Ponzo, M., & Scoppa, V. (2017). Gender differences in the propensity to apply for promotion: Evidence from the Italian Scientific Qualification. *Oxford Economic Papers*, *69*(4), 986–1009.

Ductor, L., Goyal, S., & Prummer, A. (2022). Gender and collaboration. *Review of Economics and Statistics*, *in press*.

Ductor, L., & Visser, B. (2022). When a coauthor joins an editorial board. *Journal of Economic Behavior & Organization*, *200*, 576–595.

Engellandt, A., & Riphahn, R. T. (2005). Temporary contracts and employee effort. *Labour Economics*, *12*(3), 281–299.

Fisman, R., Shi, J., Wang, Y., & Xu, R. (2018). Social Ties and Favoritism in Chinese Science. *Journal of Political Economy*, *126*(3), 1134–1171.

García-Pérez, J. I., Marinescu, I., & Vall Castello, J. (2019). Can Fixed-term Contracts Put Low Skilled Youth on a Better Career Path? Evidence from Spain. *Economic Journal*, *129*(620), 1693–1730.

Goldschmidt, D., & Schmieder, J. F. (2017). The Rise of Domestic Outsourcing and the Evolution of the German Wage Structure. *Quarterly Journal of Economics*, *132*(3), 1165–1217.

Hengel, E. (2022). Publishing while female: Are women held to higher standards? Evidence from peer review. *Economic Journal*, *in press*.

Hoenen, S., & Kolympiris, C. (2020). The Value of Insiders as Mentors: Evidence from the Effects of NSF Rotators on Early-Career Scientists. *Review of Economics and Statistics*, *102*(5), 852–866.

Kim, S. D., & Moser, P. (2021). *Women in Science. Lessons from the Baby Boom*

(Working Paper No. 29436). National Bureau of Economic Research. https://doi.org/10.3386/w29436

Kolympiris, C., Hoenen, S., & Klein, P. G. (2019). Learning by Seconding: Evidence from National Science Foundation Rotators. *Organization Science*, *30*(3), 528–551.

Larivière, V., Ni, C., Gingras, Y., Cronin, B., & Sugimoto, C. R. (2013). Bibliometrics: Global gender disparities in science. *Nature*, *504*(7479), 211–213.

Lindenlaub, I., & Prummer, A. (2021). Network Structure and Performance. *Economic Journal*, *131*(634), 851–898.

Ma, Y., Zhao, Y., Gong, X., Sun, L., & Zheng, Y. (2018). Close the gender gap in Chinese science. *Nature*, *557*(7703), 25–27.

National Academy of Sciences, National Academy of Engineering, & Institute of Medicine. (2007). *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*. Washington, DC: The National Academies Press. https://doi.org/10.17226/11741

Niederle, M., & Vesterlund, L. (2007). Do Women Shy Away From Competition? Do Men Compete Too Much? *Quarterly Journal of Economics*, *122*(3), 1067–1101.

Ross, M. B., Glennon, B. M., Murciano-Goroff, R., Berkes, E. G., Weinberg, B. A., & Lane, J. I. (2022). Women are credited less in science than men. *Nature*, *608*(7921), 135–145.

Shen, H. (2013). Inequality quantified: Mind the gender gap. *Nature News*, *495*(7439), 22.

Shi, Y., & Rao, Y. (2010). China's Research Culture. *Science*, *329*(5996), 1128–1128.

Vásárhelyi, O., Zakhlebin, I., Milojević, S., & Horvát, E.-Á. (2021). Gender inequities in the online dissemination of scholars' work. *Proceedings of the National Academy of Sciences*, *118*(39), e2102945118.

Wennerås, C., & Wold, A. (1997). Nepotism and sexism in peer-review. *Nature*, *387*(6631), 341–343.

Yang, W. (2017). China's basic research has made remarkable progress in the past five year. *Bulletin of National Natural Science Foundation of China (in Chinese)*, *31*(6), 521–522.

Yao, Y., & Xiong, J. (2017). How to improve the quality of the proposal: Discussion based on NSFC's project application and review procedures. *Bulletin of National Natural Science Foundation of China (in Chinese)*, *31*(6), 524–528.

Zhang, L., Zhao, Y., Zhao, L., Wang, C., & Zhou, Y. (2019). Thoughts on the system of rotating program director in science funding agencies: Case study on NSFC. *Bulletin of National Natural Science Foundation of China (in Chinese)*, *33*(3), 296–300.

Zinovyeva, N., & Bagues, M. (2015). The Role of Connections in Academic Promotions. *American Economic Journal: Applied Economics*, *7*(2), 264–292.

Appendix

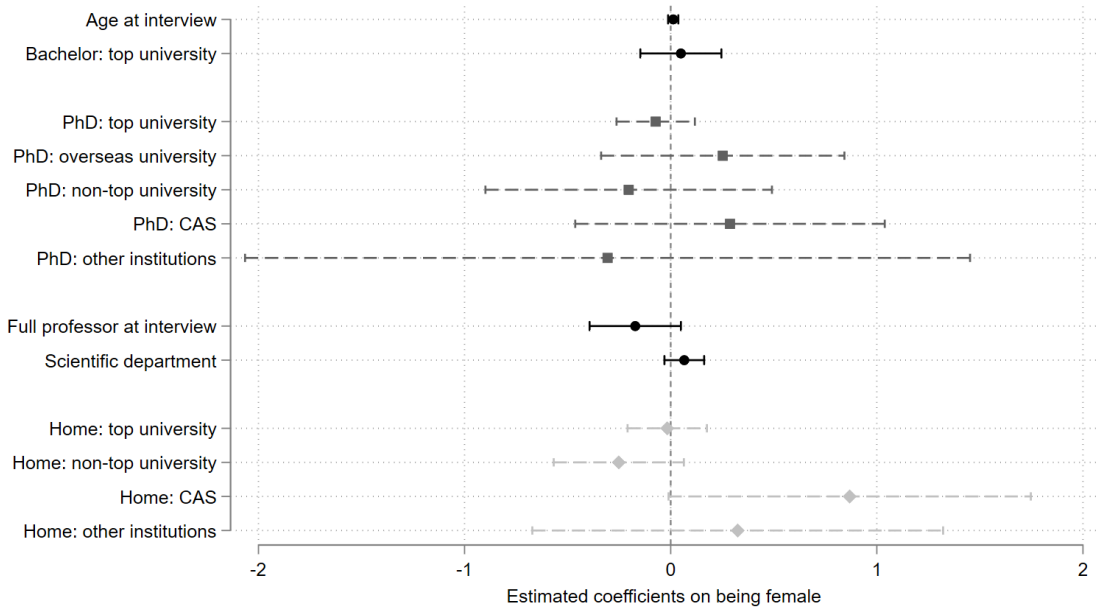
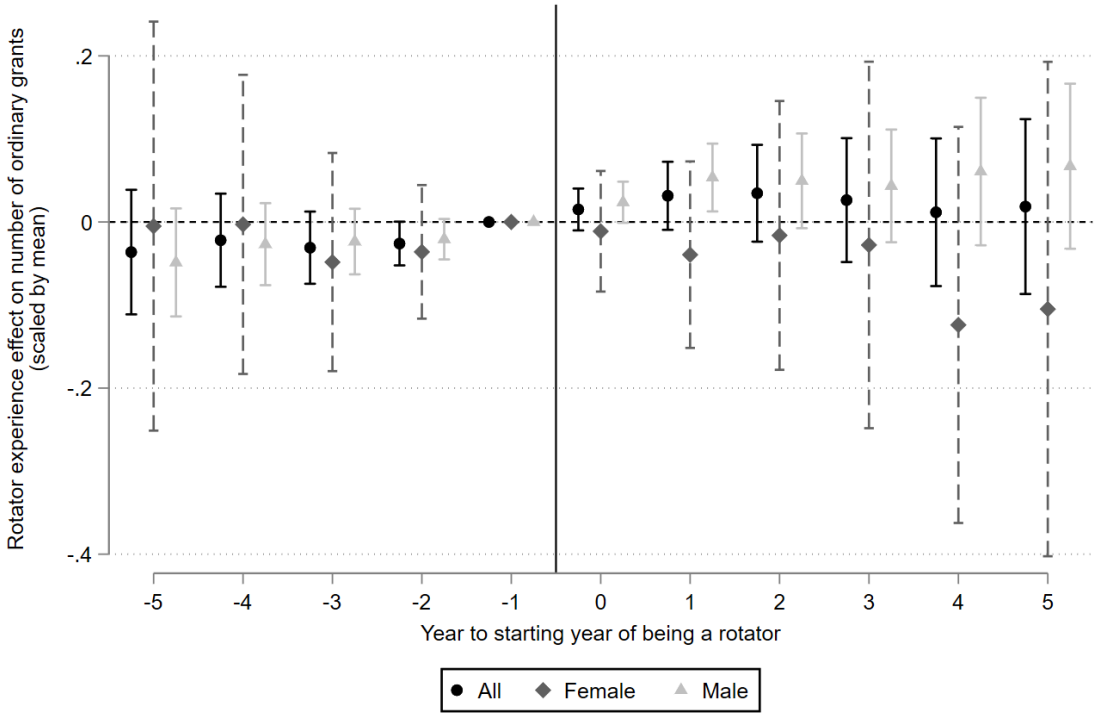
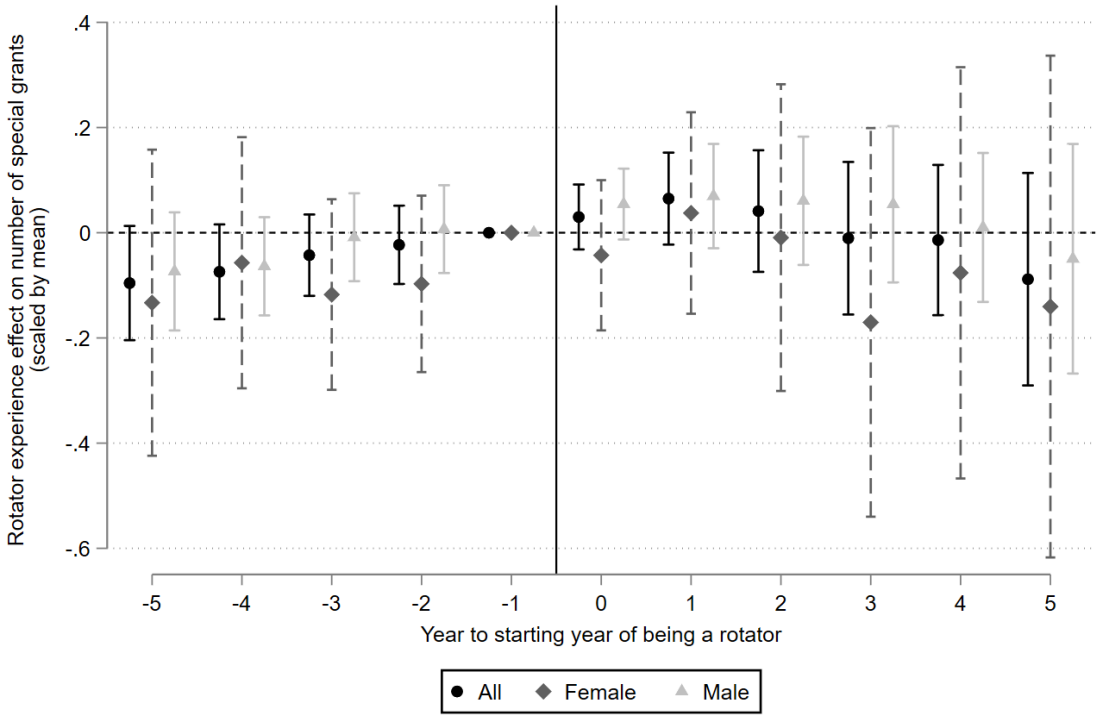


Figure A1 Gender differences in rotators' characteristics

Note: This figure shows gender differences in rotators' characteristics. We regress each characteristic on a dummy for being female and no other control variables. All estimated coefficients and 95% confidence intervals are scaled by the mean of each characteristics.



(a) Number of NSFC grants received by colleagues: ordinary grants

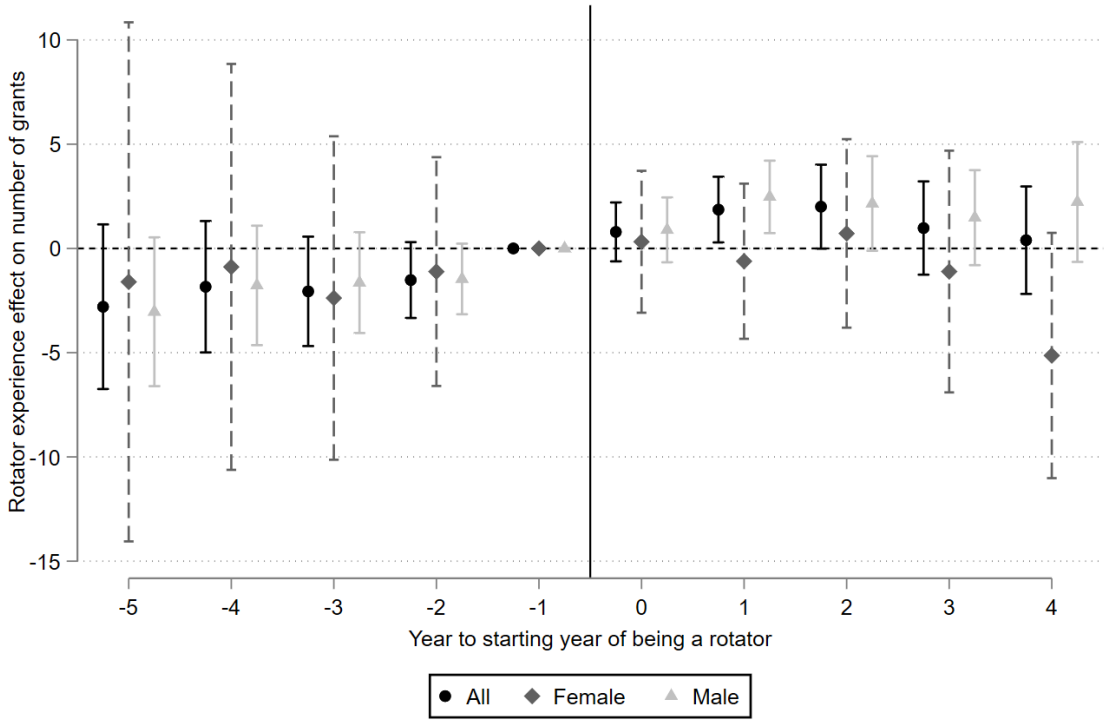


(b) Number of NSFC grants received by colleagues: specific grants

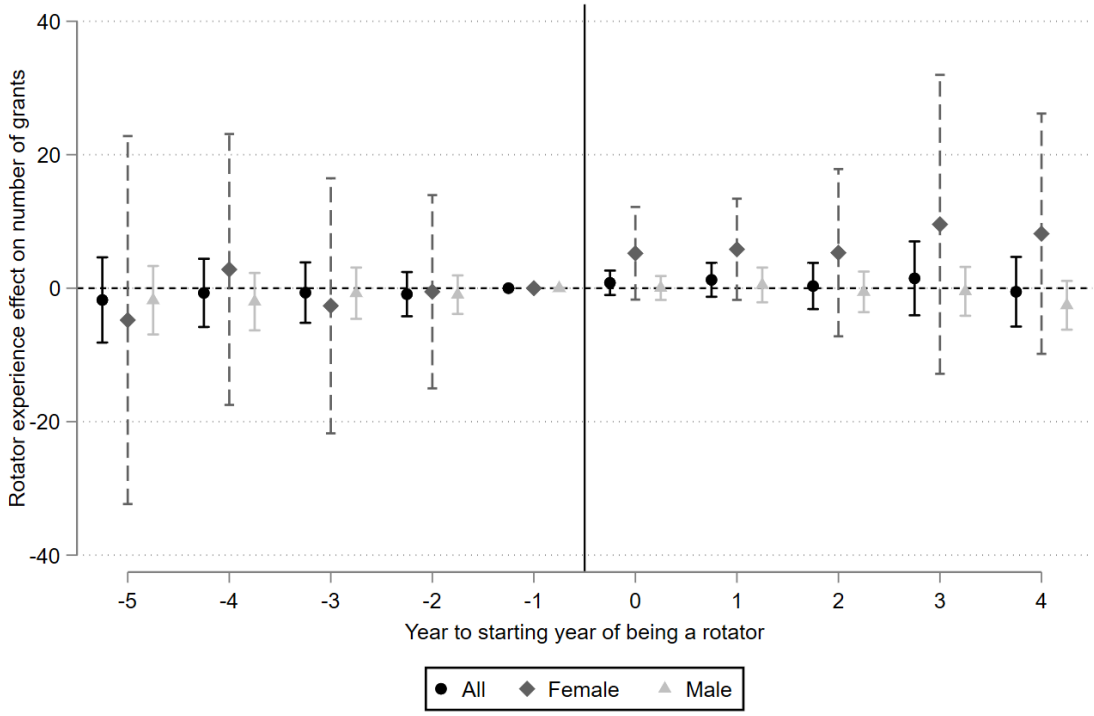
Figure A2 Rotator experience and number of NSFC grants received by colleagues: by grant type

Note: this figure shows the heterogeneity in terms of grant type in the event study point estimates and 95% confidence intervals of the coefficients $\alpha_{1\#T}$ in Equation (1), which represent how rotator experience

affects the number of NSFC grants awarded to a person's colleagues at their home institution, for all candidates and then separately for female and male rotators. We control for both individual and year fixed effects in all regressions. Panel (a) shows how rotator experience affects the number of low-stakes ordinary grants awarded to colleagues. Panel (b) shows results for the number of high-stakes special grants awarded to colleagues. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Standard errors are clustered at the rotator candidate level.



(a) Rotator experience and number of NSFC grants received by colleagues: rotators working at NSFC scientific departments

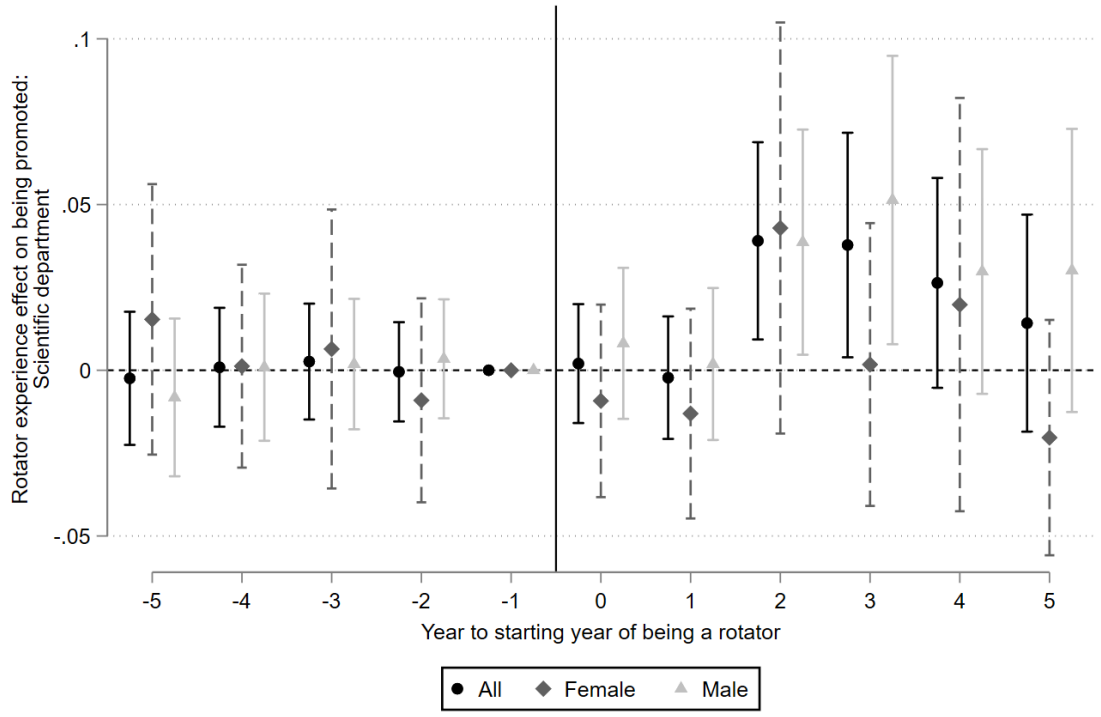


(b) Rotator experience and number of NSFC grants received by colleagues: rotators working at NSFC supportive offices

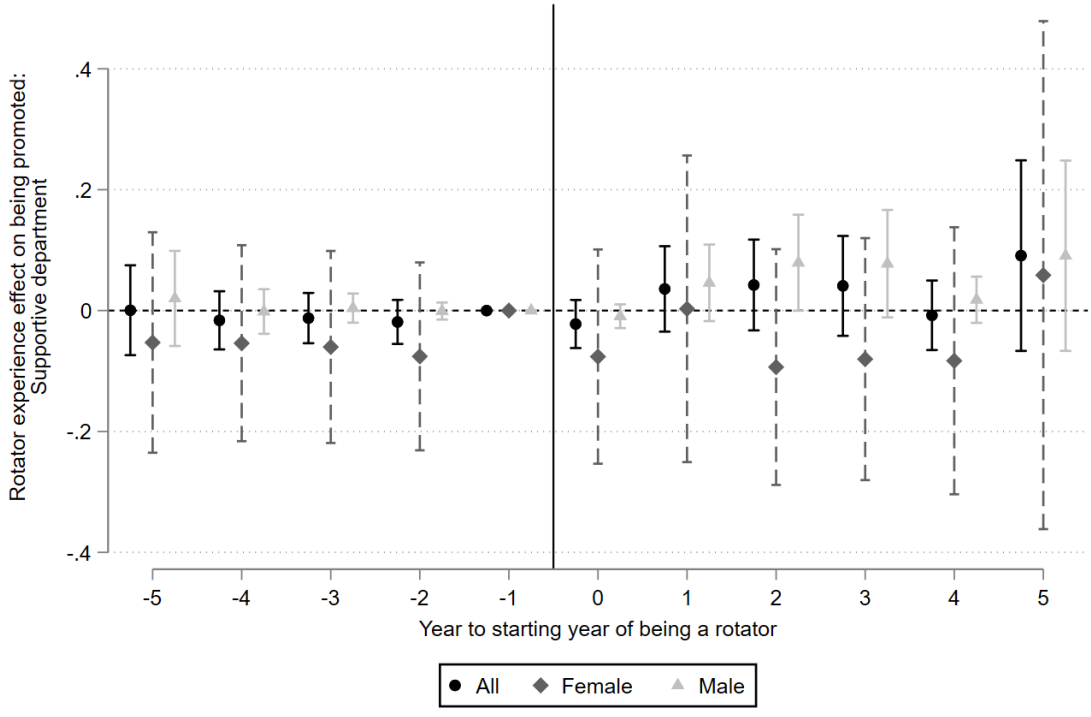
Figure A3 Rotator experience and number of NSFC grants received by colleagues: by NSFC department type

Note: this figure shows the heterogeneity in terms of NSFC department type in the event study point estimates and 95% confidence intervals of the coefficients $\alpha_{I\#T}$ in Equation (1); the outcomes we study here are the number of NSFC grants awarded to colleagues at a person's home institution, for all

candidates, and then separately for female and male rotators. We control for both individual and year fixed effects in all regressions. Panel (a) shows how rotator experience affects the number of NSFC grants awarded to colleagues at the home institution for rotators working in NSFC scientific departments. Panel (b) shows results for rotators working in NSFC supportive offices. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Standard errors are clustered at the rotator candidate level.



(a) Rotator experience and probability of being promoted: rotators working at NSFC scientific departments



(b) Rotator experience and probability of being promoted: rotators working at NSFC supportive offices

Figure A4 Rotator experience and probability of being promoted: by NSFC department type

Note: this figure shows heterogeneity by NSFC department type in the event study point estimates and 95% confidence intervals of the coefficients $\alpha_{I\#T}$ in Equation (1); here our outcome variable is a person's

likelihood of being promoted, estimated for all candidates and then separately for female and male rotators. We control for both individual and year fixed effects in all regressions. Panel (a) shows how rotator experience affects a person's chances of being promoted for rotators working in NSFC scientific departments. Panel (b) shows results for rotators working in NSFC supportive offices. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Standard errors are clustered at the rotator candidate level.

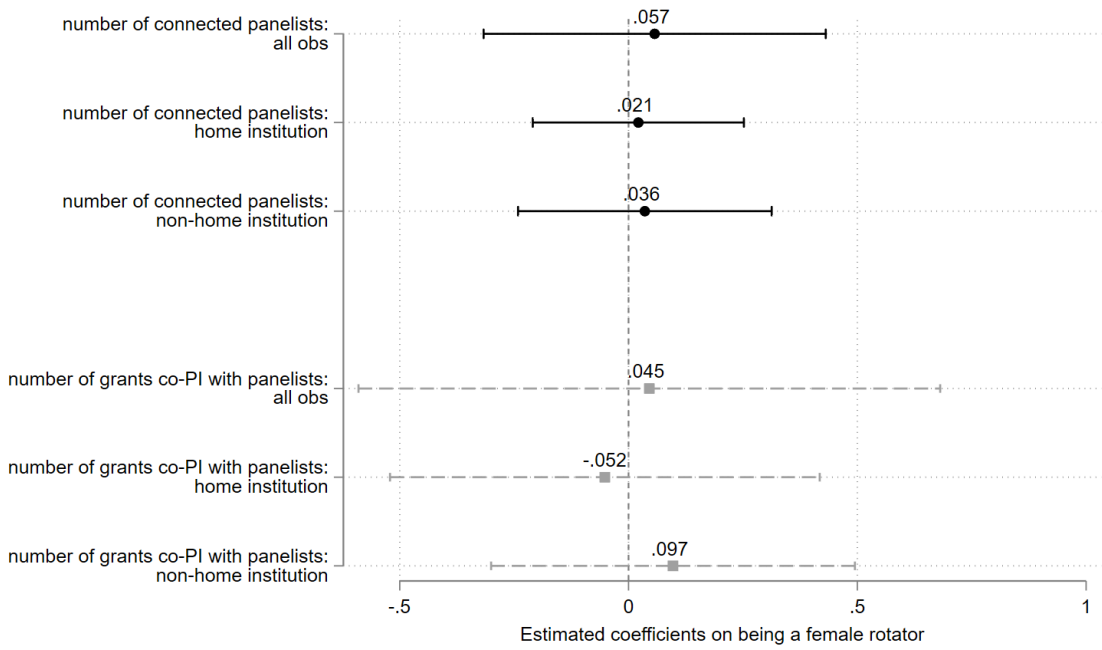
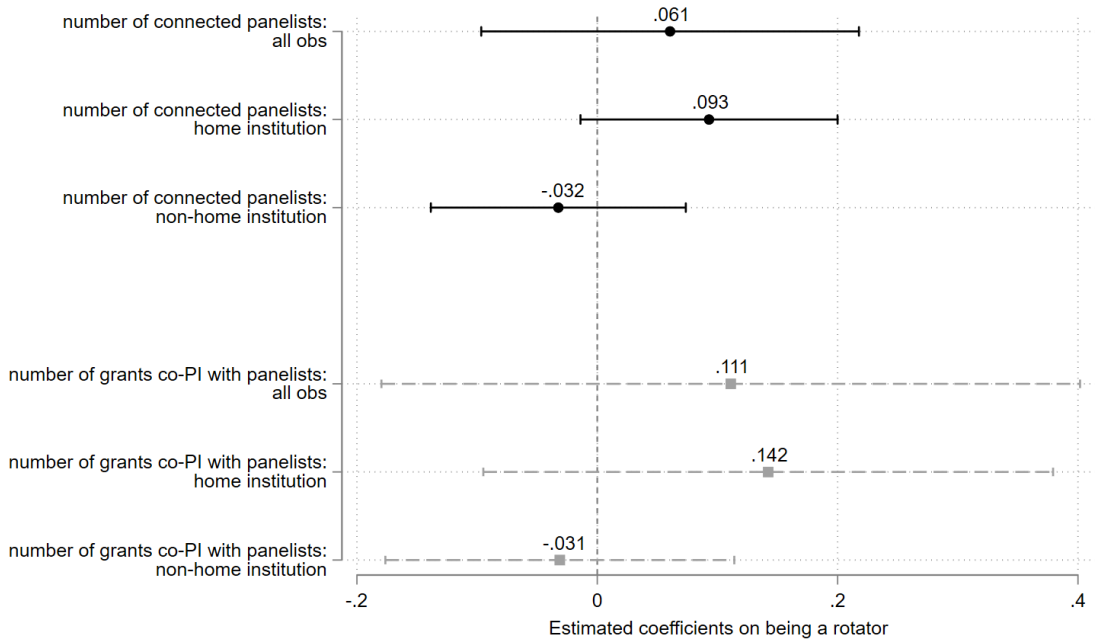
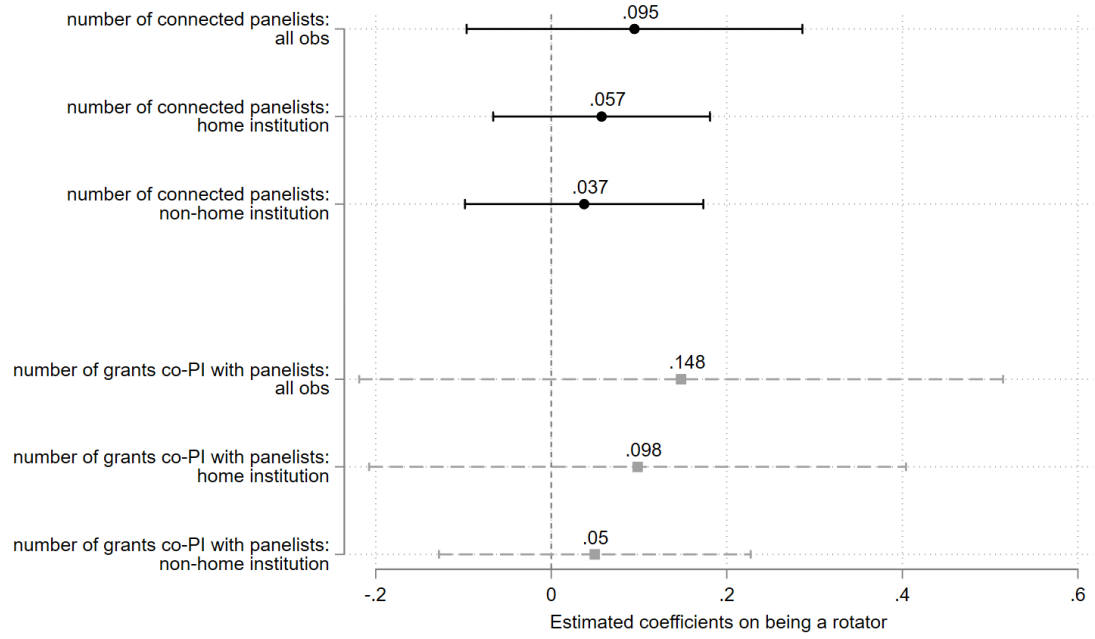


Figure A5 Gender differences among candidates in connections with NSFC panelists before becoming rotators: controlling for individual characteristics

Note: this figure shows point estimates and 95% confidence intervals of the relationship between being a female rotator and the outcome variable listed at the left part of the figure. The sample comprises rotator candidates who attended the NSFC interview in 2017 or after. We also present estimates separately for panelists from home institutions and for outside panelists. We control for the following individual characteristics: age at the interview date, whether to obtain bachelor from a top-tier university, dummies for institutions where a rotator obtained PhD, whether to be a full professor, whether to temporarily work for an NSFC scientific department, and dummies for home institutions where a rotator works.



(a) no controls



(b) controlling for individual characteristics

Figure A6 Differences in connections with NSFC panelists between rotators and failed candidates

Note: this figure shows point estimates and 95% confidence intervals of the relationship between being a female rotator and the outcome variable listed at the left part of the figure. The sample comprises rotator candidates who attended the NSFC interview in 2017 or after. We also present estimates separately for panelists from home institutions and for outside panelists. In Figure A6(b) we control for the following individual characteristics: age at the interview date, whether to obtain bachelor from a top-tier university, dummies for institutions where a rotator obtained PhD, whether to be a full professor, whether to temporarily work for an NSFC scientific department, and dummies for home institutions where a rotator works.

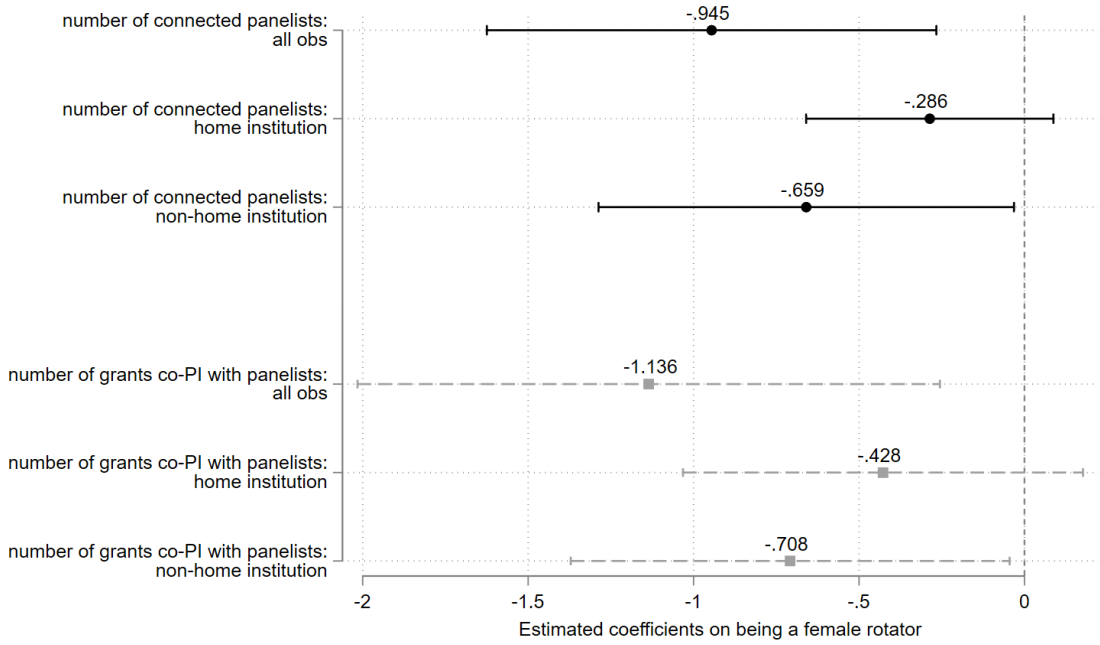
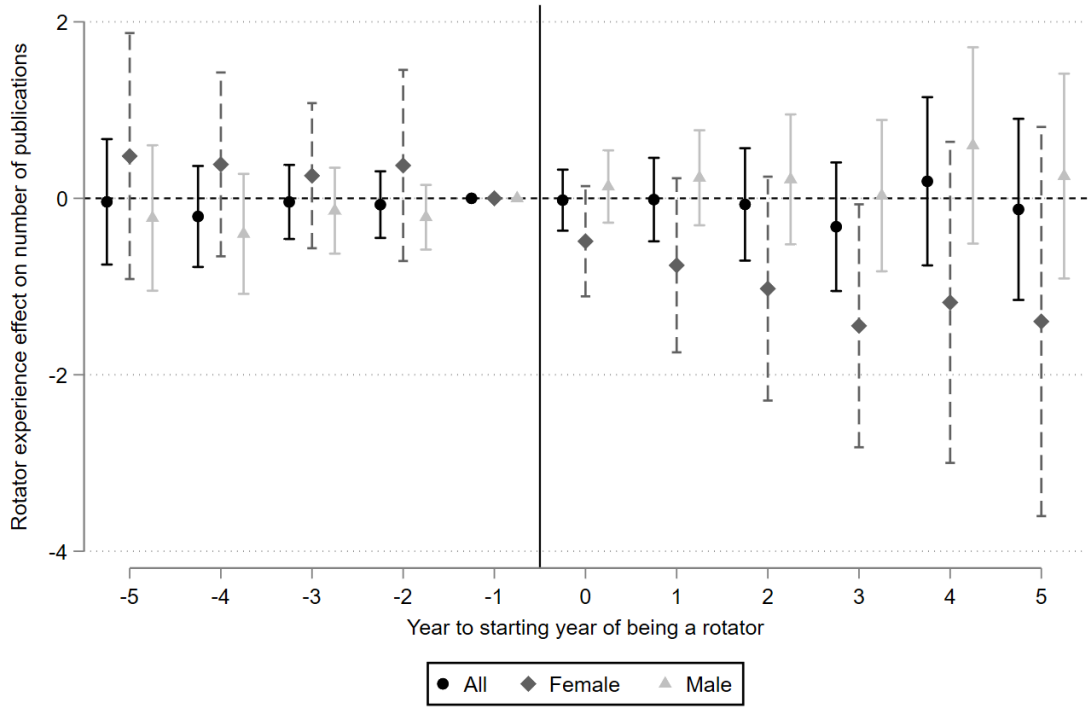
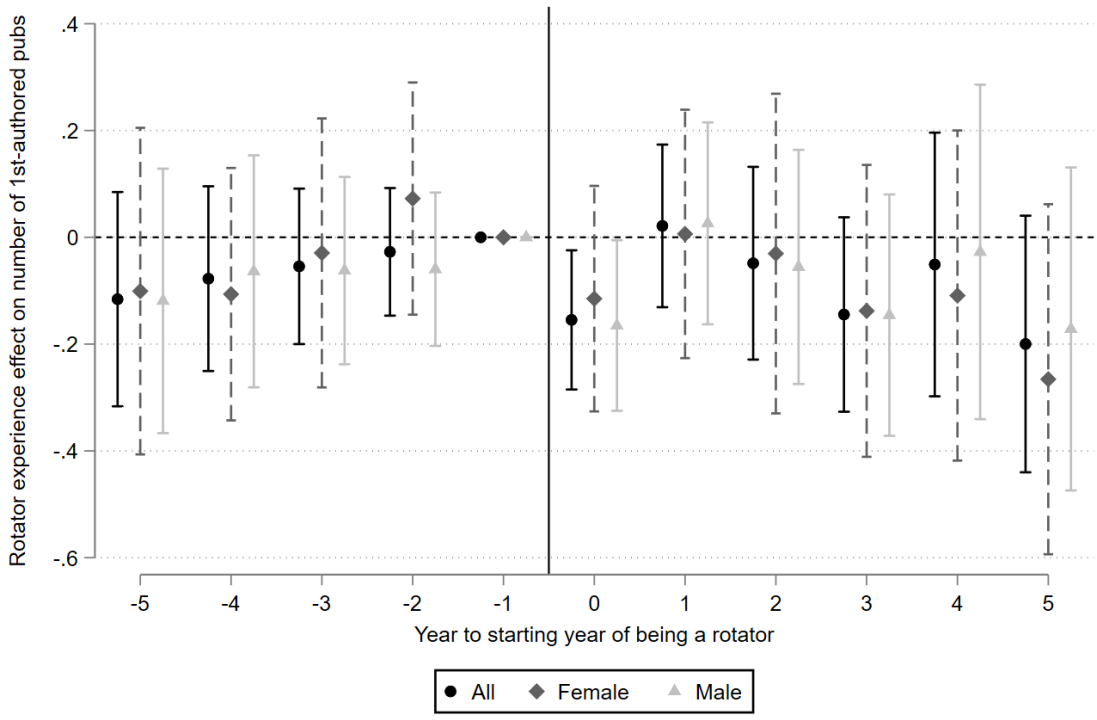


Figure A7 Gender differences among rotators in connections with NSFC panelists: controlling for individual characteristics

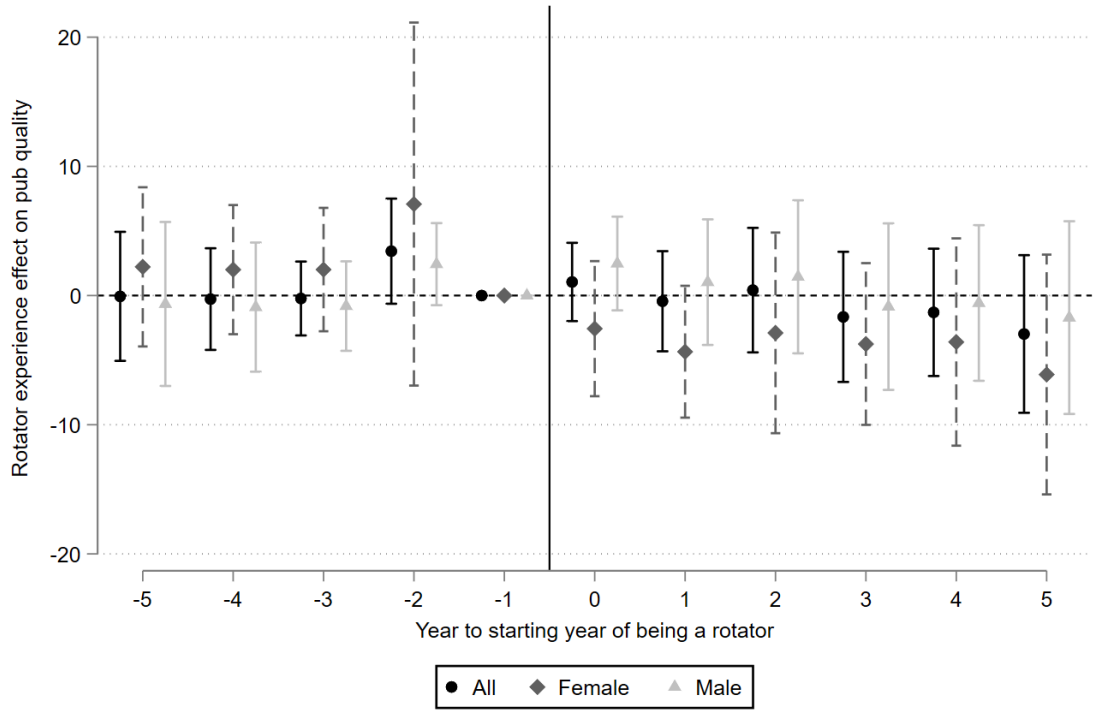
Note: this figure shows point estimates and 95% confidence intervals of the relationship between being a female rotator and the outcome variable listed at the left part of the figure. The sample comprises rotator candidates who attended the NSFC interview in 2016 or earlier. We also present estimates separately for panelists from home institutions and for outside panelists. We control for the following individual characteristics: age at the interview date, whether to obtain bachelor from a top-tier university, dummies for institutions where a rotator obtained PhD, whether to be a full professor, whether to temporarily work for an NSFC scientific department, and dummies for home institutions where a rotator works.



(a) Rotator experience and number of journal papers



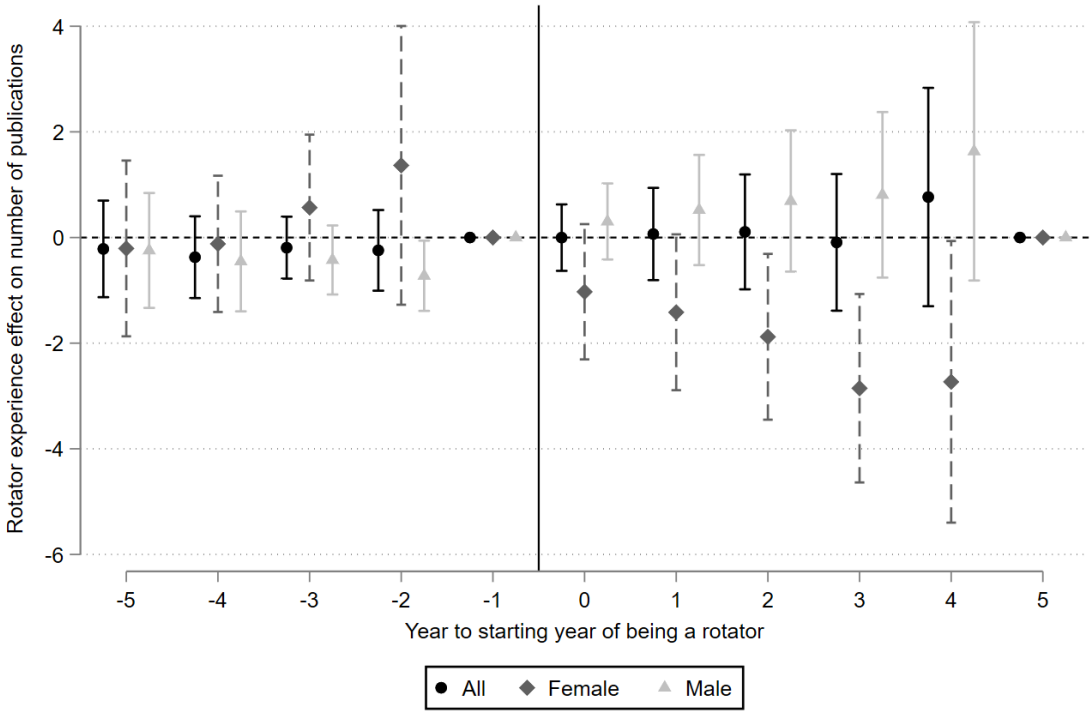
(b) Rotator experience and number of first-authored journal papers



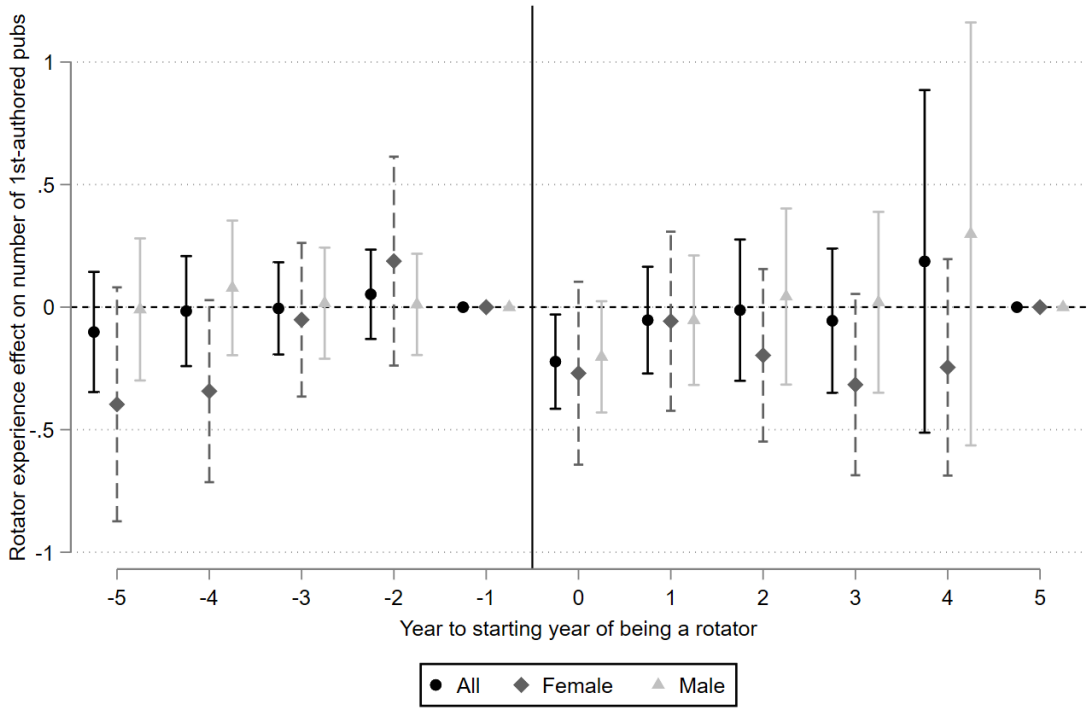
(c) Rotator experience and journal paper quality

Figure A8 Rotator experience and scientific productivity: journal papers

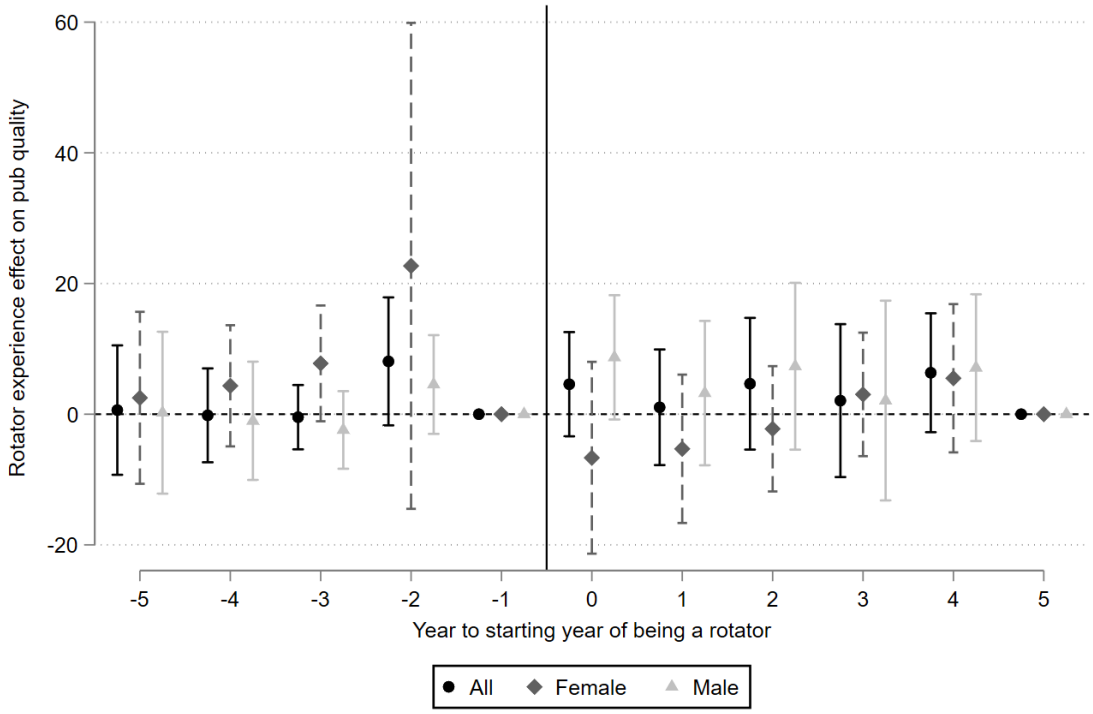
Note: this figure shows the event study point estimates and 95% confidence intervals of the coefficients $\alpha_{1\#T}$ in Equation (1); here the outcome variables we study are various measures of scientific productivity. We present estimates for all candidates and then separately for females and males. We control for both individual and year fixed effects in all regressions. Panel (a) shows how rotator experience affects a person's number of all academic publications. Panel (b) shows how rotator experience affects a person's first-authored publications. Panel (c) shows the rotator experience effect on quality of a person's scientific productivity. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Standard errors are clustered at the rotator candidate level.



(a) Rotator experience and number of publications



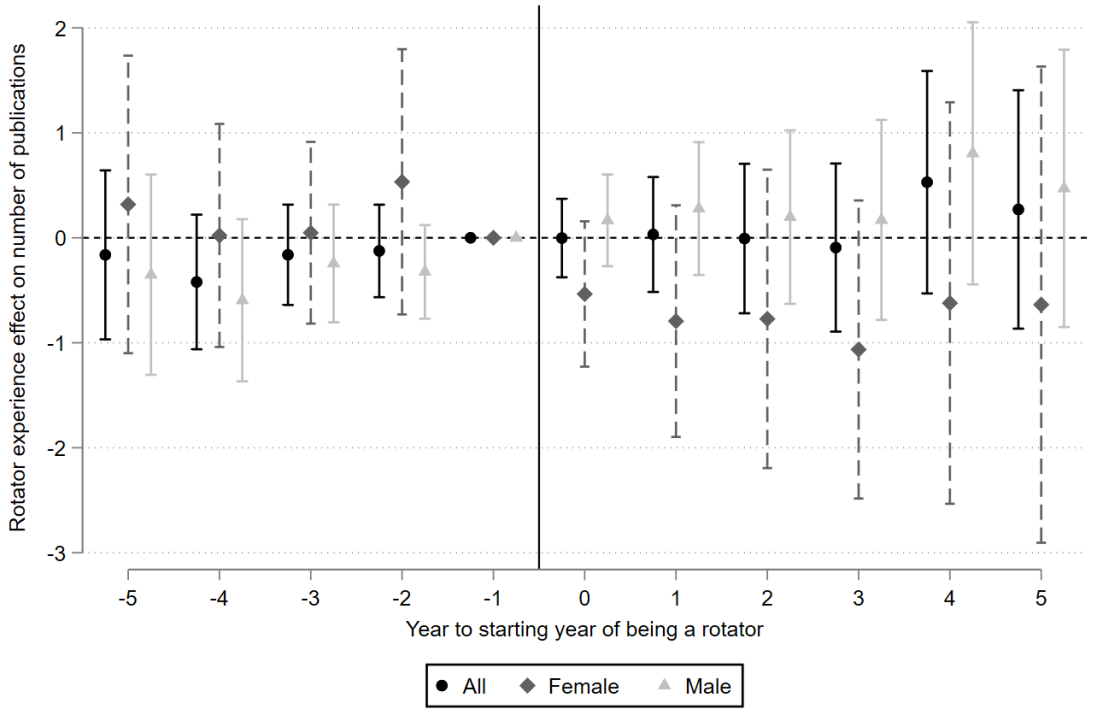
(b) Rotator experience and number of first-authored publications



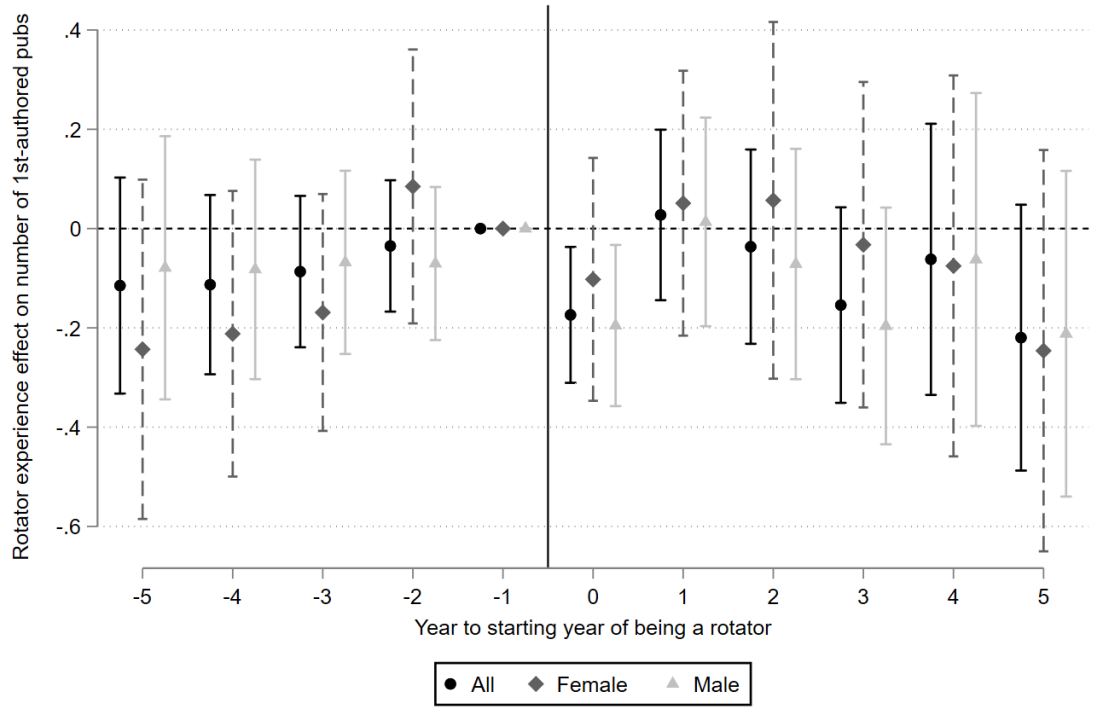
(c) Rotator experience and publication quality

Figure A9 Rotator experience and scientific productivity: candidates after 2017

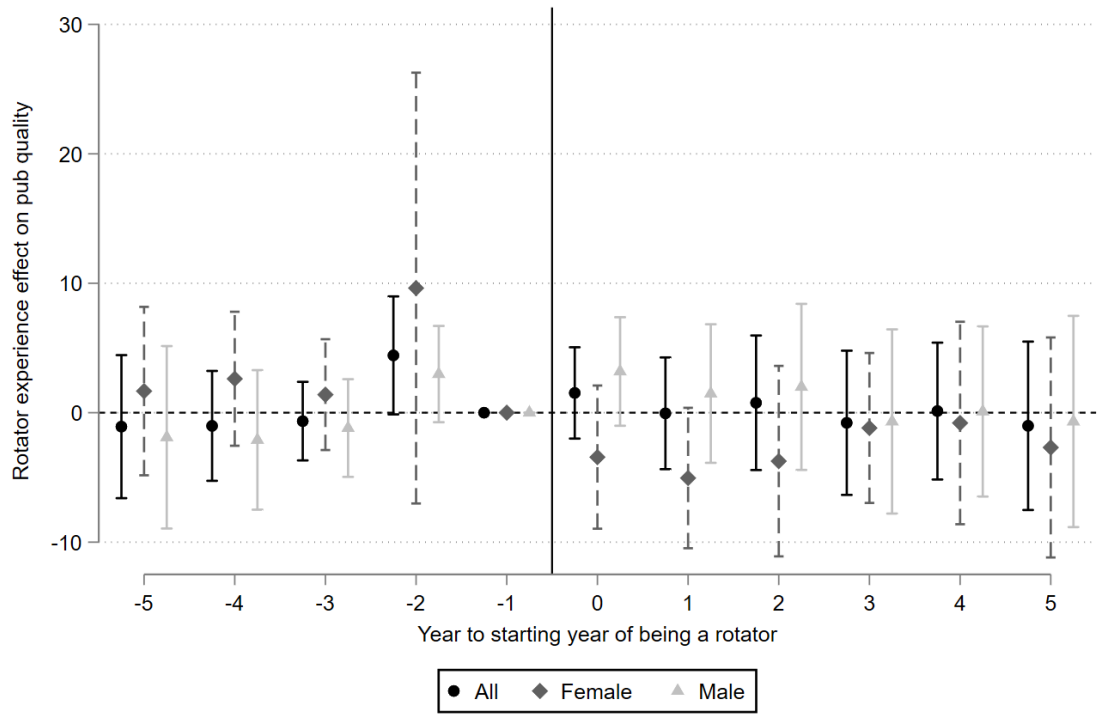
Note: this figure shows event study point estimates and 95% confidence intervals for the coefficients $\alpha_{1\#T}$ in Equation (1); here the outcome variable we study is again scientific productivity, and again we present estimates for all candidates, and then separately for females and males. We control for both individual and year fixed effects in all regressions. Panel (a) shows how rotator experience affects a person's number of all academic publications. Panel (b) shows how rotator experience affects a person's first-authored publications. Panel (c) shows estimates of the effect on the quality of a person's scientific productivity. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Standard errors are clustered at the rotator candidate level.



(a) Rotator experience and number of publications



(b) Rotator experience and number of first-authored publications



(c) Rotator experience and publication quality

Figure A10 Rotator experience and scientific productivity: excluding permanent NSFC employees

Note: this figure shows event study point estimates and 95% confidence intervals of the coefficients $\alpha_{1\#T}$ in Equation (1); here the outcome variable is again scientific productivity, and is again estimated for all candidates and then separately for females and males. We control for both individual and year fixed effects in all regressions. Panel (a) shows how rotator experience affects a person's total number of academic publications. Panel (b) shows how rotator experience affects a person's number of first-authored publications. Panel (c) shows how rotator experience affects the quality of a person's scientific output. All coefficients are plotted relative to the starting year of being a rotator (year of attending the interview for failed rotator candidates). Standard errors are clustered at the rotator candidate level.

Table A1 Anecdotal evidence on NSFC rotators' role in grant reviews and networking

Anecdotes	Sources
基金委就像皇帝，翻牌子来决定借调哪个学校的人，能被借调的学校倍感皇恩浩荡。到了皇帝身边，可以为婆家说好话，谋利益，比如各种本子函评会评都会有好处。皇帝宠幸结束会婆家，自己申请项目也方便，给基金委的前同事打个招呼，什么项目大差不差都能中。我知道一个三本毕业没什么干货甚至没几篇论文的给基金委宠幸三年回头上了杰青。资源多了以后多找博士博士后，很快论文就摞起来了，现在论文几百篇。	https://exp.newsmth.net/topic/1cdea01ba1768f8221c5eebaa5a1422c/1
你的本子要能上会，他打个招呼就给你搞定了。	https://www.mysmth.net/nForum/#!article/QingJiao/599679
我们这里两个人去基金委借调后，一个 4 年之内拿三个项目（分别是 2015、2016、2018），一个连续三年中奖，五年拿四个（分别是是 2014、2016、2017、2018）。你要说这里面没猫腻，那就见鬼了。	https://www.mysmth.net/nForum/#!article/QingJiao/599679
自己和单位或熟人，在不同程度上都可受益吧。	http://muchong.com/t-3551062-1
今年有一个担任项目主任，上了杰青的。你说有没有意义？	http://muchong.com/t-3551062-1
基金委每年都在高校公开招聘“流动编制项目主任”，这确是好差事，大家心知肚明。此流动部主任一般任期 2 年，哪个学校有的话，据说当年申请基金数目上涨。他们也经常被很多学校邀请去作报告、进行交流。目的大家是懂的。	http://muchong.com/t-3444071-1-authorid-1073943
坚决避免从下面高校借调人员参与基金委送审、打包等工作。这是明显的不公平的地方，借调去的人能做什么我想大家心里都会有个预期。难道基金委就不能多招些工作人员吗？非得用这种方式？借调过去的人能为谁谋福利？是他所在的学校的人？是和他有竞争关系的同学科的人？是他的本单位的领导？等等，大家都会有自己认识的。	http://muchong.com/html/201505/8975199.html

Note: these anecdotes are drawn from two large discussion forums for scientists in China: Xiaomuchong (http://muchong.com/bbs/) and Shuimu community (https://www.mysmth.net/nForum).

Table A2 Balance tests for rotators and finalists

	(1)	(2)
Female	-0.027	-0.040
	(0.039)	(0.052)
Full professor at the interview	0.030	0.063
	(0.033)	(0.045)
Affiliated home institution (Reference group: Top-tier Chinese university)		
Other Chinese university	-0.054	-0.055
	(0.037)	(0.056)
Chinese Academy of Sciences	0.002	0.064
	(0.062)	(0.099)
Other research institution	-0.094	-0.033
	(0.076)	(0.119)
Age at the interview		-0.004
		(0.006)
Bachelor from a top-tier university		-0.009
		(0.050)
Institution of PhD graduation (Reference group: Top-tier Chinese university)		
Other Chinese university		0.184***
		(0.062)
Overseas university		0.033
		(0.087)
Chinese Academy of Sciences		0.036
		(0.083)
Other research institution		-0.233
		(0.177)
Joint test of overall significance	0.83	1.57
F-statistic (p-value)	(0.525)	(0.104)
Observations		
R-squared	763	488

Note: the outcome variable is a dummy variable for being successful rotator (as opposed to a finalist). We control for NSFC department fixed effects and face-to-face interview year fixed effects in the regressions. In column (1) we do not control for the rotator's age, BA- and PhD-granting institutions, since there are many missing values for these variables. *** < 0.01.